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Putting pen to paper

As a freelance technical journalist I am constantly invited to put the latest technology to the test. It strikes me that companies often pursue technology as much for its own sake than for fulfilling a genuine need. The computer sector seems especially prone to this.

Take PDAs, for example. The Personal Communicators, or Personal Digital Assistants, either available or coming from Apple, EO, Amstrad and Casio. Without doubt Apple's Newton is a remarkable piece of technology. It recognises cursive script, which in plain English means joined-up writing. It plays a clever trick to make users teach it the peculiarities of their writing, by challenging them to a game.

But there were glum faces at Apple in Cupertino when I was asked for honest comments and asked in reply for good reasons why I would want to use a $700+ PDA, rather than a 50p notepad and pen. Writing on the LCD screen is nowhere near as easy as on paper.

Because of the communications feature, came the reply. You can write notes on the move and send them electronically. For another $150 extra for the modem feature, Newton can send faxes or electronic mail. (Provided of course that you can find a friendly phone socket).

OK, I said, let's use Newton to log into Telecom Gold, via Tymnet. No go. Newton has no terminal emulation. This shuts off the market for on-the-movers who have spent the last ten years learning email and Hayes AT commands, and have grown one arm longer than the other by humping round a keyboard PC with big enough batteries to keep it running for longer than a short-haul hop.

Software houses appear just as indifferent to real needs; new does not necessarily mean better. The thick manuals that come with new software equate to a lost weekend. The latest version of IBM's OS/2 comes on 25 disks, and sentences anyone willing to try it to a whole new world of unexpected compatibility problems while learning a new command vocabulary.

I would try Hayes' new version of Smartcom if it came with a utility that automatically converts all the telephone directories and logon scripts from my existing comms software.

I would upgrade to the warring Word or Wordperfect if either had a simple utility to convert a decade's worth of text files stored in an old format, without the hassle of going through ascii export routines. But instead of writing in facilities that people actually want, the purveyors of this modern software have spent their time on piling in fancy features that most users will never discover, let alone need, want or use. In so doing they have missed the simple trick of winning new customers who are currently trapped into continuing with old software.

They miss the trick because, in their mad rush to innovate, the innovators do not stop to think what people might actually want. They have lost sight of the purpose of innovation, and the object of the whole exercise.

All of which prompts a thought. Perhaps the best thing to come out of the recession is the buying public's growing resistance to things that are new for the sake of being new.

Barry Fox.

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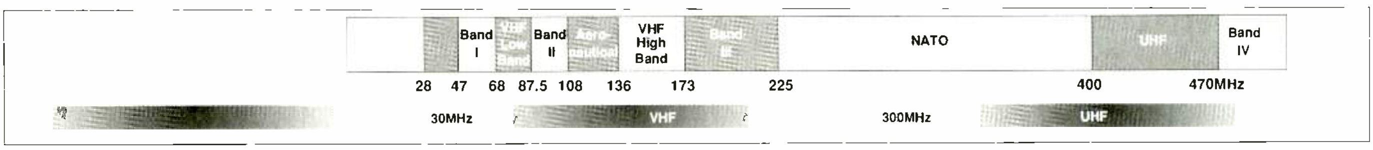
UPDATE

FM stations may close in spectrum shake-up



Services in the band under review include broadcasting, aviation, business radio networks, the emergency services — a bit of almost everything other than television and cellular telephones

FM broadcasting by BBC and commercial stations could come virtually to a stop in little more than 15 years, if plans to supersede it with digital technology are put into effect. The proposal is expected to be among the recommendations of Sir Colin Fielding's independent spectrum review committee, which is preparing an assessment of present and future use of the 28-470MHz spectrum.

If the Government follows its practice with previous spectrum reviews, it will accept and implement most of the committee's conclusions.

Terrestrial digital audio broadcasting, T-DAB, could open in a temporary parking band in about two years. But the committee proposes a strict timetable for rehousing it in Band II: from 2007 onwards, national and regional FM transmitters would close to make room, leaving only a few community stations on FM. The remainder of Band II would be occupied by ancillary services such as programme links and talkback.

Broadcasting was just one of the areas of spectrum activity discussed by committee members when they presented their emerging conclusions at a seminar in London. A major problem facing them is lack of time: the CEPT is beginning its own Euro-study of the VHF and UHF bands, and the DTI wants to have the UK report ready as input for it.

Specific issues on which the committee has focused include finding a suitable temporary band for T-DAB; identifying military frequencies which can be released to meet demand from civilian users; relieving the overcrowding of business radio in the private mobile radio (PMR) bands, especially in London (described by a committee member as "a disaster area"); and deciding how the current regulatory regime might be improved.

Of the 800,000 or so mobile radio users, 77% of licences were for systems with 10 mobiles or fewer. Radio is vital to the business of these smaller users, who might be unwilling to move to shared (trunked) systems if it meant losing control of their communications. But to what extent would they shift to public networks over the next 10 to 15 years as services such as cellular and the PCNs became cheaper?

The role of the Radiocommunications Agency had attracted adverse criticism, the most damning of all from the RA's main consultative body on mobile radio, which accused it of "lack of strategic direction, lack of openness, regulatory culture, lack of available data and inappropriate performance measures."

Sir Colin Field said at a seminar in July that there was clearly a case for having a single spectrum management authority for the UK, for which the RA had some of the credentials. However, there ought to be independent oversight of spectrum management, with wide consultation in the radio community.

One major problem is lack of time: the CEPT is beginning its own Euro-study of the VHF and UHF bands, and the DTI wants to have the UK report ready as input for it.

Virtually every user of the band would like more channels, even the armed services, which, despite the ending of the cold war, are sitting on no less than 55% of the band. The Ministry of Defence view is that the world is still a turbulent place and that British forces are needed to maintain a high state of readiness.

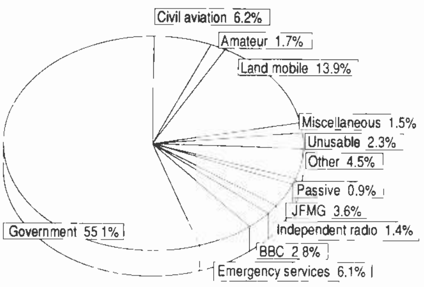
Signal set to "go" for DLR

When the Docklands Light Railways' Beckton extension opens in October, it will be controlled by the most advanced signalling system curerently available. It replaces the traditional block working – admitting one train at a time to a section of track – with a software-controlled "moving block" system which maintains a distance, variable according to speed, between trains. When extended to the rest of the railway it will increase capacity fourfold.

The new system, Seltrac, designed by Candian firm Alcatel, is part of an £800m upgrade designed to rid the the DLR of the stigma of failure and ridicule which has dogged it – built on a £77m shoestring in 1985 – since development in the area overtook capacity. Reliability fell to an ignominious 66% in 1991.

Signalling is something of a misnomer, since the computer controls the driverless trains like a life-size model railway, commiunicating with their on-board computers through induction loops laid between the rails. An independent computer system keeps track of train locations by counting axle revolutions. This device has been introduced to prevent a repetition of Seltrac's worst moment, when the Vancouver Sky Train system went down. All trains had to be manually driven to known points – an operation lasting four hours - before it could be restarted.

More than half of the 28-470MHz region is occupied by the armed services: is it time now for a peace dividend?



No major concession would be possible without the joint agreement of the Nato powers, since much of the military spectrum was under the control of Nato HQ in Belgium. However, there is room for manoeuvre, for example, many ancillary radio systems are similar to civilian PMR installations. Sharing of frequencies could well be possible since civilian users were concentrated in the towns while military activity was mainly in the country.

This may go some way towards soothing the civil mobile radio community, who, because of the complexity of their requirements and their current overcrowding, present the committee with one of its toughest jobs.

One block of channels Nato seems prepared to concede is in the 380 to 400MHz region. This is under consideration as a home for Tetra, – a new European digital trunked radio technology and the Home Office's choice for future emergency services networks – and as a means of solving a long-standing and troublesome continental interference problem.

This nuisance, which affects users as much as 100 miles inland, is due to a slip-up years ago by which split-frequency duplex UHF mobile networks in England and Wales were misaligned with Europe. Thus, police patrols calling their control rooms are competing for attention not with faint continental mobiles but with well-sited, high-powered, continental base stations.

The consultants hired by the Radiocommunications Agency concluded that the only certain solution was to reverse the entire band – with immense cost and disruption. But, given frequencies in which to resettle existing users, the Home Office could at last make a start.

Richard Lambley, *Mobile and Cellular*

● *The Radio Spectrum Review Secretariat can be contacted at the Radiocommunications Agency, Room 506, Waterloo Bridge House, Waterloo Road, London SE1 8UA. Telephone 071-215 2157; fax 071-215 0992.*

Mercury to launch new mobile phone service

Mercury, British Telecom's main rival in the British telecommunications market, is now embarking on its biggest gamble yet. Mercury is launching a cellular phone service, called One-2-One, to rival the established networks, BT's Cellnet and Vodafone. Although the potential rewards are high, Mercury is in uncharted waters.

Mercury is allowed by law to sell its service direct to subscribers, whereas Cellnet and Vodafone must sell through a third party layer of "service providers". This gives Mercury a price advantage. But it will be short-lived because the DTI plans to change the rules for Cellnet and Vodafone. Also, while Mercury has to build a completely new network of base stations, Cellnet and Vodafone already have them and can easily slash prices to undercut One-2-One.

At the same time Mercury faces a completely new set of technical problems, never before faced by any cellphone operator. Whereas the existing services use analogue technology to carry the speech signals, Mercury's One-2-One service will use new all-digital technology. By unhappy coincidence Mercury's launch comes just as the main cellular operator in the US, Ameritech, announces the results of a long term trial which has convinced Ameritech that digital technology is not yet ready to offer the public.

One-2-One's technology was born from the mess of incompatibility between the existing cellphone services in Europe.

Cellnet and Vodafone launched their UK services in January 1985, using the Total Access Communications System. TACS was based on technology developed in the US. Although the control signals which set up calls, and switch them from cell to cell, are digital, the speech is analogue. All the other services in Europe are analogue, but differ from country to country.

In the mid eighties all European governments agreed on a new pan-European standard, called Global System for Mobile communications. GSM is all-digital. Speech is converted into digital code before transmission. Eight speech channels are then squeezed into one transmission channel using a technique called Time Division Multiple Access. TDMA relies on the natural spaces between words of human speech. Each digitally coded conversation is chopped into short bursts, and the code bursts interleaved. The receiver stitches them together again.

Both Cellnet and Vodafone are obliged, by European Memorandum of Understanding, to co-operate in providing a pan-European GSM service, using frequencies (at around 900MHz) reserved for GSM in all countries. This will eventually let travellers use their cellphones anywhere in Europe. The service is already behind schedule, because GSM cellphones are heavier and more expensive than analogue phones, and consume more battery power.

Mercury's new service will use GSM technology, but at a higher frequency (around 1800 MHz). It realises a dream enjoyed by Lord Young in January 1989 while Secretary of State for Trade and Industry. In his White Paper, *Phones on the Move*, Lord Young proposed a new Personal Communication Network of small wireless phones, providing an "office in the pocket", with freedom from wires.

The DTI granted three licences to run PCN services, to Mercury, and two other consortia, Microtel and Unitel. So far only Mercury has pursued the dream, after merging with Unitel. Instead of spending the billion pounds needed to build base stations all round the UK, Mercury is cutting costs to a third by offering a service only within the M25 ring, with around 300 base station sites. Mercury will then push slightly outside the M25, to cover 24% of the population by next April.

GSM/PCN technology uses a clever trick to limit power drain, and so let a phone work longer on each battery charge. When the phone sets up a call it automatically tests the strength of the signal coming from the nearest base station, and then adjusts the strength of the signal it transmits to the base station to the lowest level for reliable communication.

Since May, Mercury's engineers having been touring the M25 coverage area, testing the consistency of signal strength from the base stations. Mercury now feels confident to launch, but dares advertise only for business customers because it does not yet have enough phones from suppliers Motorola, Siemens and NEC to meet the demand which a consumer campaign might generate.

GSM/PCN uses smart cards (credit cards with built-in computer chips). As sold, the phones are useless. They have a slot for a card which makes them work. This lets high street stores sell the phones like hi-fi or video.

As the first company to introduce a high profile digital cellphone service, Mercury knows it must cope with questions about the electrical interference which digital phones will produce, with new and thus potentially puzzling results for sufferers. The square wave pulses that convey the digitally coded speech inevitably generate high frequency harmonics. These will break through into the circuits of a nearby tv set, hearing aid or car radio, to create mysterious buzzing noises or blips on the picture.

Nokia of Finland, Europe's leader in GSM, has studied the problem and found that it will be worst indoors or in a car, where the phone is partially shielded from the base station and must thus work at high power to communicate. The interference will also be worst whenever the phone is switched on, and goes through the automatic procedure of testing local signal strengths.

Nokia's engineers have also tested digital phones with car air bag safety devices, following scare stories in Scandinavia of bags triggering by interference from digital phones. The scare has been hardened by warnings issued by car firms not to use digital phones in cars with air bags. "Extremely unlikely" says Nokia, which makes air bag electronics as well as digital phones."So far it is all just supposition". To try and dispel rumours, Mercury is now running tests with the British car manufacturers.

Both Cellnet and Vodafone already have contingency plans to cut prices if One-2-One looks likely to be a commercial success. Mercury's publicity will in reply remind potential customers for One-2-One that their calls will be completely secure against the eavesdropping which is so easy with analogue phones. This will also create problems for Mercury.

Because PCN uses the same technology as GSM, it uses the same encryption system as GSM. This is so secure that the British government has banned its export to most countries outside Europe, for fear of giving unfriendly armies the chance to use it for military communication. The US government has rejected it, for fear of giving terrorists, criminals and drug dealers the chance to talk without being overheard by the police and security services. Mercury can thus expect to be criticised for offering a service which is ideal for the underworld.

The digital system proposed for use in the US uses much weaker encryption, but relies on the same TDMA technology. Leading cellphone operator Ameritech now says that TDMA is not yet ready for commercial use. The company loaned TDMA phones to customers, provided a trial service and asked for comments. Over 40% were not satisfied with performance. Mercury argues that although both the US and European technologies use TDMA, Europe's GSM/PCN technology is better and ready for use. **Barry Fox**

Woolies pick 'n' mix

Multimedia in retailing parlance usually means nothing more exciting than an electronic catalogue, but a more rewarding interactive system, now on trial in a handful of Woolworths stores, uses digital video and audio to allow customers to sample movie and CD titles.

Now being evaluated in a handful of Woolworths stores, it is claimed to be the first public-access multimedia system in the UK High Steet, and the first fully-digitised hard-disk system in the world.

The touch-screen system has been described by a Woolworths manager as "easier to use than a bank's cash machine - and more fun." The same cannot be said of its appearance, which calls to mind an arcade game designed by the East German government. It is eventually planned to hold details of every CD, tape and video produced in Britain. Titles not in stock in the store (the vast majority, presumably) can be ordered for mailing to home.

The system – which recently won a Silver Award from the British International Multimedia Association was designed for Woolworths by Julia Schofield Consultants, a small (18 staff) outfit based in Richmond-on-Thames which specialises in interactive systems.

Some 16,000 titles are stored, with clips for about a quarter of them. Part- screen full-motion video clips, entered using a VideoLogic MediaSpace card, last around 15 seconds, in addition to a 4.5-minute intro sequence.

Based on a 486 PC with 32 megabytes of RAM and 3 gigabytes of disk storage, the system uses a VideoLogic MediaSpace card.

Apple cuts to Newton licence

The news in July that Apple was sacking 2500 of its 16,000 employees worldwide, contained a coded message. The one division spared the axe is the division which is ploughing a new furrow on licensing policy, and thereby proving that Apple now accepts that its current predicament is born from past strategic blunders. Significantly Apple clammed up, ducking the simple question of how many people work in its Personal Interactive Electronics division, soon after letting it slip that PIE would be untouched by the cuts.

Officially Apple blames its job cuts on the bitter price war between Apple's Macintosh range and the wide variety of rival IBM-format models which have dropped in price by 40% over the last year. But there is now widespread recognition inside Apple's workforce that they are paying the price for a basic error made by their company ten years ago.

When Apple launched the Mac in 1984 it refused to licence the technology which made the computer so easy to use. Apple has continued to refuse Mac licences every since. This has created the competition from IBM-format personal computers which is now crippling Apple.

Apple has now changed its policy and will licence others to use the new technology for Newton, the new hand-held personal communicator which works with a pen and pressure-sensitive screen instead of a keyboard. PIE developed Newton and is actively licensing it to third parties.

In the early 80s Apple developed a computer called the Lisa which was very easy to use, and then refined it into the Mac. When Apple refused even to consider licensing the technology, IBM chose another US software company, Microsoft, to provide the control software or "operating system". Microsoft developed the MS-DOS opeating system which was very awkward to use, and has spent the last ten yars perfecting Windows, a refinement which now makes an IBM-PC look and feel like an Apple Mac. PIE has already licensed four companies, Motorola, Siemens, Sharp and Matsushita (under its brand name Panasonic) to use the Newton technology and make rival model communicators which adhere to the Newton standard. PIE is now talking with other electronics companies in Europe and Japan, including Philips and Sony, in an effort make Newton a new *de facto* standard. Apple will then collect royalties under patents, software copyright and a trade mark logo depicting a sylised light bulb and the word Newton.

Licences will not be required to use the Apple logo, though.

"This is a completely new experience for us" says Subra Iyer, in charge of licencing Newton. "In the past we had complete control of all hardware and software. But the old way was proven wrong. Now we have to find a new way of ensuring that anything with the Newton trade mark is compatible with anything else, regardless of who makes it and where. But we don't want licencing control to be a bottleneck".

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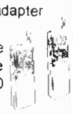

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RESEARCH NOTES

Gate opens for molecular logic

A team in the Department of Chemistry at Queen's University, Belfast, has developed the world's first molecular AND gate. It is a derivative of anthracene and is able to produce a photonic output in response to two separate ionic inputs.

Dr A P de Silva and his colleagues say (*Nature*, Vol 364, No 6432) that the gate was developed from a variety of single-input molecular switches known for some years. These are essentially molecules that fluoresce in the visible part of the spectrum in the presence of a particular ionic species, eg hydrogen ions. The "power supply" is usually a beam of ultraviolet light.

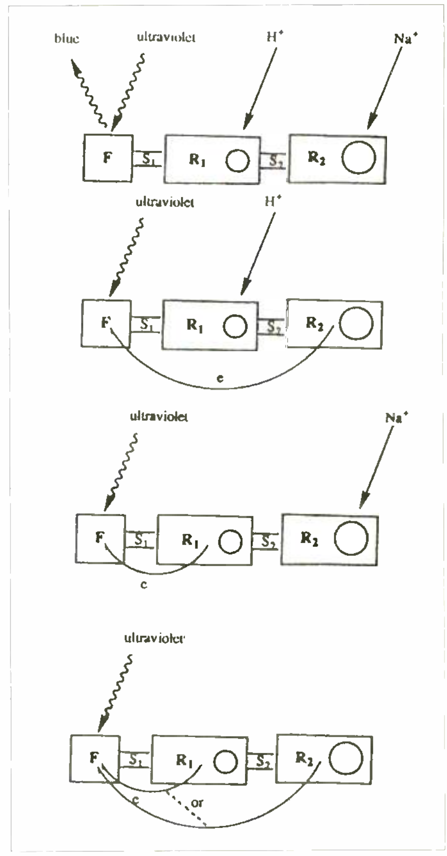
When powered by UV, the molecular gate normally provides no visible light output. Nor is there any output in the presence of just hydrogen ions (protons) or just sodium ions. But when both ions are present, the anthracene-based molecule will emit blue fluorescence. A truly "wire-less" AND gate!

The molecule itself contains two recognition sites, corresponding to the two inputs of a silicon AND gate. When both recognition sites are satisfied, the output part of the molecule – a fluorophore – generates the logical response.

Dr de Silva emphasises that the AND gate and other related molecules provide only a rudimentary foundation for future molecular photonic devices. A molecular computer is "well on the horizon, if not over it". Nevertheless, the fact that a useful logic function can be performed at the level of a single molecule must offer considerable impetus in this area. Experiments to implement a molecular OR function are already advanced.

Practical obstacles to the further development of molecular computing systems include the need to make electrical interfaces with switching devices – creating some form of molecular "wire". Alternatively it might be possible to operate in the wet chemical domain as at present: much human brain logic clearly operates very satisfactorily in this way.

In the short term, de Silva and his co-workers have found some very practical applications for their molecular logic. Interestingly enough they give a foretaste of how such devices could interface with the human body, either in the true thinking sense, or as biochemical sensors looking for malfunctions.



Chemical AND gate: Only when the two ions are both present does the and molecule emit blue light

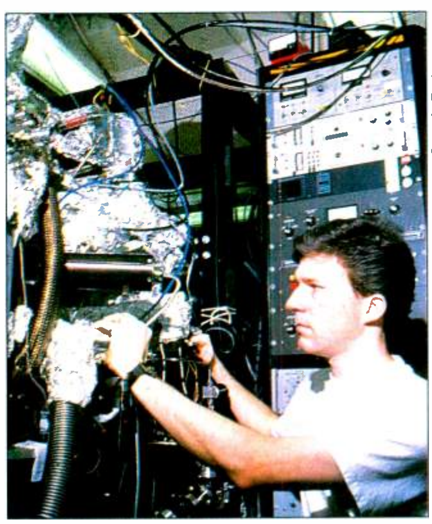
De Silva envisages his AND gate being used as an agent to spot the simultaneous presence of two ions that might, for example, be diagnostic of a particular illness. A sort of intelligent thermometer?

Soft electrons for a smoother etch

An electron assisted etching technique being developed may allow routine fabrication of nanometre scale microelectronic devices without the surface damage caused by current etching systems.

GeorgiaTech researchers hope that nanometre devices will fuel the next wave of development in the microelectronics industry. The technology may also find use in electro-optic devices, optical processing, and radiation devices.

Conventional ion-beam etching can damage surfaces altering optical and electronic properties and potentially limiting how the devices can be used. Because of their mass and high kinetic energy, the ion particles can disrupt the crystalline structure of the semiconductor surface and introduce unwanted materials.



Georgia Tech

The new process, however, uses low energy electrons (10 to 500eV) with reactive hydrogen to cut the electronic features through the patterning process. Because the electrons are lighter and carry less energy, there is less damage to the surface.

Dr HP Gills, an associate professor working on the project said: "If we can make this process work commercially, it will help enable the routine fabrication of these quantum scale devices."

He added: "The impact on the microelectronics industry is tied to the ultimate impact of these quantum well devices, which will be quite important in the future."

According to Gills, it is easy to disorder the surface of a material so that it no longer functions properly as a transistor junction.

But one worry is the potential surface effects from the reactive hydrogen.

Gills explained: "It remains to be seen whether hydrogen has any detrimental effects in our process. But hydrogen is attractive because the chemistry is simple compared to the species used in the conventional technique."

He estimated that there is at least two years of work to go before the research produces a practical process that can be used routinely.

Magnetic fields that upset the brain

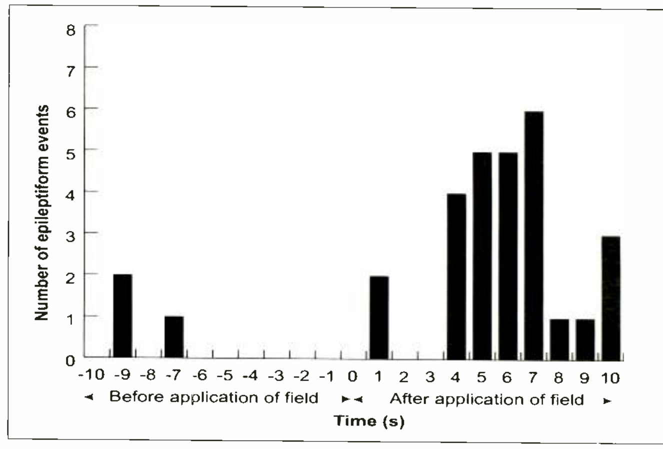
Nerve activity in brains of patients with epilepsy has been shown by an international team of scientists to be triggered by weak external magnetic fields. And it is the presence of magnetic particles in the brain that could be what makes the organ sensitive to magnetism.

Investigations into the safety of electromagnetic fields have rightly concentrated on the interactions of AC fields with biological tissue, whether in test-tubes or in people. If the amplitude is big enough and the frequency high enough, an AC field can cook: but the effects of smaller signals are much less clear.

Static fields, whether electric or magnetic, have not been addressed to anything like the same extent. Such fields are a permanent feature of the Earth's atmosphere; they rarely drop below 100V/m even in settled weather conditions. Animal studies suggest that exposures as high as 340kV/m have no effect on physiology or reproductive capability. The only adverse effects on human health appear to be the micro-shocks than can result from surface charges.

As for static magnetic fields, we are all constantly exposed to the Earth's magnetic field, varying from 30-70μT over the surface of the planet. Even large static fields of 1-2T seem to have no adverse effects on health – at least not in the short term. In a report published last year, the National Radiological Protection Board concluded that although static magnetic fields might have effects on biological enzyme reactions, any health implications have yet to be established.

But the new twist to the story comes with publication of a US/Swiss study showing that external magnetic fields can trigger nerve activity in brains of patients with epilepsy. A team from the University of California, Santa Barbara, the Institut für Geophysik in Zurich and the University Hospital in Zurich have shown that fields only 100 times stronger than the Earth's can trigger brain cell discharges associated with epileptic seizures. At a meeting of the American Geophysical Union, evidence was also produced for the presence of magnetic particles in the same region of the brain. Although there is no proven link, these particles would be a plausible means by which the magnetic field exerts its effect.



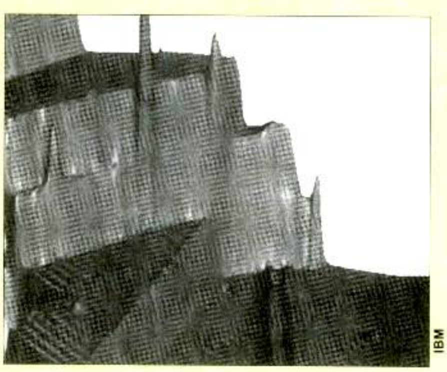
Anomalous activity in the 10s periods prior to and following the field charge. Random activity is represented by the incidence of events in the 10s intervals prior to field applications.

Not only do these discoveries shed new light on the extent of human sensitivity to magnetic fields, they may also provide a new tool that neurosurgeons could use in the treatment of drug-resistant epileptics. Being able to induce epileptic firing to order will make sit easier to identify the precise area affected. That in turn would greatly increase the precision of any subsequent surgery.

The question remains as to whether smaller fields, such as those generated by commonplace consumer devices could trigger an epileptic seizure. The Swiss and US team say no. They argue that such devices generate fields about ten times too small to bring about the effect observed. Yet there remains strong evidence from animal and human studies that biological systems can detect magnetic fields as small as the Earth's – that may be how pigeons (and some humans) can navigate.

Being able to detect something and being affected by it are two very different things. But if a biological system can respond in any way at all to an external stimulus, it must at least be worth asking a few more questions about the health implications of regular exposure.

STM that puts electrons in the picture



The thought of being able to magnify electrons enough to see them is mind-boggling in the extreme. But that in effect is what has been done by an IBM team at their Almaden Research Division in California.

The team has produced a computer generated picture (*Nature*, Vol 363, No 6429) showing waves and ripples, together with what look like ranges of mountain peaks and flights of steps. The intervening flat surfaces represent a "sea" of electrons flowing from one atom to another, the electrons in the conduction bands of the atoms.

Don Eigler, one of the IBM team, says that the ripples on this surface are created when electrons bounce off surface features.

The electron ripples – to give some idea of the scale – are about a thousand times smaller than a single atom. They are also, without doubt, the smallest things that have ever been "seen". Better still, they provide a direct visual demonstration of the wave nature of the electron. IBM has long been at the forefront of atomic imaging. It was an IBM team in Zurich who won the Nobel Prize for their invention in 1981 of the tool that made it all possible – the scanning tunnelling microscope or STM. This now-universal atomic probe works by suspending a metal needle a few atomic diameters above the surface to be scanned. If a small potential is then applied between the two, a tiny current tunnels its way across the gap, a current critically dependent on the spacing.

To make the STM into a practical instrument, the vertical drive of the needle is incorporated into a feedback loop that seeks to preserve a constant tunnelling current. If the needle is then moved horizontally across the surface of a sample, the feedback loop generates an error signal corresponding to the surface topography. In practice these data are fed into a computer that generates the spectacular pictures we now see.

IBM says this apparently "blue-skies" research is essential because the ability to resolve quantum mechanical interference patterns of surface electrons is the most powerful means yet of studying defects on metallic surfaces. Understanding such defects, which are important in regulating film growth and surface catalysis, will be a vital step in the development of new quantum devices, especially sensors.

Computer has designs on its own patent rights

A computer program has submitted a patent application for some of its own inventions, according to the June issue of *Chemistry In Britain*. The program called *Invention* is named as the primary applicant, along with its developer Todd Wipke of the University of California, Santa Cruz.

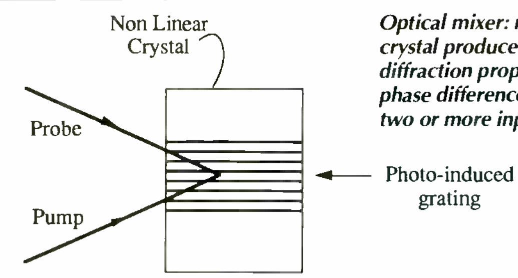
Zany perhaps, but *Invention* has now designed a whole series of morphine analogues that have the same overall chemical structure as the natural substance. The fact that none of these compounds exists and none has yet been synthesised is immaterial: they could well form the basis of some of tomorrow's pharmaceutical drugs.

Invention took a whole day to churn out hundreds of morphine look-alikes and has chosen the three best ones for the patent disclosure. The University has yet to decide on whether to submit a full patent application.

Wipke says that in future, computer programs are far more likely than human chemists to invent new chemicals. He believes that, like their white-coated counterparts, computer programs are more able to make inventive leaps and are less constrained by preconceived ideas. More importantly still, they have no problems visualising complex three-dimensional chemical structures.

Invention will now be harnessed to the task of trying to think up potential new AIDS drugs.

Optical switch that needs no power



Optical mixer: non-linear crystal produces angular diffraction proportional to phase difference between two or more input signals.

Researchers in the Department of Electrical and Electronic Engineering at King's College London has demonstrated an all-optical switch, at a recent summer exhibition of the Royal Society. It is a novel method of routing optical signals to different destinations without the need for mechanical or electronic switching. At the moment it is still very much at the laboratory stage, but the new device demonstrates clearly the potential for locating optical data switches away from the main switching centres traditionally employed in electronic data networks. Jeremy Everard, one of the team, says there is no reason in principle why an optical routing switch could not be located in the middle of the Atlantic.

Secret of the optical switch is that it dispenses with the traditional "three-terminal" approach; there is no external signal to control the switch. Instead, the switching signal is coded in the data itself. So when a stream of data reaches the switch, the switch is able to recognise where, of maybe ten different destinations, it is meant to go.

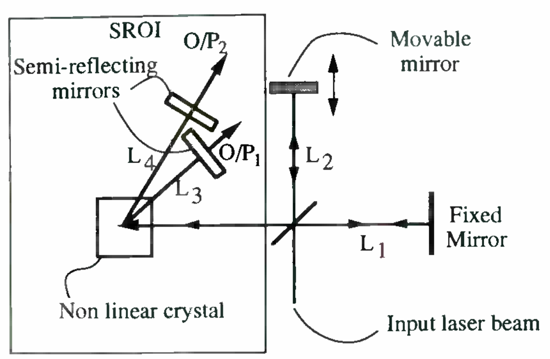
The switch itself relies on the fact that when two laser beams are applied to an optically non-linear crystal (barium titanate), they give rise to a three-dimensional diffraction grating. What happens then is complex. The "pump" beam is created, not by a second laser, but by a process of phase conjugation within the crystal. This, together with the addition of semi-reflecting mirrors at varying distances from the non-linear crystal enables the system to route an input signal only to (and through) the mirror that reflects a beam that is phase-coherent with the input beam. The angle of routing is determined in practice by superimposing on the input signal a slightly delayed version of the same signal.

In the experimental system, demonstrated at the Royal Society, routing to two different outputs was achieved by creating the delayed signal using a second set of mirrors. Jeremy Everard is confident that in a future practical system, the destination address could be coded opto-electronically at source. In this way the switch itself could be buried under the streets, maybe miles away from the source. Instead of being a bench-top arrangement of lasers, mirrors and crystals, it would be miniaturised inside an integrated optic package only a few millimetres across.

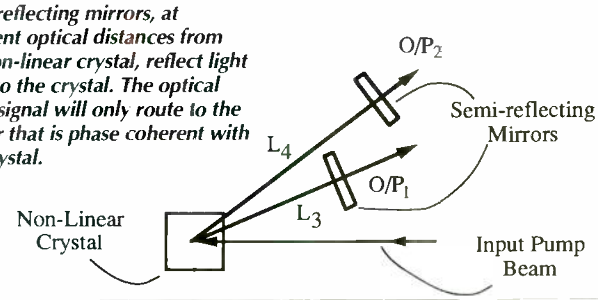
Looking even further ahead, Dr Everard sees the possibility of cascading these switches in such a way that it might be possible to code an input signal so that it would route itself automatically to any one of hundreds of thousands of different destinations.

At the moment this remains a dream; the experimental switch is still cumbersome and slow. But with new crystal materials and integration technologies, the day is not too far off when thousands of tv or data channels could be routed almost anywhere with total reliability and without the overheads of electrically switched networks. ■

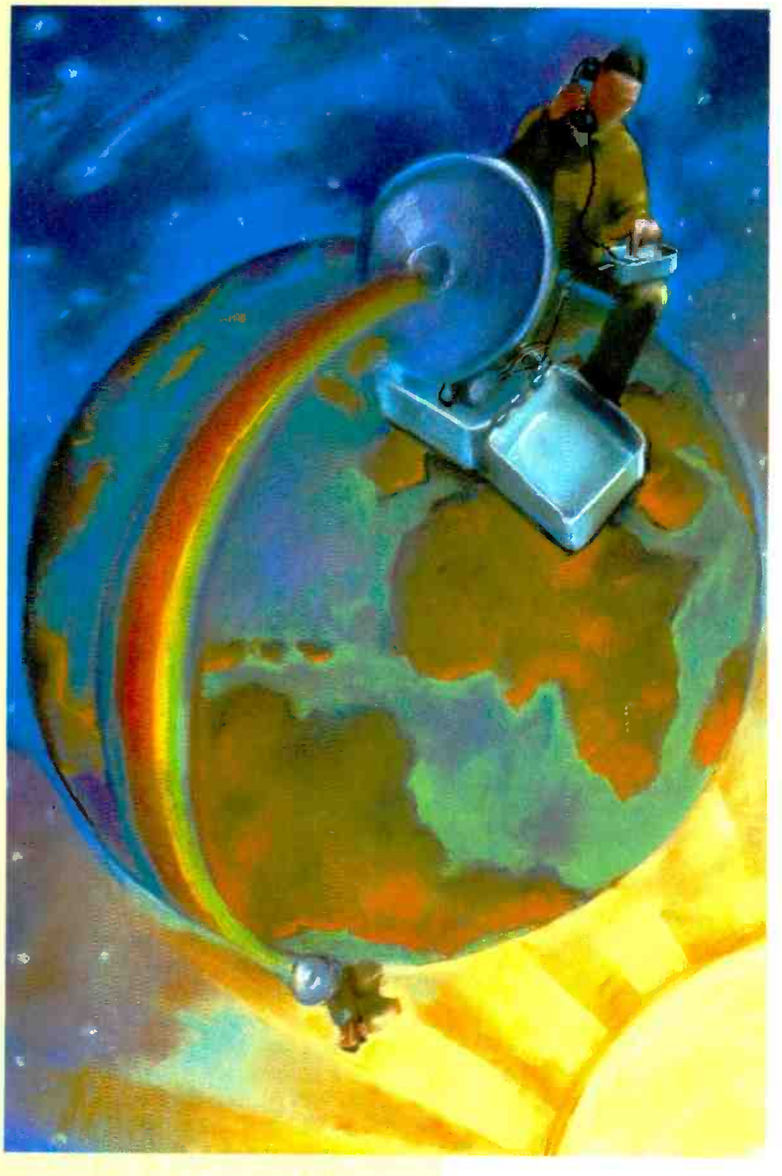
Experimental system, demonstrated at the Royal Society, switching to different outputs, by changing the phase between two samples of a laser beam.



Semi-reflecting mirrors, at different optical distances from the non-linear crystal, reflect light back to the crystal. The optical input signal will only route to the mirror that is phase coherent with the crystal.



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



Until quite recently spread spectrum techniques were almost exclusively in the military domain. Their use in GPS and the latest cellular phones will be followed by many other civil applications. This article, the first of three parts, examines the technology by describing an experimental direct sequence voice transmission system as a worked example.

By James Vincent.*

Voice link over spread spectrum radio

1: basic principles

*James Vincent G1PVZ works for a major aerospace company.

Most Communication Engineers are used to minimising transmission bandwidths. The trend has been to use narrower bandwidths, as with the transition from double sideband to single sideband modulation. It is quite obvious that narrower bandwidths permit more communication channels to be packed into a defined frequency band.

However the rationale of using the very wide bandwidths required by Spread Spectrum systems needs explanation. Claude Shannon produced a ground breaking paper on the mathematical theory of communication in 1949. Shannon's resulting theorem can be expressed as:

$$C = W \log_2 \left[1 + \frac{S}{N} \right] \text{bits}^{-1}$$

where C = data rate in bits per second, W = bandwidth (Hz), S = average signal power (W), N = mean white gaussian noise power (W). It can be seen from the equation that the only options available to increase a channel's capacity are to increase either the bandwidth (W) or the signal to noise ratio (S/N).

An increase in the signal to noise ratio requires an increase in transmitter power as the noise within the channel is beyond our control! Thus we can either trade power or bandwidth to achieve a specified channel data rate. Because of the logarithmic relationship, increasing the power output is often unrealistic. However if frequency allocation constraints permit, the bandwidth can be increased. An appreciable increase in data capacity or signal to noise ratio (for a fixed data rate) can then be achieved.

Spread spectrum systems utilise very wide bandwidths and low signal to noise ratios. From Shannon's theorem:

$$C = W\log_2\left[1+\frac{S}{N}\right]$$

$$\frac{C}{W} = \log_2\left[1+\frac{S}{N}\right]$$

changing bases

As $\log_a P = \dfrac{\log_b P}{\log_b a}$

$$\therefore \log_b P = \log_b a \ \log_a P$$

$$\frac{C}{W} = \log_2 e \times \log_e\left[1+\frac{S}{N}\right]$$

Now $\log_a b = \dfrac{1}{\log_b a}$

$$\frac{C}{W} = \frac{1}{\log_e 2}\times\log_e\left[1+\frac{S}{N}\right]$$

$$\frac{C}{W} = 1.44\log_e\left[1+\frac{S}{N}\right]$$

By logarithmic expansion

$$\log_e\left[\frac{S}{N}\right] = \frac{S}{N} - \frac{1}{2}\left[\frac{S}{N}\right]^2 + \frac{1}{3}\left[\frac{S}{N}\right]^3 - \frac{1}{4}\left[\frac{S}{N}\right]^4 + \frac{1}{5}\left[\frac{S}{N}\right]^5 \ldots \text{etc}$$

In a spread spectrum system the signal to noise ratio (S/N) is typically small, much less than 0.1

$$\frac{C}{W} = \frac{1.44S}{N} \quad \text{thus } W \approx \frac{NC}{S}$$

From the derived relationship it can be clearly seen that a desired signal to noise ratio for a fixed data rate C, can be achieved by increasing the transmission bandwidth.

For example, assume a data rate of 32Kbits^{-1} and a signal to noise ratio of 0.001 (-30dB)

$$W \approx \frac{CN}{1.44S}$$

$$\text{thus } W \approx \frac{32\times10^3\times1000}{1.44} \approx 22\text{MHz}$$

So for a data rate of 32Kbits^{-1}, operation at the very low S/N ratio of -30db is achievable by spreading the signal over a bandwidth of 22MHz. By using a very much wider bandwidth than that of the original data it is possible to maintain data capacity without increasing the transmitter output power. It is an extreme example of a power-bandwidth trade off.

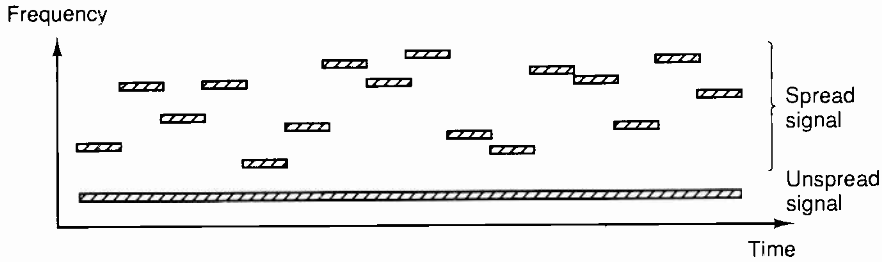


Fig. 1. Frequency hopping spread spectrum provides anti-jam communications. The transmission frequencies change periodically in discrete, pseudorandom steps, the sequence of which is known only by the intended receiver. Multiple users interleave transmissions.

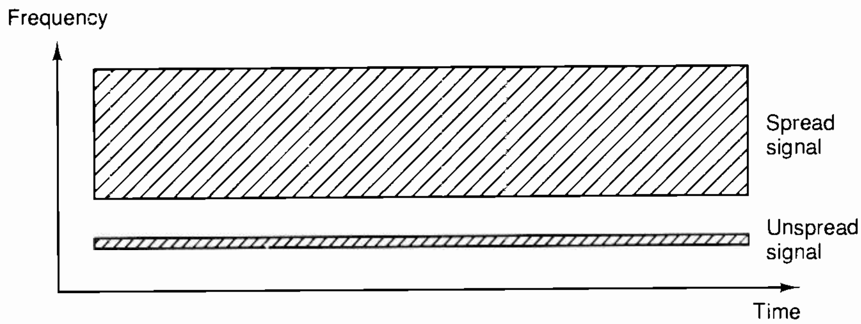


Fig. 2. Direct sequence spread spectrum. An RF carrier modulated with this pseudorandom code will be spread into a wide bandwidth continuous spectrum signal which looks like noise. At the receiver, the same pseudorandom code is used to correlate and hence despread the signal. Many transmissions may use the same frequency simultaneously; signals using different pseudorandom codes do not correlate and hence look like an addition to the background noise.

Two criteria (see Dixon) for a spread spectrum system are:

- that the transmitted bandwidth is much greater than the bandwidth or rate of the information being sent; and
- that some function other than the information being sent determines the resulting radio frequency bandwidth.

The two major techniques used in spread spectrum systems are frequency hopping (fh) and direct sequence (ds). Of the two, frequency hopping is perhaps the easiest to visualise. In a frequency hopping system the frequency or channel in use is changed rapidly. The transmitter hops from channel to channel in a pre-determined but pseudo-random sequence (see **Fig. 1**). The receiver has an identical list of channels to use (the hop set) and an identical pseudo-random sequence generator to that of the transmitter. A synchronising circuit in the receiver ensures that the pseudo-random code generator in the receiver synchronises to the one in the transmitter. When the transmitter and receiver are synchronised the user is unaware that the transmitter and receiver are rapidly changing frequency.

However should the receiver not be synchronised to the transmitter or a conventional receiver be used, nothing will be heard unless the transmitter hops onto the receiver's tuned frequency. As a frequency hopping transmitter typically hops over tens to thousands of frequencies per second (the hop rate), the time it stays on a particular channel (the dwell time) is very short and as a result the signal would appear as a burst of interference.

The other major spread spectrum technique is known as direct sequence or pseudo-noise. In this technique a pseudo-random code directly phase shift keys the carrier increasing its bandwidth (see **Fig. 2**). In a typical direct sequence system a double-balanced mixer (DBM) is driven by the pn code to switch a carrier's phase between 0° and 180°. This is known as biphase shift keying (BPSK) or sometimes phase reversal keying (PRK). Unlike a frequency hopping transmitter where the pseudo-random sequence commands a synthesiser to change frequency, the direct sequence signal is directly generated by the pseudo-random sequence.

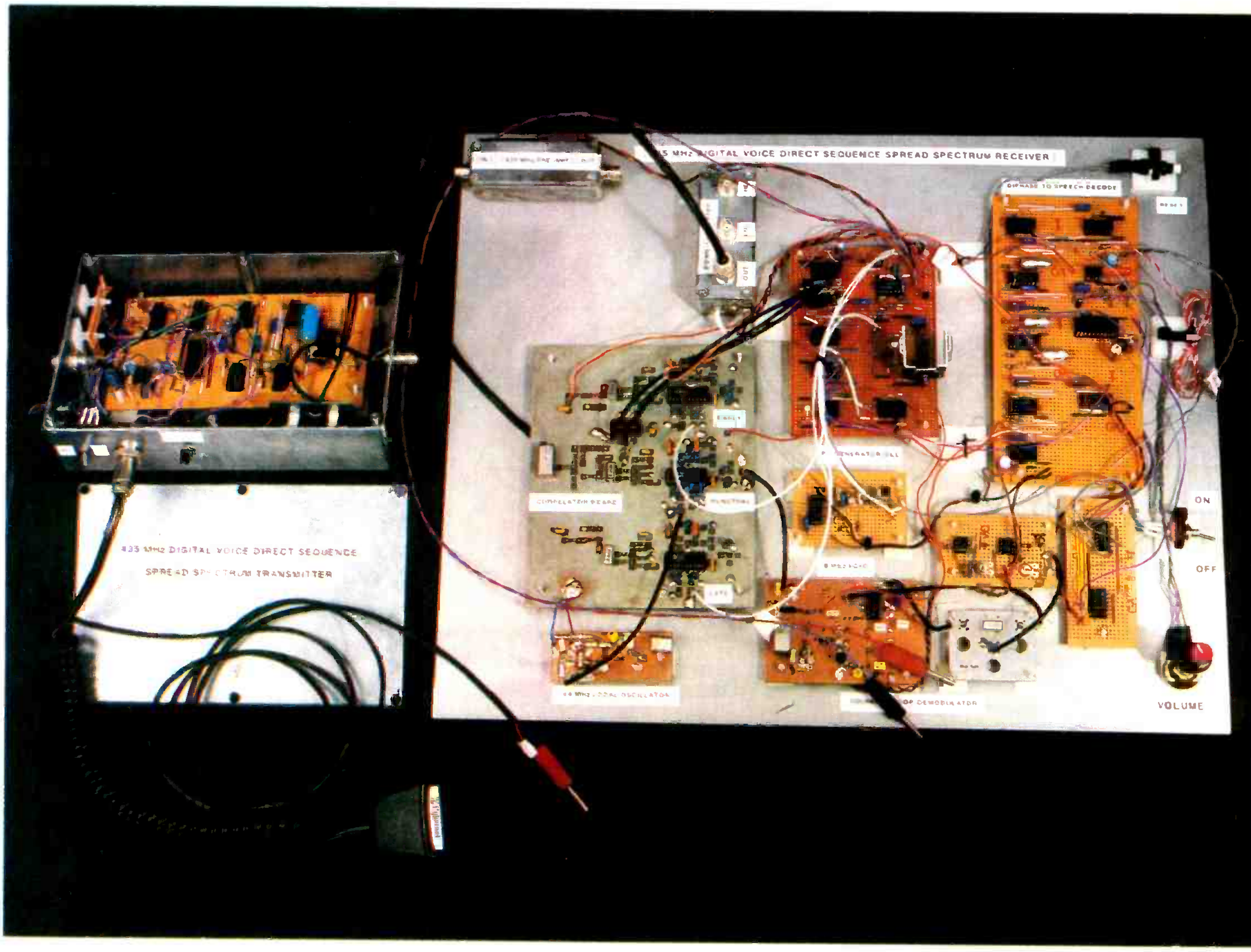
The receiver despreads this wideband signal by using an identical synchronised pseudo-random code to that in the transmitter. As with the frequency hopper, the receiver must use a circuit to adjust its clock rate so that the receiver's pseudo-random code is at the same point in the code as the transmitter. A tracking circuit is necessary to maintain synchronism once it has been attained.

Sending data with spread spectrum

Spread spectrum signals (whether direct sequence, frequency hopping or their hybrids) can support any conventional analogue or digital modulation scheme to impress data onto the spread spectrum carrier.

Obviously some modulation formats are less suitable than others. Amplitude modulation and its derivatives are the least desirable as their use will destroy the signal's uniform power spectral density. This constant carrier envelope is very desirable for spread spectrum systems designed for covert usage.

Frequency modulation (frequency shift keying for data) is often used in frequency hopping systems, but is infrequently used in direct sequence systems. This is because when a direct sequence signal passes through a squar-



ing or frequency doubling circuit, a carrier at twice the signal's centre frequency is produced. This twice frequency narrowband carrier will contain any modulation impressed on the direct sequence signal. Thus with analogue modulation it is possible for the signal to be demodulated without any prior knowledge of the pseudo-random spreading code.

One of the commonest modulation techniques used in conjunction with direct sequence is known as code inversion or modification. The digitised voice or digital data is exclusive ORed with the pn spreading code. This will invert the pn code sequence if the data is a "1" or pass the pn code unmodified if it is a "0". Provided that the data stream is synchronised with the pn code, the correlation properties of the code are unaffected.

Prototype direct sequence spread spectrum exciter and receiver system for 435MHz. Detailed circuitry will be appear in the next two issues of Electronics World

Assuming synchronisation at the receiver, the unmodified code despreads the direct sequence signal. This produces a narrowband signal which is still biphase shift modulated, but this time with the data or digitised speech. This signal can then be demodulated by a conventional biphase shift demodulator such as a squaring or Costas loop demodulator.

This code modification modulation is simple to implement in the transmitter and relatively easy to demodulate in the receiver. It also has the advantage of providing message privacy which the analogue modulated direct sequence signal does not have. It should be noted that it

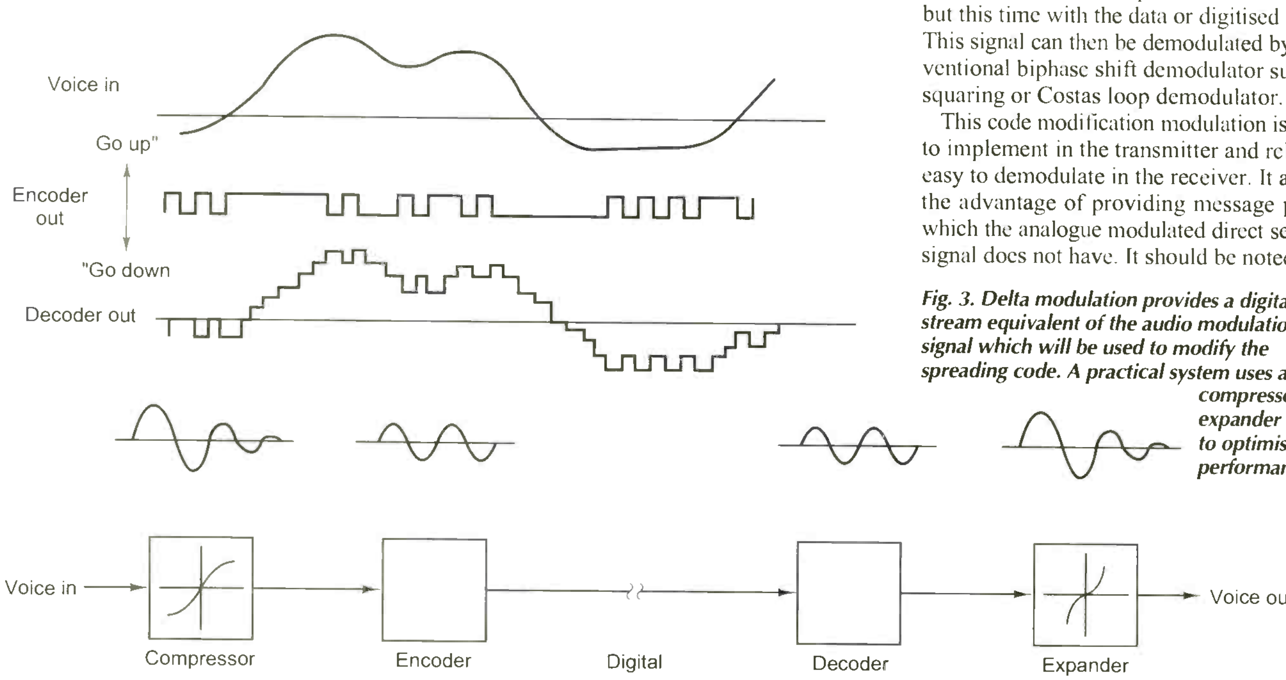


Fig. 3. Delta modulation provides a digital bit stream equivalent of the audio modulation signal which will be used to modify the spreading code. A practical system uses a compressor/ expander system to optimise performance.

is possible to directly demodulate uncorrelated spectral components of an analogue modulated direct sequence signal should the demodulating receiver be very close to the transmitter. In addition the code modification technique preserves the constant power envelope of the direct sequence signal.

One disadvantage of code modification is that voice or other analogue signals require digitisation. As in any system design, the selection of the digitisation technique is very important. The technique selected must use the lowest possible data rate as data rate is inversely proportional to the process gain of the system. The technique selected for the system described uses a enhanced form of delta modulation to digitally encode the voice into a serial data stream.

Delta modulation

Delta modulation is a variation of pulse-code modulation. It compares successive signal samples and transmits only their differences, rather than the actual amplitude as in PCM. This reduces the number of bits required to code the speech. The continuous audio signal is sampled at periodic intervals. The sampled value is then compared with a staircase approximation of the output signal. If the sampled waveform exceeds the staircase approximation, a positive pulse is generated. If the sampled waveform is less than the staircase approximation, a negative pulse is generated. This output pulse, positive or negative, forms the next step in the staircase approximation, i.e. the sum of the binary pulse train at the output of the encoder produces the delta-modulated waveform (see **Fig. 3**).

At the receiver, the transmitted pulses are integrated and passed through a lowpass filter to remove unwanted high frequency components. The output consists of the original analogue signal together with some additional noise somewhat similar to quantisation noise.

Continuously variable slope delta modulation (CVSD) takes advantage of the fact that voice signals do not change abruptly and that there is only a small change from one sample to the next. A reasonably good reproduction can be obtained by transmitting in a given interval whether the output signal should increase or decrease. A linear delta modulated system has the undesirable feature that there is one input level which maximises the signal to noise ratio. In CVSD this is overcome by compressing the large amplitude in the signals relative to the smaller ones prior to encoding using a compressor circuit. In this way the input level to the encoder can be maintained close to the value which gives the maximum signal to noise ratio.

The receiver decodes the delta modulated binary stream and passes the analogue signal through an expander to counteract the effects of the transmitter compressor. Companding is optimised for the human voice. CVSD is considerably more effective than standard delta modulation and also exhibits less serious sound degradation in the presence of digital noise interference than PCM.

Auto-Correlation and Cross-Correlation

The main basis of spread spectrum communications is the correlation function, a measure of the similarity between functions. For the autocorrelation function:

$$\Psi_A(\tau) = \int_{-\infty}^{+\infty} f(t) \times f(t-\tau)dt$$

A time dependent function (such as Sinωt) is compared with an identical replica time shifted by a magnitude and summed (integrated) for all values of t. This function has a maximum at $\tau = 0$ which shows that (obviously) a function is most similar to itself when it has not been time-shifted. For periodic functions, further maxima appear for a multiple of this period.

The response of the correlation function at other values than $\tau = 0$ determines how well the original function $f(t)$ can be found again by variation of the time shift τ. It is also possible to compare various functions $f(t)$ and $g(t)$ using the cross-correlation function:

$$\Psi_K(\tau) = \int_{-\infty}^{+\infty} f(t) \times g(t-\tau)dt$$

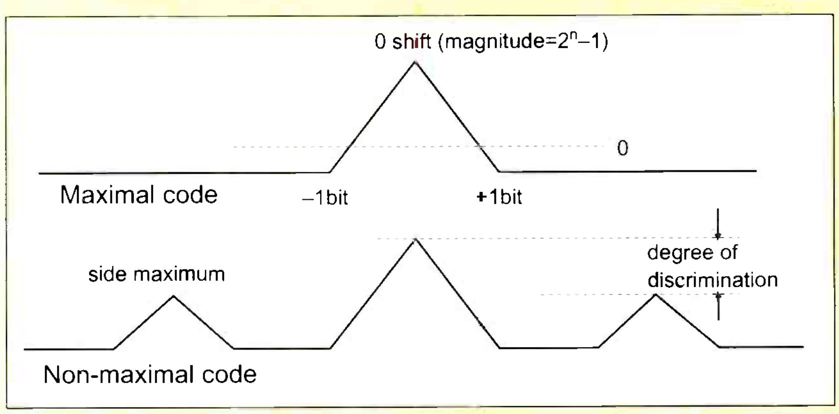
This cross-correlation function is a measure of the degree of agreement between functions. Since the functions to be compared are different $\Psi_K(\tau)$ may never achieve the maximum value of $\Psi_A(\tau)$. It is an indication that the functions are different when a certain threshold (–1 in the case of a binary code) is not exceeded.

In the correlation of binary code sequences, the result for cross-correlation will be +1 if the functional values coincide and –1 if they do not. The integration then forms a summing of all bits of the code. The correlation value for a certain phase-shift can therefore be simply calculated by placing the bits over another and comparing them bit by bit. The correlation rate is the sum of agreements and disagreements.

For example, the maximal code sequence 1110010 is compared with itself in the seven possible phase-shifts.

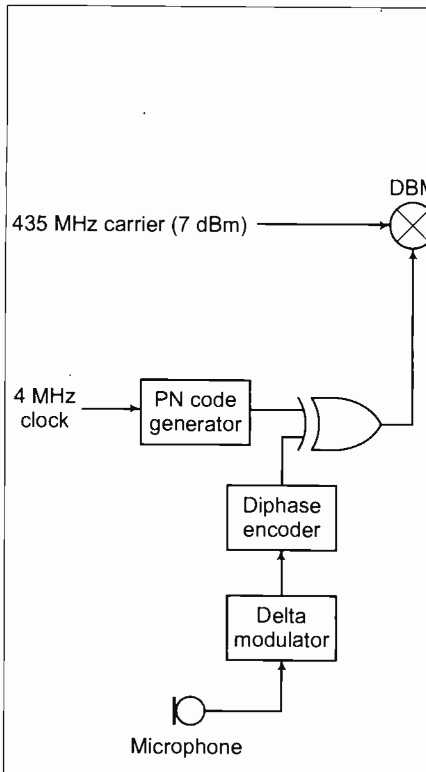
shift	sequence	agreements	disagreements	agreements minus disagreements
0	1110010	-	-	-
1	0111001	3	4	–1
2	1011100	3	4	–1
3	0101110	3	4	–1
4	0010111	3	4	–1
5	1001011	3	4	–1
6	1100101	3	4	–1
7	1110010	7	0	+7

As can be seen the auto-correlation function value is always –1, except for the case of coincidence, where it is a maximum. The greater the length of the code, the higher the auto-correlation amplitude and the greater the code discrimination or cross-correlation response. The auto-correlation function for maximal and non-maximal codes are shown in the drawing below. As shown in the figure, maximal codes have only one auto-correlation

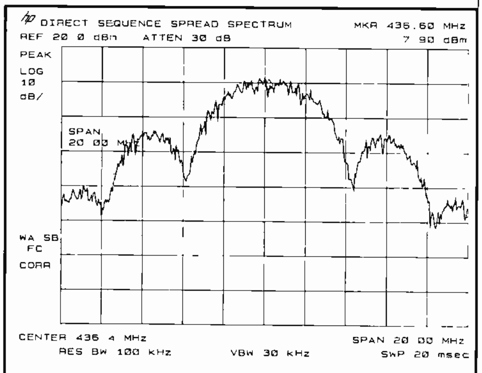


maximum, whereas non-maximal codes have side maxima as well.

When non-maximal codes are used it is important to ensure that a sufficiently large spacing exists between the main and side maxima. Despite these disadvantages, non-maximal codes are used to exploit their main advantages of rapid synchronisation and message security.



Block diagram of the digital voice direct sequence transmitter. Detailed circuitry will be carried in the next issue.



Spectrum analyser plot: direct sequence spread spectrum signal at transmitter helical filter output

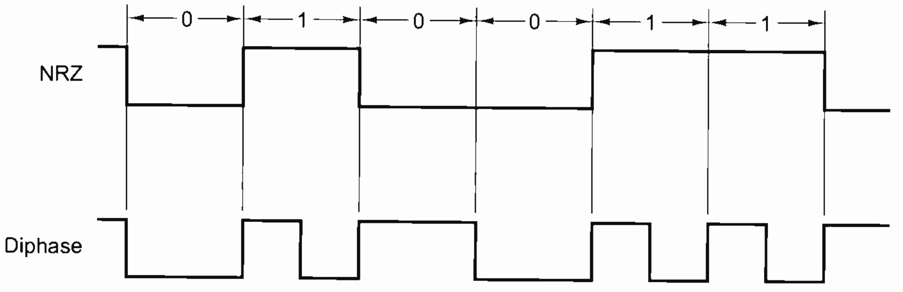


Fig. 4. The transmitted signal must be insensitive to phase. Digitised audio in phase-sensitive NRZ is converted to its diphase equivalent for transmission enabling the receiver to recover the data with the correct polarity. This diphase code is exclusive-ORed with the pseudorandom spreading code to provide a drive signal for the double balanced modulator of the sort shown below.

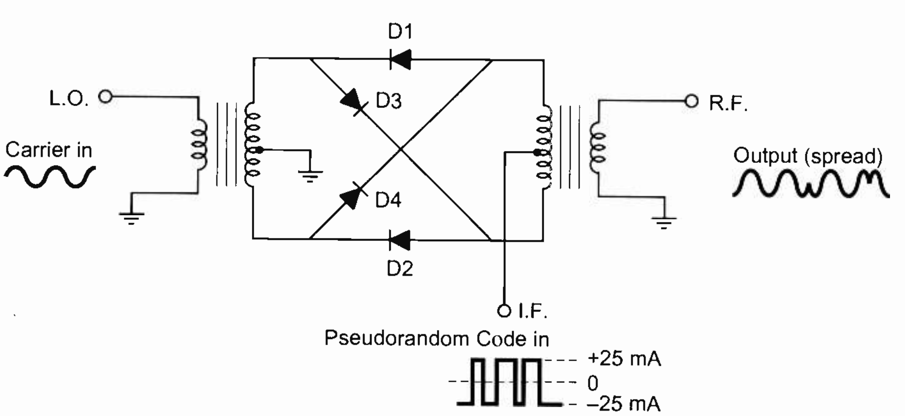


Fig. 5. The biphase modulator. Diode pairs D_1, D_2 and D_3, D_4 alternately switch with the pseudorandom code signal causing phase reversal between the local oscillator and output ports

Circuit description

The system is described in functional blocks. First, the transmitter direct sequence modulator. The exciter's clock frequencies are provided by a master 4MHz crystal oscillator and a divider. Power-up reset (with manual override) is configured around a Schmidt-trigger.

A shift register and exclusive OR gates are configured as a 4MHz 127 chip (code bit) long maximal pseudo-random code generator (see section *pseudo-random codes and generation*).

Microphone audio is amplified by the vogad (voice operated gain adjusting device) to the optimum level for the input of the delta modulator. The delta modulator converts the audio into a 32Kbits^{-1} serial data stream. This serial binary data stream must be coded into a format which is polarity insensitive because the receiver demodulator cannot recover the despread data's absolute phase. Only data transitions are recovered at the receiver, hence there is no way of determining whether the output data stream is inverted or not.

The digitised audio is converted from a non return to zero (NRZ) format into a polarity insensitive diphase (biphase-mark) data stream. This subcircuit produces a diphase signal (**Fig. 4**), where a logic 1 has start, mid-bit and end transitions and a logic 0 has only start and finish transitions.

In addition to providing phase insensitive data transmission, the format also makes clock recovery at the receiver relatively easy, as unlike NRZ even a continuous stream of diphase encoded 0's results in many start and finish data cell transitions. The diphase encoded delta modulated digital voice signal is ex-ORed with the pseudo-random code producing a code modified pn spreading code.

The data modified pn code from the output of the exclusive-OR gate provides a balanced drive (±24mA as an *AC* logic family device has equal sink and source currents) via a coupling capacitor and 50Ω matching pad, to a double balanced mixer (DBM) configured as a biphase shift keyer.

The pn code output alternately sinks and sources current, causing the diodes in the DBM to alternately switch on and off producing 180° phase reversals in the 435MHz carrier signal (see **Fig. 5**). The output spectrum consists of a series of symmetrical sidebands which have a Sinc^{2}x distribution due to the many frequency components of the pseudo-random code.

As the spreading code has a pseudo-random character, the occurrence of a particular frequency is pseudo-random in time and the direct sequence output appears as noise on a spectrum analyser. The spread spectrum signal has a main lobe bandwidth of 8MHz (twice the pn code clock rate for BPSK). This is amplified by a *MAR8* MMIC (monolithic microwave integerated circuit) and further amplified to around 100mW by a Motorola *CA4812* class A amplifier module. Helical band pass filtering is used to ensure that the output signal is within the permitted bandwidth before free-space transmission.

Spread spectrum terminology

Process gain (Gp) is a fundamental concept in spread spectrum systems. The process gain indicates the gain or signal to noise improvement exhibited by a spread spectrum system by nature of the spreading and despreading process. Process gain can be estimated by the following empirical relationship:

$$\text{Process Gain} = \frac{G_p}{R_{info}} = BW_{RF}$$

$$\text{Process Gain} = 10\log_{10}\left[\frac{BW_{RF}}{R_{info}}\right]\text{dB}$$

where

BW_{RF} = 3dB bandwidth of the transmitted spread spectrum signal (Hz). R_{info} = data rate of the information transmitted (bits per second).

For a direct sequence signal, BW_{RF} is assumed to be equal to the 3dB bandwidth of the spectrum (which is 0.88 times the pseudo-random code clock rate for a biphase shift keyed direct sequence system). For a frequency hopping system BW_{RF} is equal to m times the channel bandwidth where m is the number of frequency channels available

Jamming Margin. Although the process gain is directly related to the interference rejection properties a more indicative measure of how a spread spectrum system will perform in the face of interference is the jamming margin (M_j). The process gain of a system will always be greater than its jamming margin.

$$M_j = G_p - \left[L_{system} + (S/N)_{out}\right]\text{dB}$$

where

L_{system} = system implementation losses (dB); G_p = process gain (dB); $(S/N)_{out}$ = signal to noise ratio at the information output (dB).

A spread spectrum system with a 30dB process gain, a minimum required output signal to noise of 10dB and system implementation loss of 3dB would have a jamming margin of 30–(10+3)dB which is 17dB. The spread spectrum system in this example could not be expected to work in an environment with interference more than 17dB above the desired signal.

Power spectral density. By nature of the spreading process, the output power of the spread spectrum transmitter is spread over typically many megahertz of bandwidth. The spectral density is the number of Watts of radio frequency power present per Hertz of bandwidth. Thus for a direct sequence transmitter of 1W output and a spread bandwidth of 8MHz the power spectral density is:

$$\frac{1}{8{,}000{,}000}\ \text{W/Hz} = 125\text{nW/Hz}$$

For a conventional AM transmitter,

power spectral density is around

$$\frac{1}{6000}\text{W/Hz} = 166\mu\text{W},$$

some 31dB greater

The advantage to the military user is that the signal strength apparent to a conventional narrowband receiver is very, very low and would probably not be recognised as a communications signal, hence the expression "Low Probability of Intercept" and "Low Probability of Recognition".

Glossary

***Antijamming* (AJ):** Techniques used to minimise the effects of jamming or unintentional interference.

***Auto-correlation*:** This is a measure of similarity between a signal and a time shifted replica of itself. Auto-correlation is a special case of cross-correlation. The auto-correlation function is the fundamental theoretical basis of spread spectrum communications.

Biphase Shift Keying (BPSK): A phase shift keying technique where the carrier phase changes between 0° and 180° (0 and π radians) under the control of a binary code. BPSK is frequently used to generate direct sequence spread spectrum signals, where the binary code is a pseudo-random sequence.

***Chip*:** A single element of the spreading code. This may be one or more of the pn code bits, depending on the modulation technique used. For BPSK one chip represents one code bit, whereas for quadrature phase shift keying (QPSK) one chip represents two code bits.

This is because there are four states for QPSK (0°,90°,180°and 270°) and only two states for BPSK (0°and 90°). Obviously two binary bits are required to represent four states and only one bit for two states.

***Code*:** The term code usually refers to the pseudo-random code used to control the modulation technique used to spread the carrier.

Code Division Multiple Access (CDMA): A multiplexing technique where each user is given a different pseudo-random spreading code. To communicate with a particular user, the sender must select the code assigned to that user.

If the CDMA codes are carefully selected to ensure good correlation properties, then unwanted CDMA transmissions will not be correlated and hence rejected as wideband interference (up to the limit of the jamming margin M_j of the system). This technique can permit many users to operate simultaneously on the same frequency.

***Correlator*:** A device to measure the similarity of two signals. Sometimes referred to as a de-spreader in direct sequence systems.

***Costas Loop*:** A compound phase locked loop sometimes called an I-Q (In-phase/Quadrature phase) loop. It is used for demodulating double-sideband suppressed carriers (DSBSC) which is the modulation format of a biphase phase-shift keyed signal.

***Cross-correlation*:** This is a measure of the similarity of two signals.

***Delay Locked Loop*:** A tracking circuit which ensures the direct sequence receiver pn clock tracks (follows) any variation in the transmitter's pn clock rate once synchronisation has been achieved. (See column The Delay Locked Loop).

***Delta Modulation*:** A analogue to digital conversion technique (see column Sending Data with Spread Spectrum).

Diphase (biphase-mark): A polarity -insensitive waveform, where a transition occurs at the beginning of every data period. A logic 1 is represented by a transition one half period later There is no second transition for a logic 0.

Direct Sequence (ds): A spread spectrum modulation technique where a pseudo-random code directly phase modulates a carrier, increasing the bandwidth of the transmission. The resulting signal has a noise-like spectrum. The signal is despread by correlating with a pseudo-random code identical to and in synchronism with the code used to spread the carrier at the transmitter.

Frequency Hopping (fh): A spread spectrum modulation technique where the transmitter frequency hops from channel to channel in a predetermined but pseudo-random manner. The signal is de-hopped at the receiver by a frequency synthesiser controlled by a pseudo-random sequence generator synchronised to the transmitter's pseudo-random generator.

Jamming Margin (M_j): A measure of a spread spectrum system's resistance to jamming or un-intentional interference, (see column Spread Spectrum Terminology).

***Linear Codes*:** Pseudo-random codes generated using only modulo-2 addition or subtraction,(see column Pseudo-random Codes and their Generation).

***Maximal Code*:** A maximal code is the longest that can be generated with a feedback type pseudo-random generator (see column Pseudo-random Codes and Generation).

Process Gain (G_p): The measure of the gain or signal-to-noise improvement exhibited by a spread spectrum system by nature of the spreading and de-spreading process.

***Pseudo-noise*:** Code sequences which have noise-like properties. The term pseudo-noise (pn) is often used for direct sequence systems which use such codes to spread the carrier.

***Sinc x*:** Sinc x is the mathematical term for the following expression:

$$\text{sinc}x = \frac{\sin x}{x}$$

A BPSK spread spectrum has a Sinc2x power spectrum.

***Squaring Loop*:** A BPSK (or DSBSC) demodulator which regenerates the suppressed carrier through a frequency squaring (or doubling) process. This doubling process produces a twice frequency unmodulated carrier, which when divided by two can be multiplied with the input BPSK signal to recover the data.

In next month's issue: detailed transmitter circuitry.

Audio induction technology for the deaf

Magnetic induction loops provide an electronic communications channel for deaf people. J P Wilson details the essential design data for induction audio systems.

Magnetic induction loops are valuable to hearing aid users because they effectively bring the ears much closer to the source of the sound so reducing the muddling effects of reverberation.

Sound intensity decreases according to the inverse square law and the direct sound pressure P_{dir} is inversely proportional to the distance r and is given by $P_{dir} = (\rho_0 c W/4\pi r^2)^{0.5}$; W is the acoustical source power and $\rho_0 c$ = 415Pa s m^{-1}, the characteristic air impedance.

A room acts like an acoustic hall of mirrors in which the sound energy density builds up until the rate of sound absorption by the walls and furnishings equals the source power W. The absorbing properties can be expressed as an equivalent area A of perfect sound absorber equal to the total surface area S times the mean absorption coefficient a. The resulting reverberant sound pressure is given by $P_{rev} = (4\rho_0 c W/A)^{0.5}$, where A can be calculated from the reverberation time, T, and the volume of the room, V, by $A = 4\ln 10^6 V/cT = 0.161V/T$.

If we choose a distance r_{crit}, where $P_{rev} = P_{dir}$, substitution in the above equation gives $r_{crit} = (V/312T)^{0.5}$. For distances less than r_{crit} the direct sound pressure will be greater and speech will be clear whereas beyond r_{crit} the reverberant sound will suffer, particularly for those with hearing difficulties.

The purpose of a loop system is in effect to place the ears of the user within this critical distance, which might typically be, say, 2m.

Two other factors influence this critical distance. First, the presence of other sound sources can drastically reduce it so, at a party with 100 people talking together, the critical distance would be reduced by $100^{0.5}$ corresponding to 0.2m in this example.

Secondly, the use of a directional microphone can improve matters substantially. Cardioid and figure of eight patterns each pick up only a third of the reverberant power and therefore increase the critical distance by a factor of 1.73 and, better still, noise cancelling microphones are insensitive to the plane waves of the reverberant field. Although the message here is to get close to the microphone, its penalty is undue sensitivity to speaker distance and, for directional microphones, a distance dependent emphasis of the lower frequencies.

But using a voice operated gain adjusting device (vogad) accommodates different speaker distances and voice strengths, letting a less powerful amplifier produce the required mean current without clipping, and avoiding the need for critical adjustment of gain setting.

Magnetic basis of the loop system

A loop works by direct magnetic induction and does not involve conversion to radio frequencies or infra red light. The system acts as a transformer whose primary winding is the horizontal loop and whose magnetic core with secondary winding is vertical in the hearing aid. This replaces the internal microphone when the aid is on the T (telephone) setting.

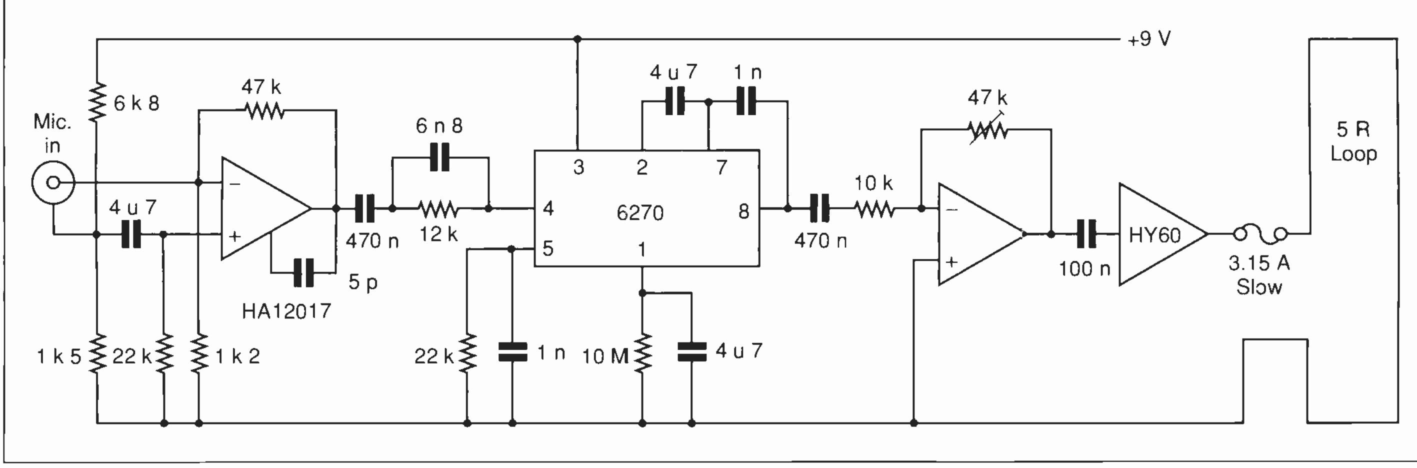
The loop is normally one or more turns of wire surrounding the area concerned and connected in place of a loudspeaker to a normal audio power amplifier. The average magnetic field specified for the loop system is 0.1Am^{-1} (IEC118, part 4, 1981, BS6084).

Any practical layout can usually be typified as either a singular circular turn of diameter d and current I, where the field at the centre is I/d, or as a pair of parallel wires separated by h, where the field halfway between is $2I/\pi h$.

Excessive vertical field components near the conductor can be avoided by mounting the loop at a distance h above or below the receiver, giving a volcano shaped field profile with a null just outside the loop. For the field to remain within ±3dB the rim must not exceed the crater by more than 6dB, which requires $d/h < 13$. A maximally flat top (mesa) will be obtained under the Helmholtz-coil condition of $d/h = 4$, and a rounded top for lower values of d/h. But lower values need higher currents.

Empirical equations, correct to within a few percent for $2 < d/h < 20$, for the field 3dB

Preamplifier for dynamic (M) or electret microphone (E) followed by gain adjusting amplifier (6270), loop current setting amplifier, power amplifier (HY60), and magnetic loop.



below the rim or peak, and therefore covering the greatest area within ±3dB, are given by $H = 0.19(d/h)^{0.7}I/d$, for a circular loop and for a rectangular loop of the same area with sides a and b [giving $d = (4ab/\pi)^{0.5}$]. But when $a \gg b$ a similar approximation for parallel wires gives $H = 0.14(b/h)^{0.7}I/b$.

The field specification implies frequency independence for loop current with a resistive load, giving a pick-up voltage proportional to frequency in the receiving coil; this is corrected in the aid. A loop also has self inductance estimated from the length l and diameter d of the conductor from $L(\mu H) = 0.4\log 4\ l/d$ for single turn layouts. The inductance produces a 6dB/oct cutoff for frequencies above $f_c = R/2\pi L$, which if moderate can be corrected without loss of available power, due to the reduced level of high frequencies in speech.

Multiple turns N will increase field strength proportionately but, if closely spaced as in multicore cable, will reduce cutoff frequency by the same factor ($R \propto N$, $L \propto N^2$). Wire gauge and number of turns should be chosen so that R matches amp impedance and $f_c >$ 1kHz. Loops used in adjacent rooms need a more complex multiple loop geometry to minimise crosstalk[1-3].

Electronic design

The circuit has a universal preamp for low impedance dynamic and electret microphone inputs, *6270* vogad and *HY60* power amp. As the vogad's output is only 90mV sine or 30mV long term speech average, extra gain of about 4.5 x is needed to fully drive the power amp module without clipping, giving a speech average of 5V. The 47k preset feedback resistor is set for the mean loop current needed. The 12k coupling resistor determines the level at which compression starts, and reducing it excessively renders ambient noise and microphone noise obtrusive in the absence of signal.

The parallel 6n8 capacitor is set for loop inductance correction at 2kHz and should be adjusted according to requirements. The attack time of the vogad is determined by the capacitor from pin 1 to earth and the recovery time by the combination of this capacitor and resistor. Overall the response covers 70Hz to 10kHz ±3dB and subjectively gives high quality reproduction of speech and music. ■

References

1. D Bosman and LJM Josten: "A new approach to a space confined magnetic loop induction system", IEEE Trans AU-13, pp47-51, 1965.
2. E de Boer: "Analytical design of magnetic loop induction systems", IEEE Trans AU-13, pp51-61, 1965.
3. FW Umbach: "Loop-induced magnetic fields with negligible side lobes", Acustica 33, pp55-58, 1975.

BOOK REVIEW

The Multiplexer Reference Manual, by Gilbert Held, is concerned with the multiplexer in communications, rather than the more usual connotation in our field of input multiplexers for signal processing.

The first chapter sets the scene, describing the reasons for the existence of the devices, going on to recount the early uses of multiplexing in telephony and to specify the evolutionary development of the subject from frequency division to optical fibre time division.

Each of the methods of multiplexing is given a chapter to itself: frequency and time division, statistical multiplexers, packet assemblers/disassemblers, T-carrier multiplexers and optical fibres, in all cases comparing the alternatives. In the last chapter, Held looks at currently evolving methods, including fast packet multiplexing and low bit-rate voice digitisation.

Networks are, of course, an important aspect of multiplexing and are accorded their rightful share of attention, while perhaps the most importants section are those on statistical and T1 multiplexers, which are given extensive treatment.

Engineers concerned in any way, however peripherally, with communications and networking will find the book a valuable reference, although the style is rather unattractive. A more extensive use of the active voice would have helped to make it a little more appealing, but this is a personal preference and in no way detracts from the value of the work.

John Wiley, 188 pages, hardback, £24.95.

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DOWNWARD TREND IS GOOD NEWS FOR DESIGNERS

Manufacturing constraints combined with power-saving demands of the portable market are forcing designers to rethink their device supply levels. **Rupert Baines** reports on an industry in transition.

Traditionally, you could be fast, but you were power-hungry – increasing a device's switching speed required a proportionate boost in power consumption. But manufacturers are now finding different ways to improve on the established compromises by releasing chips running off lower voltages.

Many are offering device variants for different supply rails, optimised for particular markets. AMD's release of 3.3V-supply *386* clones was a deliberate attempt to offer something different to Intel. But designers are gradually abandoning the general standard of the revered 5V V_{cc} altogether. DEC's new *Alpha* is only available in a 3.3V form, and while Intel's *Pentium* may be available in either 3.3 or 5V versions, future processors in the line will solely operate at 3.3V or less.

The reasoning stems from the physics of the devices that make up the chip.

A processor such as *Alpha* (100MHz, true 64 bit) has to squeeze a massive number of transistors (1.7 million of them) onto a single 230mm^2 die. For reliable manufacture, the die – and its components – must be as small as possible, demanding finer connections that are able to withstand less electrical stress. So the voltage that can be withstood is lower, and the designer must reduce the supply rail.

Happily, that helps power consumption. In a cmos circuit, most of the power is needed at transitions to charge and discharge capacitances within the gates (in contrast to TTL or, even worse, ECL, which need current continually).

Reduce the voltage and proportionately less energy is needed to charge the capacitor, reducing power consumption. For the *Alpha*, already throwing off 30W, 3.3V operation is crucial if the chip is not to burst into flames.

Finally, chips designed for this supply can be faster. Voltage range from logic 0 to 1 is reduced, so the transition time can be cut too.

Margins cut

Of course the gains do not come without cost. The reduced voltage level makes design more difficult by cutting down device noise margins, a situation worsened by the higher frequencies involved.

But all future "super processors" are likely to be based on low voltage operation. Indeed, 3.3V may be too high – the successor to the *Alpha* is rumoured to run at 300MHz on 2.5V. 100MHz chips are here now, and we are likely to see 500MHz PCs by year 2000.

There is a second, parallel track in this market. While the new super-processors are using 3.3V from necessity, manufacturers are releasing low voltage versions of existing designs, such as the *386* or *68030*, through choice. These are intended for the portable market, where power consumption is a premium.

The chip is merely a variant of the existing 5V standard rather than being expressly designed with smaller geometries. Same mask and geometry as the original are used, but the chemical doping levels, and hence the electrical characteristics, are slightly different, allowing for different energy densities and switching levels. But as the geometry, designed to withstand 5V, is unchanged, they are actually too large for the new supply. As a result, the chip runs much slower, primarily because of the proportionately larger capacitances that need to be charged, with less voltage to do so.

For example, Motorola's *68340V*, at 3.3V, draws 140mW at 8MHz, whereas its 5V counterpart (the plain 68340) needs four and a half times as much power to operate at twice the speed (650mW at 16MHz). Or you can build a faster basic design, but run it on a lower voltage to slow it down to a standard speed: AMD's *386DX-40*, and *386SX-25* operate on 3.3V, and dissipate 28% less power than their 5V counterpart running at the same clock frequency.

The shift to lower voltages also affects other components, especially memory.

A dram cell consists of very little more than a single capacitor. Speed is determined by how quickly the cell can be charged, and so the attraction of low voltage operation is reinforced. Hitachi have just announced a prototype dram that runs off just 1.5V.

Serial notes

Computers do not exist in isolation and must communicate with other equipment. The RS232 serial interface (the "standard" that exists in more varieties than any other), specifies a maximum data rate of 20kbaud/s, and minimum output levels of ±5V.

Given the move to a lower supply rail, it is not surprising that a new version of 232 has been developed to suit the demand for more efficiency. EIA562 has been specified by the EIA (electrical industry association) as an improved version of the old standard. It is compatible such that a laptop with the new link will work with a printer or modem using

the old standard. But it uses less power and allows faster transmission rates and at up to 64Kb/s is more than three times as fast).

The uprating has been achieved by having a maximum slew rate of 30V/μs (making the pulses trapeziums rather than rectangles) and tighter rules on waveform shape and allowable ripple, <5% of voltage swing, enabling faster transmission and a reduction in error rate.

But major change has been in the levels. Whereas 232 had levels of ±5V, the 562 specifies a minimum output level at the driver of ±3.7V. The receiver's sensitivity remains unchanged at ±3.0V. As a result the minimum power required by the new driver will be just 55% of the power delivered to the load by a 232 driver. These power savings will be there whether the receiver uses the old standard or the newer one, as power consumption is fixed by the transmitting device.

Disadvantage of reducing levels is that the noise margin (the space between the minimum output of the driver, and the sensitivity of the receiver) is lessened. It has now dropped to just 0.7V, rather than the 2.0V of 232, making the new standard more sensitive to corruption from external interference, cross-talk from other cables, or ground loops. But the problem should not prove too important. For a start it will be somewhat balanced by the benefits of waveform shape. Also, the difference between the two noise margins is not that significant in practice: if you have problems with 562, you would probably have had them anyway with 232. The solution is the same, involving shorter cables, lowering the baud rate, and moving equipment to the same power source to eliminate ground loops.

If corruption remains, moving to a more robust protocol – RS485 for example, differential not single ended – might be the answer.

Most of the major manufacturers (Maxim, Linear, TI etc) are producing interface chips for 562. Increasingly commonly, these contain internal charge pumps to generate the required voltages, allowing them to operate from the single 3.3V supply. ■

POWER POLITICS

There is growing concern about the power consumption of computer systems as a whole. In the US, President Clinton has announced that the US government will give preference to items meeting the Energy Star standard. To qualify, a computer, monitor or printer must have an idle mode in which it consumes 30W or less (45W for colour printers and some other special items). Conventional components use 200-250W.

Given that computer equipment is estimated to use between 5 and 10% of commercial energy use, the potential for saving is clear; the EPA (Environmental Protection Agency) believes that widespread adoption of Energy Star could save $1bn a year.

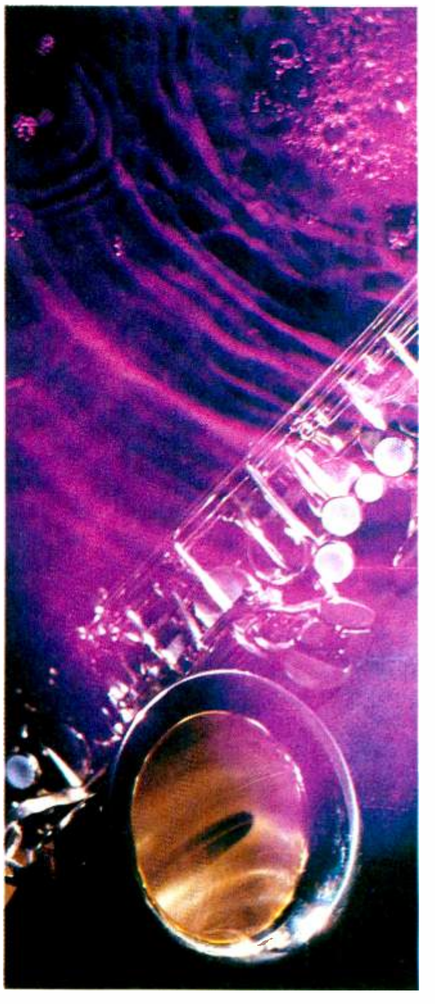
Though computer users could make even more savings. According to the EPA, 30-40% of commercial machines are left running 24h/day. As the number of networks increases, even more PCs will be left switched on "in case someone needs to access my disk".

Switching off before leaving work would be vastly more effective (and would mean that air conditioning need only be set to comfortable, rather than "arctic" so making more savings).

However, where there is a bandwagon, people are going to jump on it. The latest PC Expo was full of "Green PCs", which – of course – were no such thing. Instead they were conventional pieces of equipment, upgraded with a timer circuit and a suitable exorbitant price.

One machine that takes a more thorough approach is IBM's PS2/E, using the power saving ideas of a portable in desktop machine: flat screen, smart power management (eg sending the hard drive to sleep) and low power PCMIA expansion cards.

Of course, it still has an exorbitant price tag, and the misleading "Green" motif. A truly green PC would go far further, reducing "whole life" energy consumption, improving recycling and



Input stage design is not something to be taken lightly for minimal amplifier distortion. Even the fine details of current distribution at this point can have a surprisingly powerful effect on distortion.

By Douglas Self.

Distortion in power amplifiers

2: the input stage

The input stage of an amplifier performs the critical duty of subtracting the feedback signal from the input, to generate the error signal that drives the output. It is almost invariably a differential transconductance stage; a voltage-difference input results in a current output that is essentially insensitive to the voltage at the output port. Its design is also frequently neglected, as it is assumed that the signals involved must be small, and that its linearity can therefore be taken lightly compared with that of the voltage amplifier stage (VAS) or the output stage. This is quite wrong, for a misconceived or even mildly wayward input stage can easily dominate HF distortion performance.

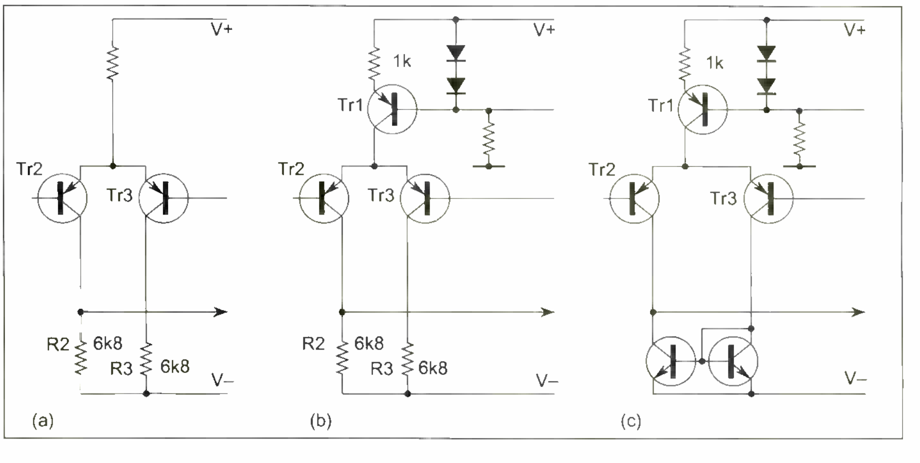
The input transconductance is one of the two parameters setting HF open-loop (o/l) gain, and thus has a powerful influence on stability and transient behaviour as well as distortion. Ideally the designer should set out with some notion of how much o/l gain at 20kHz will be safe when driving worst-case reactive loads – a precise measurement method of open-loop gain was outlined last month – and from this a suitable combination of input transconductance and dominant-pole Miller capacitance can be chosen.

Many of the performance graphs shown here are taken from a model (small-signal stages only) amplifier with a Class-A emitter-follower output, at +16dBu on ±15V rails. However, since the output from the input pair is in current form, the rail voltage in itself has no significant effect on the linearity of the input stage. It is the current swing at its output that is the crucial factor.

Vive la differential

The primary motivation for using a differential pair as the input stage of an amplifier is usually its low DC offset. Apart from its inherently lower offset due to the cancellation of the Vbe voltages, it has the added advantage that its standing current does not have to flow through the feedback network. However a second powerful reason is that its linearity is far superior to single-transistor input stages. **Figure 1** shows three versions, in increasing order of sophistication. The resistor-tail version at **1a** has poor CMRR and PSRR and is generally a false economy; it will not be further considered. The mirrored version at **1c** has the best balance, as well as twice the transconductance of **1b**.

Fig. 1: Three versions of an input pair: a) Simple tail resistor; b) Tail current-source; c) With collector current-mirror to give inherently good I_c balance.



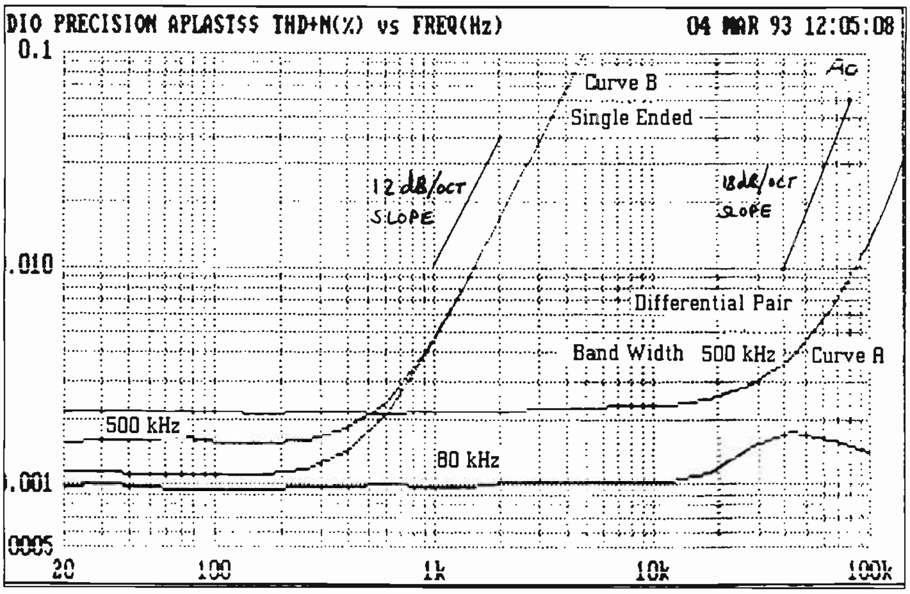


Fig. 2: Distortion performance of model amplifier differential pair at A compared with singleton input at B. The singleton generates copious second-harmonic distortion

Intuitively, the input stage should generate a minimal proportion of the overall distortion because the voltage signals it handles are very small, appearing as they do upstream of the vas that provides almost all the voltage gain. However, above the first pole frequency P1, the current required to drive C_{dom} dominates the proceedings, and this remorselessly doubles with each octave, thus:

$I_{pk} = 2\pi F \cdot C_{dom} \cdot V_{pk}$ (Eqn 4)

For example the current required at 100W, 8Ω and 20kHz, with a 100pF C_{dom} is 0.5mA peak, which may be a large proportion of the input standing current, and so the linearity of transconductance for large current excursions will be of the first importance if we want low distortion at high frequencies.

Fig. 2, *curve A*, shows the distortion plot for a model amplifier (at +16dBu output) designed so that the distortion from all other sources is negligible compared with that from the carefully balanced input stage. With a small-signal class A stage this essentially reduces to making sure that the vas is properly linearised. Plots are shown for both 80kHz and 500kHz measurement bandwidths to show both HF behaviour and LF distortion. It demonstrates that the distortion is below the noise floor until 10kHz, when it emerges and heaves upwards at a precipitous 18dB/octave.

This rapid increase is due to the input stage signal current doubling with every octave to drive C_{dom}; this means that the associated third harmonic distortion will quadruple with every octave increase. Simultaneously the overall NFB available to linearise this distortion is falling at 6dB/octave since we are almost certainly above the dominant pole frequency P1. The combined effect is an 18dB/octave rise. If the vas or the output stage were generating distortion, this would be rising at only 6dB/octave and would look quite different on the plot.

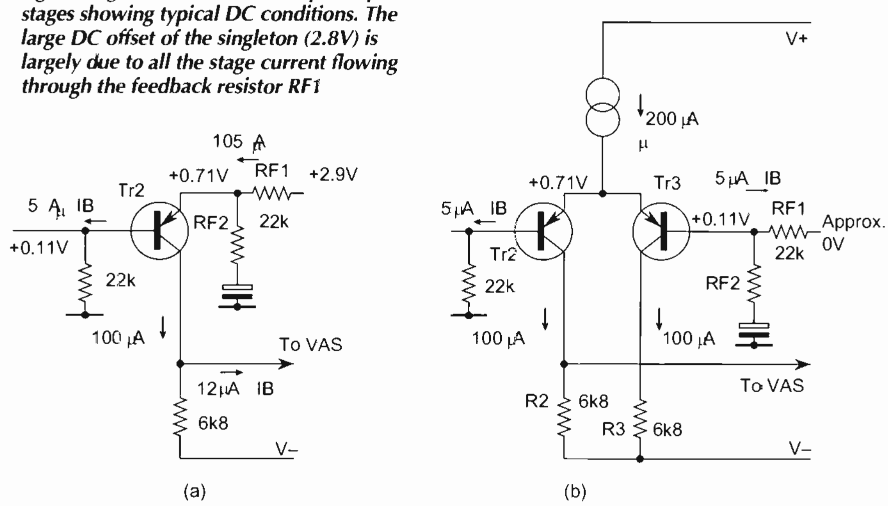


Fig. 3: Singleton and differential pair input stages showing typical DC conditions. The large DC offset of the singleton (2.8V) is largely due to all the stage current flowing through the feedback resistor RF1

This form of non-linearity, which depends on the rate-of-change of the output voltage, is the nearest thing to what we normally call TID, an acronym that now seems to be falling out of fashion. SID (slew-induced-distortion) is a better description of the effect.

If the input pair is *not* accurately balanced, then the situation is more complex. Second as well as third harmonic distortion is now generated, and by the same reasoning this has a slope of closer to 12dB/octave. This vital point requires examination.

Input stage in isolation

The use of a single input transistor (**Fig. 3a**) sometimes seems attractive, where the amplifier is capacitor-coupled or has a separate DC servo; it at least promises strict economy. However, the snag is that this singleton con-

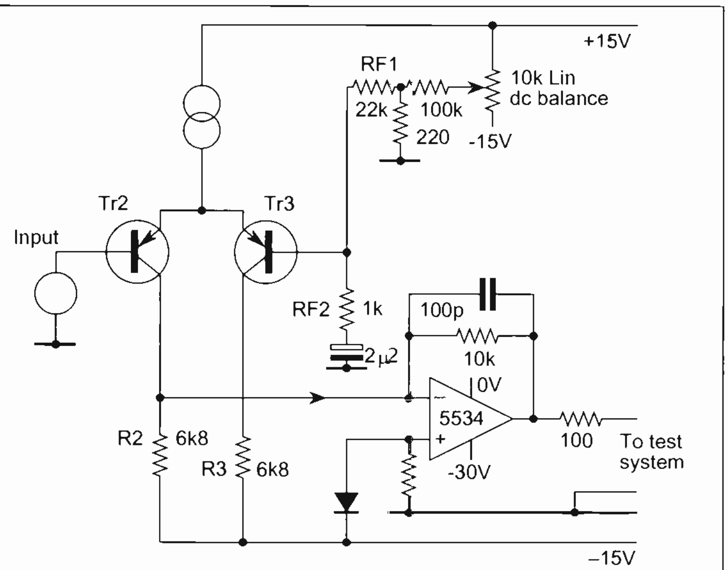


Fig. 4: Test circuit for examining input stage distortion in isolation. The shunt-feedback opamp is biased to provide the right DC conditions for Tr2.

figuration has no way to cancel the second-harmonics generated by its strongly-curved exponential V_{in}/I_{out} characteristic[1]. The result is shown in Fig. 2 curve B, where the distortion is much higher, though rising at the slower rate of 12dB/octave.

Although the slope of the distortion plot for the whole amplifier tells much, measurement of input-stage nonlinearity in isolation tells more. This may be done with the test circuit of **Fig. 4**. The op-amp uses shunt feedback to generate an appropriate AC virtual earth at the input-pair output. Note that this current-to-voltage conversion op-amp requires a third –30V rail to allow the i/p pair collectors to work at a realistic DC voltage – ie about one diode's-worth above the –15V rail. R_f can be scaled to stop op-amp clipping without effect to the input stage. The DC balance of the pair may be manipulated by VR_1: it is instructive to see the THD residual diminish as balance is approached until, at its minimum amplitude, it is almost pure third harmonic.

The differential pair has the great advantage that its transfer characteristic is mathematically highly predictable[2]. The output current is related to the differential input voltage V_{in} by:

$I_{out} = I_e \times \tanh(-V_{in}/2V_t)$

where V_t is the usual "thermal voltage" of about 26mV at 25°C and I_e the tail current.

This equation demonstrates that the transconductance, g_m, is highest at V_{in}=0 when the two collector currents are equal, and that that the value of this maximum is proportional to the tail current, I_e. Note also that beta does not figure in the equation, and that the performance of the input pair is not significantly affected by transistor type.

Fig. 5a shows the linearising effect of local feedback or degeneration on the voltage-in/current-out law. **Fig. 5b** plots transconductance against input voltage and demonstrates a reduced peak transconductance value but with the curve made flatter and more linear over a wider operating range. Adding emitter degeneration markedly improves input stage linearity at the expense of noise performance. Overall amplifier feedback factor is also reduced since the HF closed-loop gain is determined solely by the input transconductance and the value of the dominant-pole capacitor.

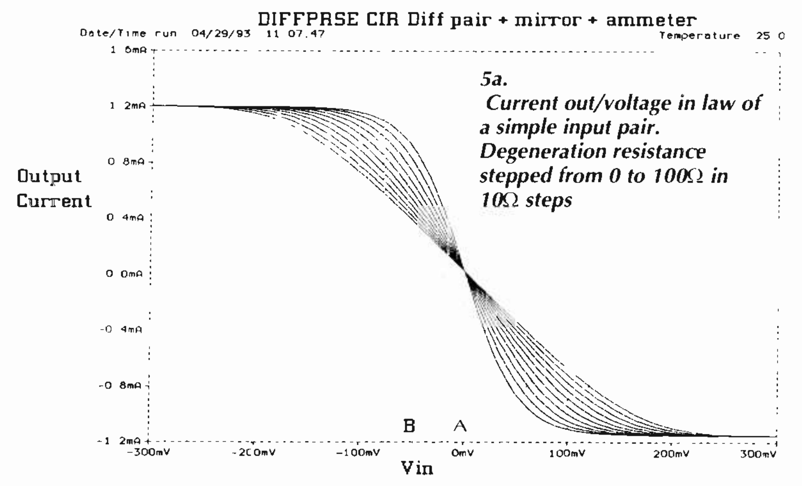
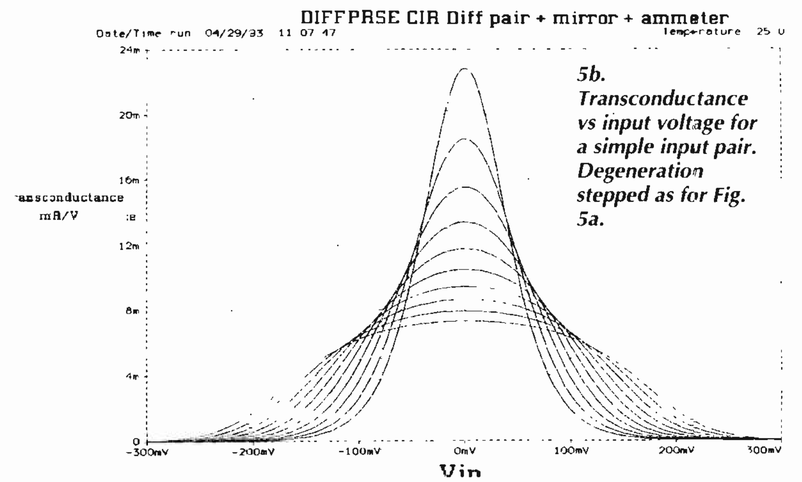


Fig. 5: Effect of degeneration on input pair V/I law, showing how transconductance is sacrificed in favour of linearity. (SPICE simulation)



Input stage balance

One relatively unknown property of the differential pair in power amplifiers is its sensitivity to exact DC balance. Minor deviations from equality of I_c in the pair seriously upset the 2nd-harmonic cancellation by moving the operating point from *A* in Fig. 5a to *B*. Since the average slope of the characteristic is greatest at *A*, serious imbalance also reduces the

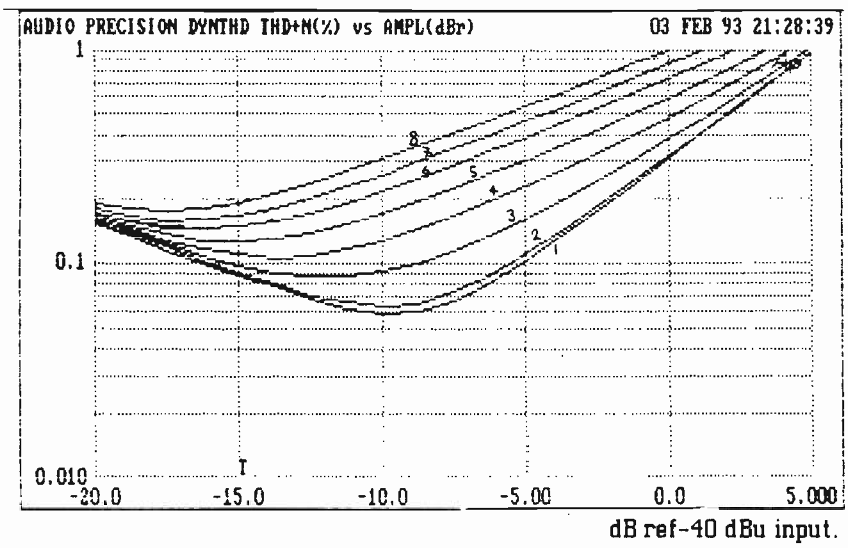


Table 1. Key to Fig. 6.

Curve No.	I_c Imbalance
1	0%
2	0.5%
3	2.2%
4	3.6%
5	5.4%
6	6.9%
7	8.5%
8	10%

Imbalance defined as deviation of I_c (per device) from that value which gives equal currents in the pair.

Fig. 6: Effect of collector-current imbalance on an isolated input pair; the 2nd harmonic rises well above the level of the 3rd if the pair moves away from balance by as little as 2%.

open-loop gain. The effect of small amounts of imbalance is shown in **Fig. 6** and Table 1: for an input of -45dBu a collector current imbalance of only 2% increases THD from 0.10% to 0.16%; for 10% imbalance this deteriorates to 0.55%. Unsurprisingly, imbalance in the other direction ($I_{c1}>I_{c2}$) gives similar results.

This gives insight[4] into the complex changes that accompany the simple changing the value of R_2. For example, we might design an input stage as per **Fig. 7a**, where R_1 has been selected as 1kΩ by uninspired guesswork and R_2 made highish at 10kΩ in a plausible but misguided attempt to maximise o/l gain by minimising loading on Tr_1 collector. R_3 is also made 10kΩ to give the stage a notional "balance", though unhappily this is a visual rather than electrical balance. The asymmetry is shown in the resulting collector currents: this design will generate avoidable second harmonic distortion, displayed in the 10kΩ curve of **Fig. 8**.

However, recognising the importance of DC balancing, the circuit can be rethought as per **Fig. 7b**. If the collector currents are to be roughly balanced, then R_2 must be about 2 x R_1, as both have about 0.6V across them. The effect of this change is shown in the 2.2kΩ curve of Fig. 8. The improvement is accentuated as the o/l gain has also increased by some 7dB, though this has only a minor effect on the closed-loop linearity compared with the improved balance of the input pair. R_3 has been excised as it contributes little to stage balance.

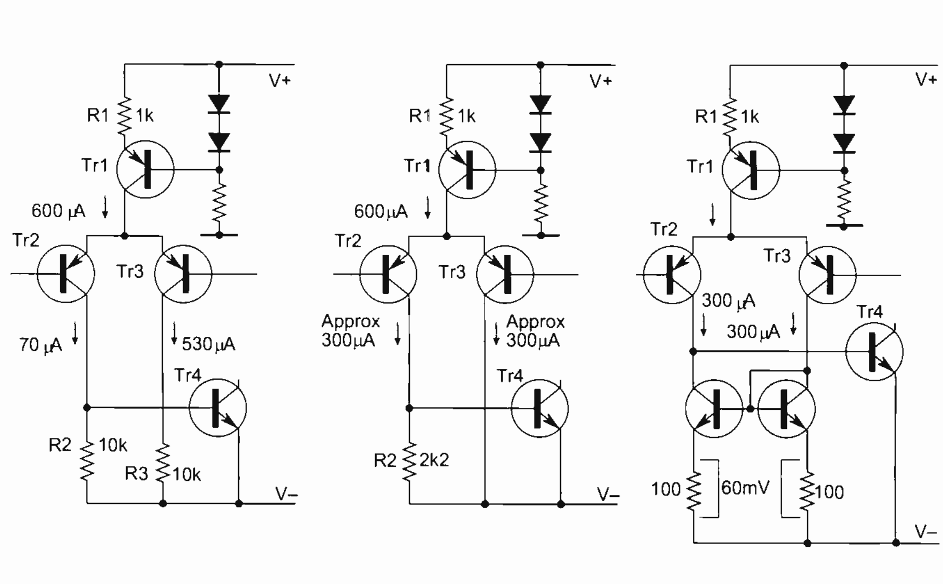


Fig. 7: Improvements to the input pair: a) Poorly designed version; b) Better... partial balance by correct choice of R_2. c) Best.. near-perfect Ic balance enforced by mirror.

The joy of current mirrors

While the input pair can be approximately balanced by the correct choice of R_1 and R_2, other circuit tolerances are significant and Fig. 6 shows that balance is critical, needing to be accurate to at least 1% for optimal linearity. The standard current-mirror configuration shown in Fig. **7c** forces the two collector currents very close to equality, giving proper cancellation of 2nd harmonic. The resulting improvement shows up in the current-mirror curve of Fig. 8. There is also less DC offset due to unequal base currents flowing through input and feedback resistances; we often find that a power-amplifier improvement usually gives at least two separate benefits. This simple mirror has its own residual base current errors but they are not large enough to affect distortion.

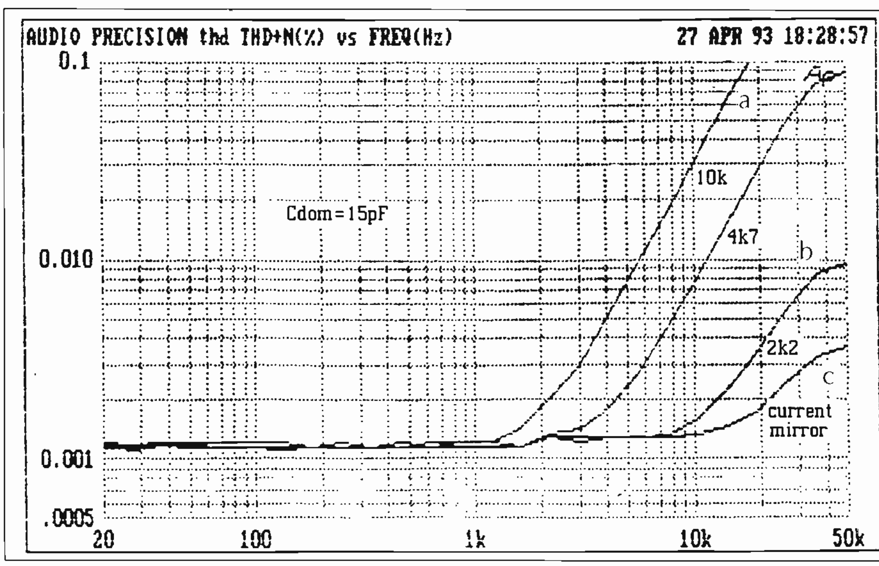


Fig. 8: Distortion of model amplifier: a) Unbalanced with R_2=10kΩ; b) Partially balanced with R=2.2kΩ; c) Accurately balanced by current-mirror.

The hyperbolic tangent law also holds for the mirrored pair[3], though the output current swing is twice as great for the same input voltage as the resistor-loaded version. This doubled output occurs at the same distortion level as for the single-ended version, as linearity depends on the input voltage, which has not changed. Alternatively, to get the same output we can halve the input which, with a properly balanced pair generating only third harmonic, will produce just one-quarter the distortion, a pleasing result.

A low cost mirror made from discrete transistors forgoes the V_{be} matching available to IC designers, and so requires its own emitter degeneration for good current-matching. A voltage drop across the mirror emitter resistors in the range 30-60mV will be enough to make the effect of V_{be} tolerances on distortion negligible If degeneration is omitted, there is significant variation in HF distortion performance with different specimens of the same transistor type.Adding a current mirror to a reasonably well balanced input stage will increase the total o/l gain by at least 6dB, and by up to 15dB if the stage was previously poorly balanced. This needs to be taken into account in setting the compensation. Another happy consequence is that the slew-rate will be roughly doubled, as the input stage can now source and sink current into C_{dom} without wasting it in a collector load. If C_{dom} is 100pF, the slew-rate of Fig. 7b is about 2.8V/µs up and down, while 7c gives 5.6V/µs. The unbalanced pair at 7a displays further vices by giving 0.7V/µs positive-going and 5V/µs negative-going.

Improving linearity

Now that the input pair has been fitted with a mirror, we may still feel that the HF distortion needs further reduction; after all, once it emerges from the noise floor it goes up eight times with each doubling of frequency, and so it is well worth pushing the turn point as far as possible up the frequency range. The input pair shown has a conventional value of tail-current. We have seen that the stage transconductance increases with I_c, and so it is possible to increase the g_m by increasing the tail-current, and then return it to its previous value (otherwise C_{dom} would have to be increased proportionately to maintain stability margins) by applying local NFB in the form of emitter-degeneration resistors. This ruse powerfully improves input linearity despite its rather unsettling flavour of something-for-nothing. The transistor nonlinearity can here be regarded as an internal nonlinear emitter resistance r_e, and what we have done is to reduce the value of this (by increasing I_c) and replace the missing part of it with a linear external resistor, R_e.

For a single device, the value of re can be approximated by:

r_e=25/I_c ohms (for I_c in mA)

Our original stage at **Fig. 9a** has a per-device I_c of 600μA, giving a differential (ie, mirrored) g_m of 23mA/V and r_e=41.6Ω. The improved version at Fig. **9b** has I_c=1.35mA and so r_e=18.6Ω. Emitter degeneration resistors of 22Ω are required to reduce the g_m back to its original value, as 18.6+22=41.6. The distortion measured by the circuit of Fig. 4 for a 40dBu input voltage is reduced from 0.32% to 0.032%, which is an extremely valuable linearisation, and will translate into a distortion reduction at HF of about five times for a complete amplifier. For reasons that will emerge later the full advantage is rarely gained. The distortion remains a visually pure third harmonic so long as the input pair remains balanced. Clearly this sort of thing can only be pushed so far, as the reciprocal-law reduction of r_e is limited by practical values of tail current. A name for this technique seems to be lacking; "constant-g_m degeneration" is descriptive but rather a mouthful.

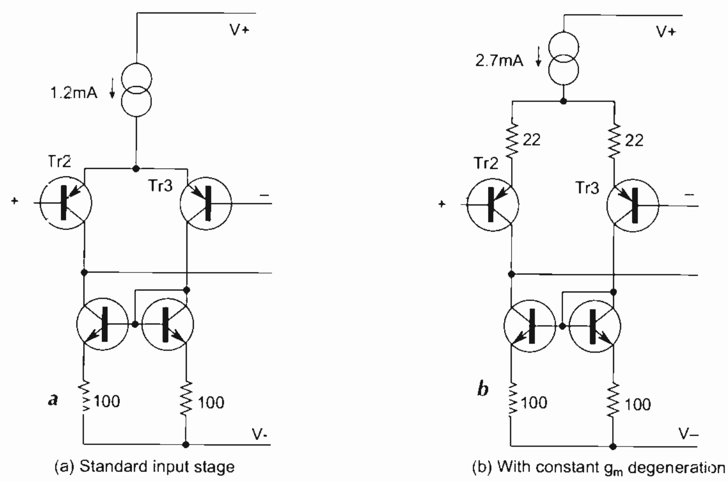
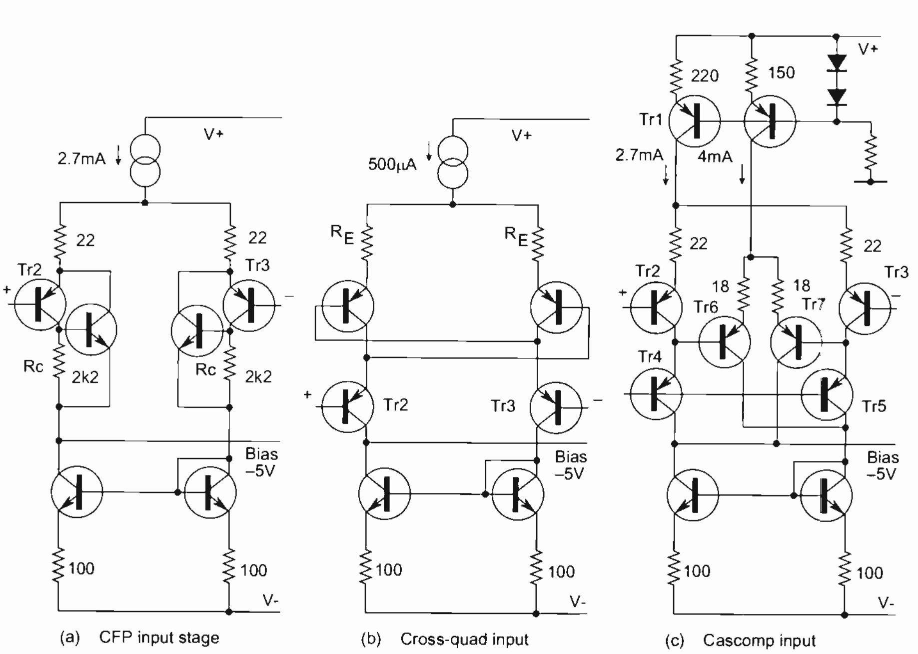


Fig. 9: Input pairs before and after constant-gm degeneration showing how to double stage current while keeping transconductance constant: distortion is reduced by about ten times.

Since the standing current is roughly doubled so has the slew rate: 10V/μs to 20V/μs. Once again we gain two benefits for the price of one modification.

For still better linearity, various techniques exist. When circuit linearity needs a lift, it is often a good approach to increase the *local* feedback factor, because if this operates in a tight local NFB loop there is often little effect on the overall global-loop stability. A reliable method is to replace the input transistors with complementary-feedback (CFP or Sziklai) pairs, as shown in the stage of **Fig. 10a**. If an isolated input stage is measured using the test circuit of Fig. 4, the constant g_m degenerated version shown in Fig. 9b yields 0.35% third-harmonic distortion for a –30dBu input voltage, while the CFP version gives 0.045%. Note that the input level here is 10dB up on the previous example to get well clear of the noise floor. When this stage is put to work in a model amplifier, the third-harmonic distortion at a given frequency is roughly halved, assuming other distortion sources have been appropriately minimised. However, given the steep slope of input stage distortion, this extends the low distortion regime up in frequency by less than an octave. See **Fig. 11**.

Fig. 10: Some enhanced differential pairs: a) The complementary feedback pair; b) The cross-quad; c) The cascomp.



The CFP circuit does require a compromise on the value of R_c, which sets the proportion of the standing current that goes through the NPN and PNP devices on each side of the stage. In general, a higher value of R_c gives better linearity, but more noise, due to the lower I_c in the NPN devices that are the inputs of the input stage, as it were, causing them to match less well the relatively low source resistances. 2.2kΩ is a reasonable compromise.

Other elaborations of the basic input pair are possible. Power amp design can live with a restricted common-mode range in the input stage that would be unusable in an op-amp, and this gives the designer great scope. Complexity in itself is not a serious disadvantage as the small-signal stages of the typical amplifier are of almost negligible cost compared with mains transformers, heatsinks, etc.

Two established methods to produce a linear input transconductance stage (often referred to in op amp literature simply as a transconductor) are the cross-quad[5] and the cascomp[6] configurations. The cross-quad (Fig. **10b**) gives a useful reduction in input distortion when operated in isolation but is hard to incorporate in a practical amplifier because it relies on very

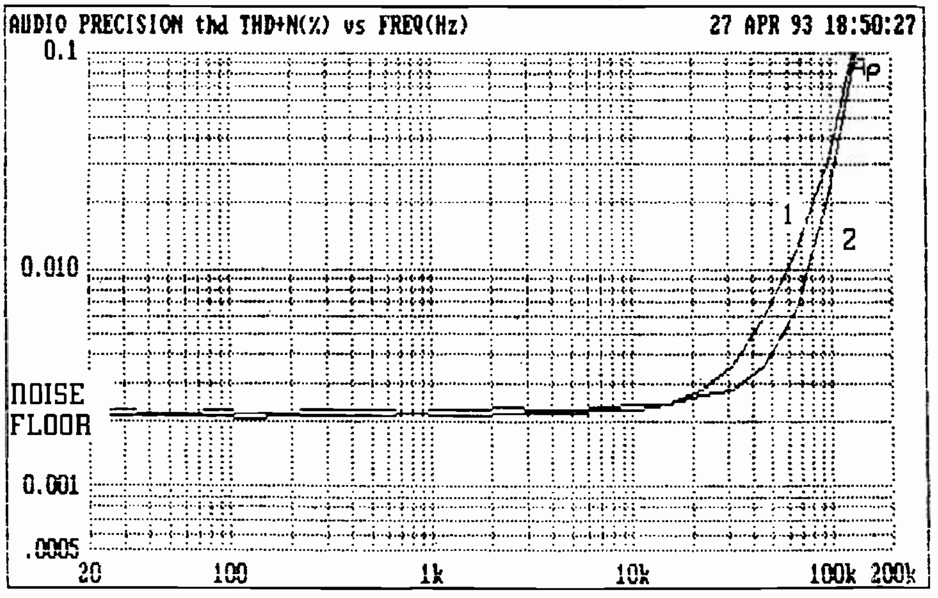


Fig. 11: Whole-amplifier THD with normal and CFP input stages; input stage distortion only shows above noise floor at 20kHz, so improvement occurs above this frequency. The noise floor appears high as the measurement bandwidth is 500kHz.

low source resistances to tame the negative conductances inherent in its operation. The cross-quad works by imposing the input voltage to each half across two base-emitter junctions in series, one in each arm of the circuit. In theory the errors due to non-linear r_e of the transistors is divided by beta, but in practice things seem less rosy.

The cascomp (Fig. 10c) does not have this snag, though it is significantly more complex to design. Tr_2,Tr_3 are the main input pair as before, delivering current through cascode transistors Tr_4,Tr_5 (this does not in itself affect linearity) which, since they carry almost the same current as Tr_2,Tr_3 duplicate the input V_{be} errors at their emitters. This is sensed by error diff-amp Tr_6,Tr_7 whose output currents are summed with the main output in the correct phase for error-correction. By careful optimisation of the (many) circuit variables, distortion at –30dBu input can be reduced to about 0.016% with the circuit values shown. Sadly, this effort provides very little further improvement in whole-amplifier HF distortion over the simpler CFP input, as other distortion mechanisms are coming into play – for instance the finite ability of the VAS to source current into the other end of C_{dom}.

Power amplifiers with pretensions to sophistication sometimes add cascoding to the standard input differential amplifier. This does nothing to improve input stage linearity as there is no appreciable voltage swing on the input collectors; its main advantage is reduction of the high V_{ce} that the input devices work at. This allows cooler running, and therefore possibly improved thermal balance; a V_{ce} of 5V usually works well. Isolating the input collector capacitance from the vas input often allows C_{dom} to be somewhat reduced for the same stability margins, but it is doubtful if the advantages really outweigh the increased complexity.

Other considerations

As might be expected, the noise performance of a power amplifier is set by the input stage, and so it is briefly examined here. Power amp noise is not an irrelevance: a powerful amplifier is bound to have a reasonably high voltage gain and this can easily result in a faint but irritating hiss from efficient loudspeakers even when the volume control is fully retarded. In the design being evolved here the EIN has been measured at –120dBu, which is only 7 or 8dB inferior to a first-class microphone preamplifier. The inferiority is largely due to the source resistances seen by the input devices being higher than the usual 150Ω microphone impedance. For example, halving the impedance of the feedback network shown in pt1 (22kΩ and 1kΩ) reduces the EIN by approx 2dB.

Slew rate is another parameter usually set by the input stage, and has a close association with HF distortion. The amplifier slew rate is proportional to the input's maximum-current capability, most circuit configurations being limited to switching the whole of the tail current to one side or the other. The usual differential pair can only manage half of this, as with the output slewing negatively half the tail-current is wasted in the input collector load R_2. The addition of an input current-mirror, as advocated, will double the slew rate in both directions. With a tail current of 1.2mA, the slew rate is improved from about 5V/µs to 10V/µs. (for C_{dom} =100pF) The constant g_m degeneration method of linearity enhancement in Fig. 9 further increases it to 20V/µs. The mathematics of voltage-slewing is simple:

Slew rate = I/C_{dom} in V/µs for maximum I in µA, C_{dom} in pF.

The maximum output frequency for a given slew rate & voltage is:

$F_{max}= S_r/2\pi V_{pk}= S_r/2\pi \times \sqrt{2} \times V_{rms}$

Likewise, a sinewave of given amplitude has a maximum slew-rate (at zero-crossing) of:

$S_{r\,max} = dV/dt= w_{max} \times Vpk= 2\pi F V_{pk}$

So, for example, with a slew rate of 20V/µs the maximum frequency at which 35V rms can be sustained is 64kHz, and if C_{dom} is 100pF, then the input stage must be able to source and sink 2mA peak.

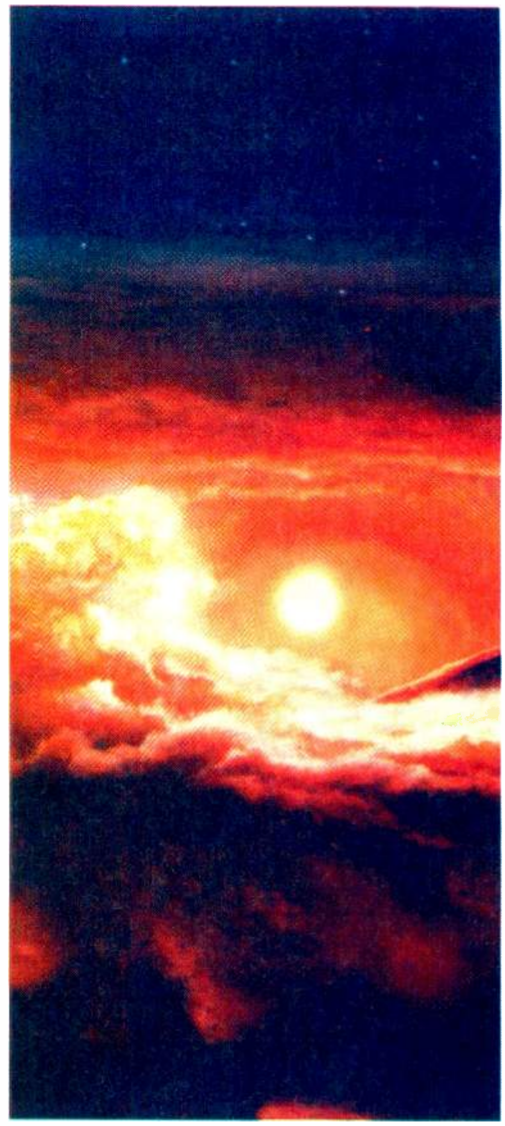
A vital point is that the current flowing through C_{dom} must be sourced/sunk by the vas as well as the input pair. Sinking is usually no problem, as the vas common-emitter transistor can be turned on as hard as required. The current source or bootstrap at the vas collector will however have a limited sourcing ability, and this can often turn out to be an unexpected limitation on the positive-going slew rate. ■

***Next month:** the voltage-amplifier stage.*

References

1. Gray & Meyer *Analysis & Design of Analog Integrated Circuits*. Wiley 1984, p172 (*exponential law of singleton*)
2. Gray & Meyer, ibid, p194. (*tanh law of simple pair*)
3. Gray & Meyer, ibid, p256. (*tanh law of current-mirror pair*)
4. Self. *Sound Mosfet Design Electronics & Wireless World*,Sept 1990
5. Feucht. *Handbook of Analog Circuit Design* Academic Press 1990, p432.
6. Quinn. *IEEE International Solid-State Circuits Conference*. THPM 14.5, p188 (Cascomp).

Using momentum to dethrone Einstein?



NASA

Stepping out from behind the towering shadows of Maxwell, Einstein and Bohr takes nerve. John Ferguson sends forth an iconoclastic Mechanistic theory into the searing light of the relativistic world.

Quantum mechanics

During the years 1905-1925 it seemed that the concept of photons could not be reconciled with the wave theory of light. A possible solution came via the work of Louis de Broglie, who pointed out that if Universal laws exhibit symmetry, then "matter" might be expected to have properties similar to those of waves.

At first, de Broglie's idea was ignored. But experiments showed that sub-atomic particles such as electrons can behave either as waves or particles. One type of experiment will demonstrate projectile behaviour with clearly defined trajectories, others will show wave characteristics, with peaks and troughs adding or cancelling to produce interference effects. As yet, no experiment has shown both simultaneously.

Common sense says that it is impossible for something to be both a wave and a particle. But quantum mechanics say light and similar entities can behave either as waves or as particles, depending on the experiment.

It is this dual wave/particle property of sub-atomic particles that is the central mystery of the theory of quantum mechanics.

An explanation of the theory was offered by Heisenberg's Uncertainty principle, which states that the so-called "complementary properties" of a quantum object cannot be determined simultaneously. For instance, if we measure a quantum object's position in space with absolute certainty, then there is infinite uncertainty in its momentum.

It is fair to add that regardless of the dual nature of quantum entities, and their illogical dependence on observers for their existence, quantum mechanics has been remarkably successful in describing the behavior of the sub-atomic world.

Electronic engineering is grounded in exact science. So it is not surprising that some electronic engineers are not entirely convinced by the enigmatic concepts making up the theory of light. Neither is it any wonder that, after reading about Special Relativity theory and quantum mechanics, a few students will abandon science and engineering altogether.

Seventy years ago, when the theory of light was being formulated, it was generally believed that beyond our galaxy lay nothing but dust, gas and a few isolated stars. We now know that there are millions of other galaxies, each containing billions of stars. So should we be asking ourselves if the theory of light might be wrong?

Many theoretical physicists find it unthinkable that anyone should question the theories of Maxwell, Einstein and Bohr: but that is my intention.

Until relatively recently, the theory of light was of little concern to electronic engineers. But ever-increasing numbers of new optical components – lasers, displays, optical fibres, discs and switches – are steadily being developed for use with electronics.

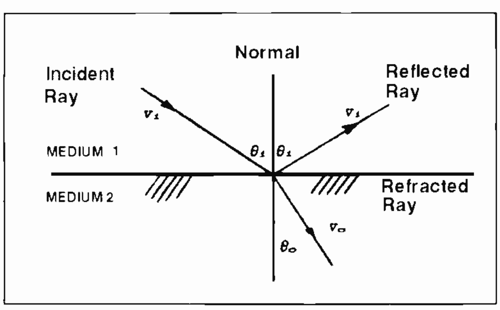
Light pulses used to transmit signals are faster and less subject to distortion than electrical pulses. They can cross each other without interference and can be sent from component to component via optical fibres and mirrors.

So tomorrow's electronic engineers will require a knowledge of the theory of light: Huygens' principle, Snell's law, Fermat's principle, Relativity theory, Maxwell's equations, Uncertainty principle, wave-particle duality and quantum mechanics. (Readers wanting to remind themselves how the theory of light has evolved should see the various boxes.)

Mechanistic theory of light

Light is a unique form of energy; it can interact with matter and be transformed into mechanical, thermal, electrical or even chemical energy. The Mechanistic theory attempts to explain its behaviour in mechanical, rather than electromagnetic terms.

The theory assumes that light is generated as particles which are bunched at the source into photons, and radiated in waves of different frequencies. White light, for example, consists of a beam of velocity-modulated bunches of particles, radiated together at the various frequencies of the spectrum.



Using Conservation of Momentum to derive Snell's law

The Mechanistic theory can explain the laws of reflection and refraction, and also permit calculation of the fraction of light that is reflected at an interface.

Reflection and refraction

If a beam of light is incident upon a surface separating two transparent media, a fraction (α) of the light is reflected back into the first medium and the remainder ($1-\alpha$) refracted into the second.

If an element of the incident ray has mass m then the law of Conservation of Momentum requires that the momentum of the incident element is equal to the total momentum of the reflected and refracted portions of the element. Therefore

$$mv_i\sin\theta_i = \alpha mv_i\sin\theta_i + (1-\alpha)mv_o\sin\theta_o$$

$$v_i/v_o = \sin\theta_o/\sin\theta_i = \mu$$

known as Snell's law. Also

$$mv_i\cos\theta_i = (1-\alpha)mv_o\cos\theta_o - \alpha mv_i\cos\theta_i$$

So

$$\cos\theta_o/\cos\theta_i = \mu(1+\alpha)/(1-\alpha)$$

These equations, obtained without reference to Fermat's principle, or Maxwell's equations, enable us to calculate, for each value of θ_i, the angle of refraction (θ_o) and the fraction (α) of the light reflected at the interface. They show that at an air-to-glass interface, for angles of incidence (θ_i) up to about 50°, less than 10% of the light energy is reflected at the interface. But for angles of incidence near to 90°, most of the light is reflected.

The Mechanistic theory differs from Einstein's in that it makes no postulates concerning the observed speed of light. So, an observer approaching the source with velocity v would measure the velocity of the

Wave theory

Dutch physicist, Huygens, postulated that light was a wave, the speed of which varied from one medium to another. He showed that if all points on a wavefront were regarded as sources for production of secondary wavelets, a geometrical construction would enable the future position of a wavefront to be deduced.

His theory gained support during the 18th century, where experiments by Thomas Young and Augustin Fresnel showed that light can round sharp edges and spread out after passing through slits, producing interference patterns similar to those formed by waves on water. Unlike the corpuscular theory, waves offered an explanation for interference patterns, and so it supplanted that theory.

EM radiation

Faraday suggested that light was electromagnetic in origin – an idea that was later developed by Maxwell, who summarised the laws of electromagnetism in a set of equations. He predicted that the speed (c) of such waves would be $c = 1/(\mu_0.\varepsilon_0)$ where μ_0 is the permittivity constant and ε_0 is the permeability. The predicted speed of electromagnetic (em) waves, calculated from electrical and magnetic constants measured in a laboratory, was found to match the observed value of the speed of light. Maxwell concluded that light comprised em waves of very high frequency, and explained the reflection and refraction of light.

The theory also explained interference effects, and correctly predicted what fraction of the incident light was reflected at the interface of two media.

Einstein compared Maxwell's equations with the classical laws of motion and saw some inconsistency between the two. But his solution was to take the surprising step of revising the well-proven laws of motion, rather than Maxwell's em theory.

Prior to Einstein, mathematicians had accepted the concepts of absolute space and absolute time, which allowed any physical event such as the collision in space of two objects, to be assigned a set of coordinates to define its position (x, y, z) and time (t).

If the event involved motion, the equations describing the motion in one frame of reference could be transformed into another reference frame by using Galilean transformations.

For example, an observer measures the coordinates of an event in space to be (x, y, z, t) from the origin (O) of the coordinate system where they are located. If a second observer, travelling with constant velocity v along the common X-axis, measures the coordinates of the same event coordinates obtained would be (x', y', z', t').

If the first observer measured the velocity of the event to be u along the X-axis, then according to Galilean velocity transformations, the second observer would measure the velocity of the event to be $u' = u + v$.

Einstein questioned use of this method on the grounds that Maxwell's equations were not invariant under Galilean transformations.

The reasoning behind his objection is made clear by an example where a light source is observed by two observers, one of whom measures the speed of the light to be c. If the second observer is travelling towards the source with a speed v, according to Galilean transformations they would measure the speed of the light to be ($c + v$).

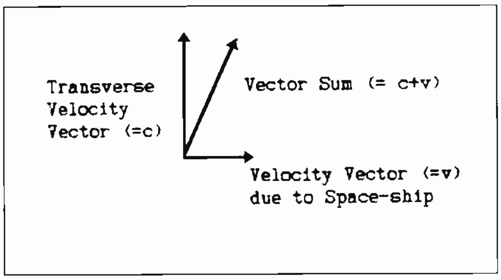
Other observers travelling at different speeds towards the source would all obtain different results. So which observer measures the correct speed of light? (which Einstein assumed was that predicted by Maxwell)

approaching wavefront to be the vector sum ($c + v$), where c is the velocity at which the wavefront is radiated by the source.

To demonstrate the particle nature of light, return to the space-ship example. From the observer's point of view, the laser pulses will have a velocity vector (v) in the direction of the space-ships's motion, and a transverse velocity vector (c).

If the pulse returned to the first space-ship after time 2τ (ie τ in each direction) the astronaut would calculate the distance of separation of the space-ships to be $c\tau$.

An observer measuring the space-ship's velocity, v, would calculate the speed of the laser pulse to be the vector sum ($c + v$) and would compute the distance travelled by the pulse to be $\tau(c + v)$.



Drawing 2. Vector factor that underlines the Mechanistic theory of light.

But like the astronaut, the observer would calculate the distance of separation to be $c\tau$ and there is no reason to invoke time dilation or to suppose time is affected by speed.

Red-shift

In the 1920s, astronomer Edwin Hubble discovered that the wavelength of light from distant galaxies is shifted towards the red end of the spectrum. According to his theory, such galaxies are receding at speeds proportional to their distances of separation.The frequency shift was at first explained as a Doppler effect. But if there is no ether, and if the speed of light is independent of the speed of the source as postulated by Einstein, then why should wavelengths change?

Cosmologists tell us that 15 billion years ago, there was a 'big bang', after which space inflated faster than light, and the Universe grew from the size of a grapefruit to its present size. Relics of the big bang can, we are told, still be measured as background radiation and observed as "ripples in space".

The Mechanistic theory offers a more down-to-Earth solution.

If a light source emits bunches of particles in waves of frequency f_m and velocity c the distance between the wave crests is $\lambda_m = c/f_m$.

An observer directly approaching the source with velocity v would measure the frequency of the wave crests to be f_o and the speed at which they approached would be $c_o = (c + v)$.

So the wave crests would reach the observer at time intervals of $\tau = \lambda_m/c_o = c/f_m(c + v)$

who would measure the frequency as $f_o = 1/\tau$. Therefore:

$$f_o/f_m = (c + v)/c \qquad (1)$$

But during time τ, the observer moves a distance (τv) towards the source, reducing the distance that each wave crest has to travel. It would appear to the observer that the distance between the wave crest was

$$\lambda_o = \lambda_m - v\tau.$$
$$= c/f_m - vc/f_m(c + v)$$
$$\lambda_o/\lambda_m = c/(c + v) \qquad (2)$$

Whither the ether

During the 19th-century, physicists believed that the whole of space was permeated by a medium known as the ether through which electro-magnetic light waves were propagated.

Some observers were assumed to be at rest with respect to the ether, and these "privileged observers" would measure the speed of light to be that predicted by Maxwell.

But when Michelson and Morley built an apparatus to measure the motion of the Earth through the ether, they failed to detect it. Einstein doubted the existence of the ether or privileged observers. So in his Principal of Relativity he postulated that the laws of physics must be the same for all observers.

He further suggested that, *in vacuo*, the speed of light is that predicted by Maxwell's em equations, independent of the motion of either the source or the observer.

Einstein saw his postulates as incompatible with Galilean transformations. So he used the Lorentz transformations in conjunction with Maxwell's equations. The outcome was his Special Theory of Relativity which formulated some controversial new laws concerning the measurement of time.

Time dilation

Measurement of "time" is central to the problem of presenting an alternative theory of light.

Newton assumed that both time and space could be defined absolutely, without reference to each other.

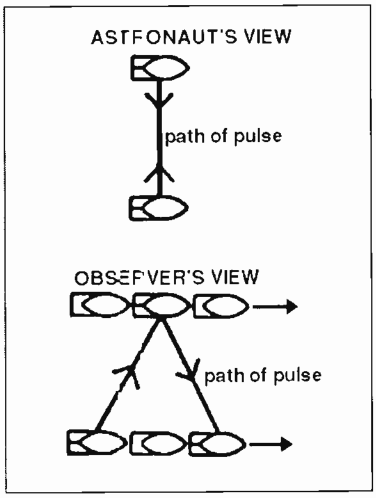
Einstein took a different view. According to his Special Theory of Relativity, time is neither constant nor absolute and is subject to "dilation" – a concept illustrated by the following example:

Suppose that two space-ships are flying side by side at a constant speed, watched by an observer on Earth. An astronaut in one spaceship sends out a laser pulse travelling at the speed of light, and to determine the distance between the two space-ships, his equipment measures the time taken for the pulse to travel between the space-ships. As far as the astronaut is concerned, the laser pulse travels to and from the adjacent space-ship by the shortest direct route. But an observer on Earth sees things differently. From his point of view, while the laser pulse is creating space, the second space-ship continues to travel forward. So the pulse will have to travel at slanting angles to reach its target and then be reflected back to the first space-ship.

It appears that the path beneath the laser pulse, as calculated by the observer, is longer than the length as calculated by the astronaut.

Einstein's postulate – that the speed of light is the same for all inertial observers implies that the astronaut and the observer would calculate different times of travel for the laser pulse.

But according to Relativity theory, time as measured aboard the fast-moving space ship would run more slowly than time as measured by the observer on Earth. So if the astronaut and the ground observer calculated the distance between the two space ships, the effect of time dilation would be that they would obtain the same answer.



An earth-based versus space based view of the same light beam. Is the path really longer?

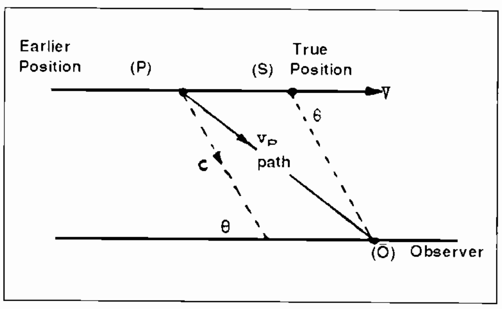
Expressed in plain English, Eq 1 and Eq 2 show that if a source is directly approaching an observer with speed v then the observer would find that frequency had increased by a factor $(c + v)/c$ and the wavelength of the light had decreased by a factor $c/(c + v)$.

For example, if a galaxy were approaching at a speed equal to half the speed of light, the frequencies in the spectrum of its light would be increased by a factor 1.5 and wavelengths would be decreased by a factor 2/3. Conversely, if the galaxy were receding at a similar speed, the wavelengths would increase by a factor 1.5 which astronomers would observe as a "red-shift".

Doppler equation

If a source is moving at an angle θ to the line-of-sight of the observer, then the Doppler equation can be derived.

Suppose a spaceship travelling at speed v relative to Earth, transmits laser pulses at a pulse repetition frequency f towards an observer at an angle.



Doppler equation obtained from a mechanistic analysis.

Since the speed of light (c) is finite, the observer would not see the spaceship at its true position (S), but at an earlier position (P) such that the time taken for the spaceship to travel from P to S is equal to the time taken for a laser pulse to travel from P to O.

The pulse's velocity from P to O can be resolved into three vectors:

V in the direction of ship's motion

$c\cos\theta$ in the direction of ship's motion

$c\sin\theta$ traverse to direction of ship's motion

The speed of the pulse from P to O is v_P where:

$v_P^2 = (V^2 + 2Vc\cos\theta + c^2)$

Therefore the observer would measure the repetition frequency of the pulse as:

$$f_o = fv_P/c = f[V^2/c^2 + (2V/c)\cos\theta + 1]^{0.5}$$

which is the Doppler equation.

The Doppler equation derived from the Mechanistic theory differs from that derived from the Special Theory of Relativity, which requires the speed (v_P) of the laser pulse from P to O, as measured by the observer, should be c regardless of the spaceship's speed.

Wave-particle duality

The Mechanistic theory assumes light is a beam of particles, modulated at source by a presently-unknown mechanism and radiated in bunches, which we can call photons.

If the theory is correct, and if suitable test equipment were available, light could be detected either as waves of photons, or as individual photons, or even as the "particles" which go to make up a photon.

The theory offers a possible explanation for most optical effects, such as interference, pressure of light, photo-electric and Compton effects, laser action and the Sagnac effect.

Surprisingly, the concept is in accord with the centuries-old Huygens principle, that all points on a wavefront can be regarded as sources for the production of secondary wavelets – and it also goes some way towards solving the modern mystery of wave/particle duality. ■

After completing a post-graduate course in electronics at the University of Southampton (1955), the author has spent a number of years working as an aerospace engineer on military projects in Canada, the USA, Germany and England.

Mass of a photon

The theory of relativity was not taken seriously for some years, during which time Einstein studied the photoelectric effect.

His work led him to conclude that the results of many optical experiments could best described by a theory of "photons" – which he regarded as localised concentrations of energy, not too unlike Newton's corpuscles.

During that same period, Planck studied the way in which light is emitted by hot bodies. Like Einstein, he concluded that energy is only emitted in "quanta" ie multiples of an energy unit, the size of which depended on the wavelength of the radiation.

Photons could explain the photoelectric effect: the wave theory could not. So the entire theory of light was thrown into confusion.

According to the Special Theory of Relativity, the relativistic energy of a free particle mass is given by:

$$E = \frac{mc^2}{\left(1 - \frac{v^2}{c^2}\right)^{0.5}}$$

For a photon, v = speed of light (c). It follows that the rest mass of a photon must be zero.

According to some books, the relativistic mass (m) is $m = E/c^2$ though not all agree on that point.

If light has mass, then a beam at right angles to a gravitational field would be deflected, and according to the General theory of Relativity, the deflection would be about twice that calculated using Newton's theory.

To find out which theory was correct, an attempt was made in 1919 to measure the deflection of star light by the Sun's gravitational field. The measurement appeared to favour Relativity theory, though in recent years, the claim has been disputed.

Corpuscular light

Newton believed that light consisted of tiny corpuscles reflected by mirrors in much the same way as balls bounce off walls. He assumed that all corpuscles could penetrate a transparent medium such as glass, but his experiments showed that part of the incident light was reflected while the remainder was refracted into the glass. He then assumed that corpuscles representing one kind of light were not all of the same size, in which case the structure of the glass would filter out a fraction of the incident light.

But tests using a beam of monochromatic light falling directly on a sheet of glass showed that a fraction was always reflected.

If the transmitted fraction was then allowed to fall on a second sheet of glass, as before, the same fraction was reflected at the surface of the second sheet.

Newton concluded that all corpuscles are capable of both reflection and transmission, but that they have "fits of reflection" and "fits of transmission" and so their behavior cannot be predicted.

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CIRCLE NO. 123 ON REPLY CARD

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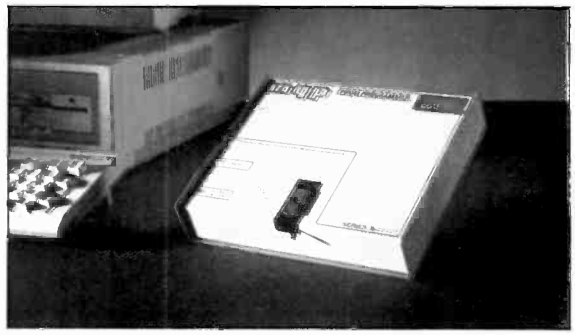

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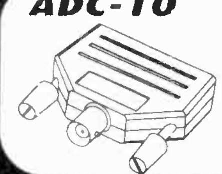

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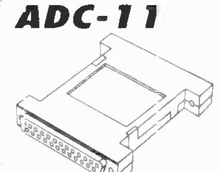

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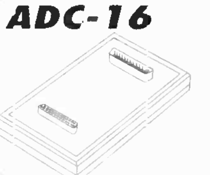

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CIRCLE NO. 125 ON REPLY CARD

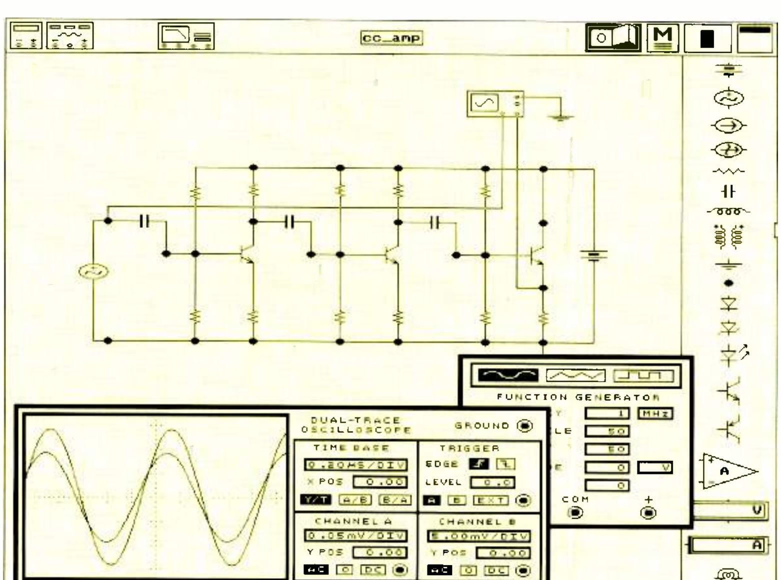
Can teachers wave bye bye to the lab bench?

Electronics Workbench could be ideal for hard pressed colleges wanting to try electronic simulation and schematic capture – if they can afford the hardware to run it, says John Anderson

Electronics Workbench is a grandly named software simulation system with integral schematic capture. Target market is the educational user, though whether the well-trodden principle of lower specification (and lower prices) for education compared with industry actually assists education is questionable. But on its own terms, how does this educational package compare with its full scale industrial rivals?

Two modes of operation are possible – distinguished by typing either "analogue" or "digital" at the dos prompt – and the resulting screen (in a tasteful shade of yellow) is the workbench where the circuit is "constructed" and "tested".

Never one for reading instructions first, I immediately started editing – and found the package a delight to use, being almost totally intuitive. A ribbon of components appears on the right hand side of the screen and these can be selected and dragged across to the display area using the mouse.



Three stage amplifier with function generator and scope. Scope trace can be blown up to about a quarter of the screen area for viewing. Its "signal" comes from clicking on the appropriate circuit node.

Components connections are made when the cursor is within range: a little black square appears at the connection node allowing a simple visible "snap" during the node connecting process. Connections can follow simple paths. *Workbench* will decide on its own route between two nodes – which may not be the best visually – but editing is very fast and a complete schematic can be put together more quickly than almost any of the industrial schematic capture programs (and this on the first time of using).

Values for individual components are input by double clicking on the component, entering the mantissa part of the value and then moving the mouse to set the exponent. The methodology is rather awkward, but usable.

Bring on the scope

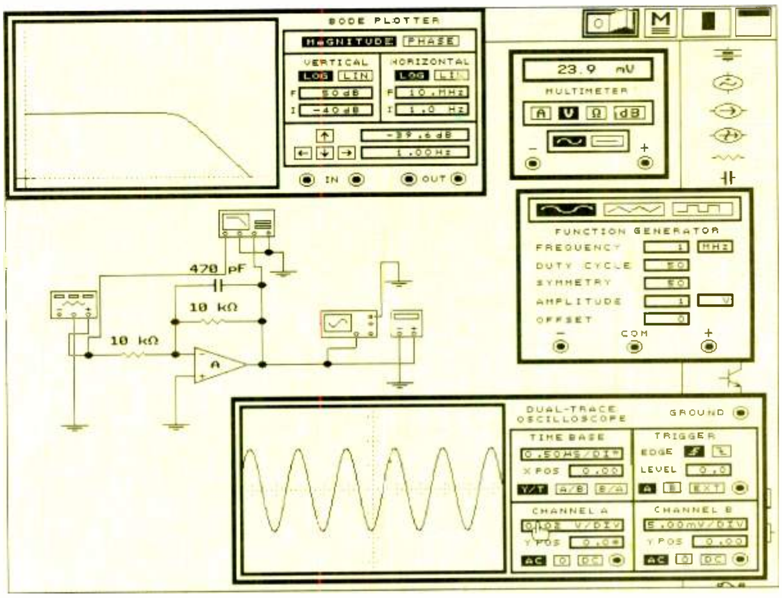
Testing with an "oscilloscope" is made easy. The scope icon is picked up from the icon ribbon at the top of the screen and dragged on to the workbench where it is connected to the circuit in the same manner that the circuit is constructed. Double clicking on the icon increases its size to about a quarter of the screen area so that the trace can be viewed.

Other analogue instruments can be brought into the test, including DVM, Bode analyser and function generator. All are used in the same neat intuitive manner, picking them up moving them onto the workbench and connecting to the circuit.

Instruments are adjusted for amplitude, gain etc by clicking on the control and moving the mouse up or down to increase or decrease that particular setting – unfortunately somewhat more cumbersome in practice than it sounds. But seeing sufficient detail on the scope and Bode analyser displays can be a problem, as even when the scope icon is maximised, it fills less than a quarter of the display. The same is also true of other instruments.

Slow simulation

A toggle switch at the top of the screen is used to "power-on the circuit" and start the simulation. Instruments are updated as the simulation progresses so that, for example, the oscil-



Add all the instruments and you have a cluttered workbench – just like the real thing.

loscope trace advances throughout the test. This is just as well because simulation run speed is lamentably slow and so it is comforting to know that something is happening.

Even so on a 25MHz *386* the simulation was so slow as to be unacceptable, and on a 33MHz *486* platform the simulation of a relatively simple op-amp circuit took several seconds. Perhaps this is the difference between professional and educational software, but it should not be so. No user should have to wait unnecessarily.

A further test using a simple two transistor circuit also took a very long time to run. Indeed for certain component values it failed to complete the simulation at all, reporting a (non-existent) connection error. The flip side of the slow simulation coin is that there is no evidence of poor simulation due to aliasing or too large a step size in solving the time equations.

Digital Workbench

In the digital mode, the editing scheme is identical to the analogue system, but the choice of library components is severely restricted. The list of components boils down to a number of basic gates, flip-flops and a BCD counter.

Simulation is also desperately slow. This might be helpful to students, showing the operation at a human speed, but the slow speed means that it is impractical to use the simulation system for any real application.

Test gear available for digital operation includes a multimeter, a word generator and a logic analyser.

Cleverest facility is the "truth table instrument" which, apart from sounding like a medieval torture, is a very neat digital synthesis tool. A truth table is entered into the tool, accomplished by selecting variables, and digital *Workbench* then generates a list of all the Boolean combinations.

Users can edit the output node for each of the combinations. With the truth table input completed, a reduction algorithm is run to produce an output expression (eg A'+BC) which in turn may be converted directly to an array of gates entered directly into the schematic. Very nice!

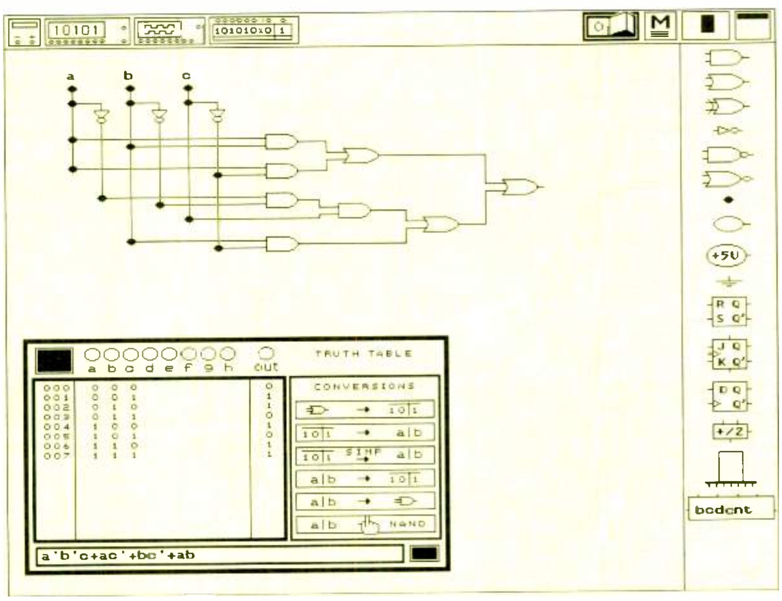
On the debit side the scheme only works for a single output and cannot support flip flops or logic state machines.

Alternative to lab work

An excellent schematic editor and a truly novel approach to simulation are reduced to almost ineffectualness because of slow simulation, poor results detail and very limited libraries.

Of these problems, the limited component library is probably acceptable in the educational environment. But slow simulation and poor results detail are not.

The product tested was optimistically described as the



Input the truth table, and Workbench will simplify the Boolean expression, select a | b → circuit and – the logic circuit is drawn.

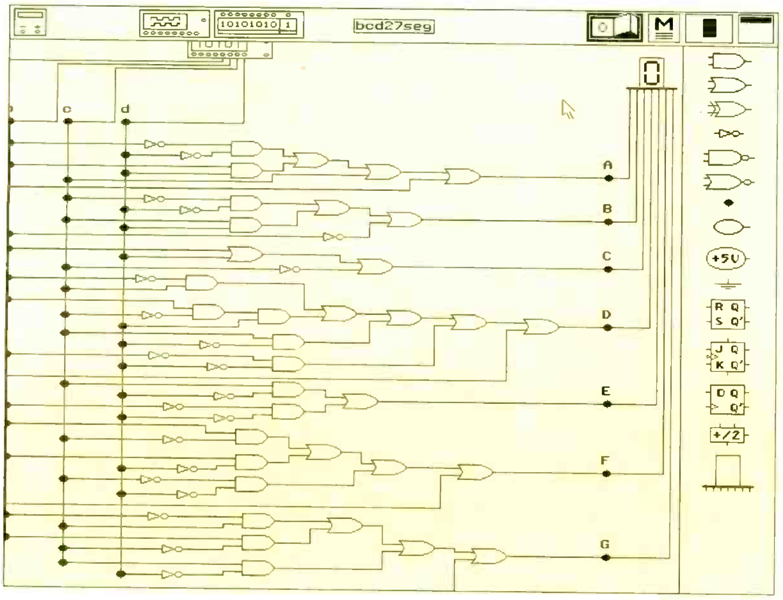
EASY INSTALLATION

The professionally produced loose leaf manual contains a complete tutorial as well as detailed operational details: a useful touch is a technical exposition covering the mathematical background to the modelling system.

Installation is quick and simple, with the name of the person or establishment installing being written back onto the master disc.There is nothing intrinsically wrong with this approach, but as a matter of principle I always write-protect master discs and so caused the installation to terminate early.

WHAT THE CRITICS SAY

The advertising material includes some glowing testimonials from Jerry Pournelle (erstwhile author or the "Chaos Manor" column in *Byte* magazine) and other notables from various magazines and companies. But although these laudatory remarks are very positive they are not in any way comparative. So despite the critics, I would recommend that the electronics educator who is a prospective purchaser look at professional simulators before buying.



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Mouse
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Dot matrix, HPGL plotter or Laser Jet printer

SUPPLIER DETAILS

Electronics Workbench, By Interactive Image Technologies Inc, Toronto, Canada.£189. Available from Robinson Marshall (Europe), 17 Middle Entry, Tamworth, Staffs B79 7NJ. Tel: 0827 66212 Fax: 0827 58533.

"professional version", but, with the exception of the simplest circuits, this is in no way a practical professional tool.

So can it provide a useful alternative to lab work for students of electronics? The answer is undoubtedly yes, qualified by the need for a college to invest in high performance PCs to run the package. Any such electronics modelling education will have to be supplemented with real lab work so that students are made aware of the differences between simplifications of components for simulation and the real world.

Cost is an important issue in all colleges, and the relative costs, depreciation and value for money need to be weighed against educational benefit. In the end, the cost of a good PC and *Electronic Workbench* is likely to be significantly less than purchasing lab equipment.

That said, many cash strapped colleges are still struggling with 8086/80286 machines and with *Workbench* running too slowly even on a 80486, the performance is woefully inadequate on more ancient hardware.

A pity, because in some senses the ideas behind *Electronics Workbench* are way ahead of its industrial cousins.

■

Nervous call for help

The letter from John Carver (*EW + WW*, July) is of some interest to me. Some 30 years ago I made some inconclusive attempts to speed the healing of fractures by the use of pulsed electromagnetic fields. The work was not completed because of lack of interest by my surgical colleagues.

Carver is of course correct in his statement that many biological processes are carried out via an electro-chemical action. A typical example is the transmission of pain sensations from the periphery to the brain interrupted by the chemicals known as local anaesthetics.

I believe that it is possible to stop pain transmission by electrical reversal of the waveform in peripheral nerves. I suggested this line of research to Professor Sykes of Hammersmith who pointed out that peripheral nerves have many fibres all having many fibres all transmitting electro-chemical waves which are not in phase. This wave form is extremely slow compared with an electrical current in a wire.

I would like to hear from your readers as to the feasibility of producing local anaesthesia by reversal of the electrical impulses in such nerves using modern equipment not available when the suggestion was first made some 20 years ago.

V Keating
Nailsworth
Gloucestershire

Mortals with golden ears

In response to the letters by Stan Curtis and Stephen Merrick (*EW + WW*, July) regarding our letter (May) concerning super-cables, it was never our intention to deny the effect that a grossly inappropriate cable link might have on listening quality.

Moreover, we mortals concede that there are those with golden ears who believe they are far more subjectively sensitive than we are to subtle flaws in sound quality caused by system inadequacies.

However, the central point of our letter remains simple. We say that there is no justification for the outrageous quasi-scientific claims made by the super-cable manufacturers who supply a product falsely specified and wildly over priced. We say that the same performance can be obtained by using standard good quality cable. If, as some audiophiles claim, they can hear a difference between two electrically appropriate cables, then we must presuppose that some other factor is involved.

Having spent effort and possibly large sums of money in a re-wiring exercise, few of us are likely to admit that it was an expensive waste of time. We convince ourselves otherwise and our wish for a positive outcome to our endeavours is fulfilled.

Merrick points out that he discerned an improvement after re-wiring his speakers, but this doesn't support super-cables, merely that there may have been an initial inadequacy in the manufacturers' conductors or connections that Merrick appears to have corrected. In this context, there is no adequate substitute for double blind tests carried out ideally by three people – one to set the conditions, one to select them, and one to listen. In this way even the person selecting one particular set of connections or cables does not know which he or she is selecting so there is no possibility of significant pre-warning being perceived by the listener.

Regarding Curtis' letter, one wonders whether he really was surprised that he could hear a difference when a 1Ω series resistor was inserted in the tweeter circuit. After all, he was affecting just one part of the system's response range – and with resistance many times greater than that of any suitable cable. We quote 0.04dB for the difference between ideal and good but this says nothing about inappropriate and inadequate conductors. No one (sensibly) would employ 1mm iron conductors would they?

Dr BC Blake-Coleman
Dr R Yorke
Southampton

CFA death exaggerated

With regards to the article by Colin Davies "CFA – RIP" (EW + WW, May) on cross field antennas, perhaps you may know that the CFA originated from my PhD research program in 1986, followed by a joint patent from Maurice Hately and myself.

Since the CFA is a two field reaction control device, it does not follow the present Maxwell's equations or present antenna art. The CFA macroscopic field dynamics follow the corrections of Maxwell's equations which is clear in our IEEE paper in October 1990.

Consequently, up to date measuring equipment could not discover or get the CFA into operation, because this equipment is current functioning, not field functioning as in a CFA; that good radiation on a CFA does not come from all input resistances.

This is why the CFA is sometimes a dummy load, poor radiator or good radiator. Of course, there are many important points about the CFA not mentioned in our articles regarding antenna design, field reaction formulas, equivalent circuit, input resistance control, the steps of setting the antenna for good radiation and so on.

The reason why Colin Davis failed to get his CFA to work was that his antenna is not CFA.

Following the CFA discovery, many scientific and more rigorous research work has been carried out with quantitative results and successful radiation, in the UK and Egypt, with different power radiation CFAs used for different purposes.

The theory of the CFA has been the subject of lectures and projects for BSc and MSc in Egyptian Universities since 1987.

Here at the Egyptian CFA Research Team, we welcome visits to our stations to confirm that the CFA is a good radiator, radiating as good as (or better) than high conventional mast antennas in regard to bandwidth and signal strength.

The radiation begins from the near field, that is $1/R$ dependence (R is the distance from the antenna), with no heat loss from any component of the CFA system. Almost all input power is radiated at an efficiency between 85 and 93%.

FM Kabbary
Cairo
Dr Kabbary supplied tabular results to support aspects of this letter – Ed.

Bring on the de-jaggers

With regards to Peter Chadwick Gregory's reply (EW + WW, July) to my letter (May), the question is are we comparing like with like? Has Gregory heard a modern cassette player? His reference to noise with a capital N seems oddly out-dated. It's been years since I've heard tape hiss on a cassette even using full (up to CD level) equalisation. It used to be a problem, but not any more.

His reference to Ferrograph amused me. Oh my, those horrid controls! Wotta clatter!

As for CD distortion, the type I was wanting information about is the kind that if you hear it once then you always do. I was making a plea for someone to evaluate to a degree that I cannot myself.

Meanwhile, Gregory and I do hear an assortment of vinyls, CDs and cassettes on radio in (hopefully) silent background stereo. Can he honestly say he can tell which is which - even given the tiny clues which station engineers spend so much time in trying to prevent? Maybe someday we shall get de-jagged D/A decoders in domestic players.

Curious how little is said about CD quirks such as the odd jumping disc, the miscuing, not forgetting the traditional bit of fluff on the head.

Far be it for me to make a blanket condemnation of CDs. The strange fact is that there are a remarkable number of new devices which seem to be hanging fire.

Ronald G Young
Peacehaven
East Sussex

Getting the wind up

The letter "Have the twins gone with the wind" (EW + WW, July) was like a breath of fresh air. At last someone has been very careful in their choice of words when discussing relativity. The use of electronics to clarify the points made showed an understanding of how to communicate difficult ideas.

If this does not put the wind up the relativitists nothing will.

C L Wee
Bagilt, Clwyd

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Racal/Dana Counters 9915M – 9916 – 9917 – 9921 – £150 to £450. Fitted FX standards.
Racal/Dana Modulation Meter type 9009 – 8Mc/s – 1.5GHz – £250.
Racal – SG Brown Comprehensive Headset Tester (with artificial head) Z1A200/1 – £350.
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Marconi microwave 6600A sweep osc., mainframe with 6650 PI – 18-26.5GHz or 6651 PI – 26.5-40GHz – £1000 or PI only £600.
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Microwave Systems MOS/3600 Microwave frequency stabilizer – 1GHz to 40GHz £1k.
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HP 3763A error detector. £250.
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Racal/Dana VLF frequency standard equipment. Tracor receiver type 900A + difference meter type 527E + rubidium standard type 9475 – £2750.
Marconi 6960–6960A power meters with 6910 heads – 10Mc/s – 20GHz or 6912 – 30kHz–4.2GHz – £800–£1000.
HP8444A–HP8444A opt 59 tracking generator £1k–£2k.
B&K dual recorder type 2308.
HP8755A scaler ANZ with heads £1k.
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HP signal generators type 626 – 628 – frequency 10GHz–21GHz.
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Systron Donner microwave counter 6057 – 18GHz – nixey tube – £600.
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Pinching electrons in the aether

Few of your readers will have heard of a phenomenon discovered by William Hooper. Hooper died in 1971. His discovery was later confirmed by researchers at Montana State University, USA.

Imagine a straight conductor bent back on itself to form a noninductive bifilar circuit configuration which has two closely adjacent oppositely directed identical current flows. It should develop no magnetic or electric field at radial distances that are significantly larger than the cross-sectional dimensions of the circuit.

Hooper incorporated 4020 such conductors in a non-inductive circuit assembly and passed up to 30A through the circuit. He encased the assembly in a stainless steel cylindrical capacitor, with the inner conductor grounded and the outer conductor connected to a high impedance voltmeter. He found that whether he used AC or DC, and even though the circuit was screened by the inner conductor of the capacitor, he obtained a DC voltage across the capacitor that was a function of the current.

I suggest that the Hooper experiment replicates in each conductor strand an action that occurs in a lightning discharge by which a filamentary pinch action on electrons develops a radial electric field within the conductor. The vacuum medium, the aether, spins in response to set up a radial electric field that cancels the effect. The effect could have escalating features causing the spin to build in strength as charge is held at the conductor surface. The actions of all the currents are additive so that the net external effect is an aether spin which can break out and spread beyond the confines of the source conductors. This would set up the radial electric DC field in the cylindrical capacitor that Hooper measured.

In thunderstorms the same action is the source of the spherical plasma balls that we sometimes see and which we term thunderballs. One may even wonder if this is a source of an invisible menace, the quasi-stable carriers of those killing fields we imagine are associated with overhead power lines.

I have thought for many years that the action of the aether in developing this spin response is powered by energy that is tapped from the vast energy resource, the quantum spin state of the. vacuum itself. On the 30th of June this year a company Raum-Quanten-Motoren AG of Rapperswill, Switzerland, distributed a prospectus announcing the marketing of a revolutionary new energy generating technology in the form of solid-state apparatus in two types of 30 and 210kW. The technical literature indicates that the device harnesses Hooper's discovery.

Can it be that we are destined to have our electrical power supplied to us freely by the aether? Having written a book in 1972 called " Modern aether science", a book which stresses the need to learn from the thunderball as an aether phenomenon, and even suggests that the sun itself is powered in this way, I should not be surprised by this Swiss development.

However, the prospect seems too daunting to be credible and yet, if ever such an invention were to intrude on the energy scene, what is more likely than that it would make its entry in this way? Certainly, no respectable energy authority would risk giving support to a proposal seen as perpetual motion Nor indeed will I, in the absence of more information, dare to venture any opinion on that Swiss initiative.

H Aspden
Southampton

BEWARE! Danger from falling satellites

The proof that the earth rotates that RG Elmendorf requests (EW + WW, August) is as follows. If the earth does not rotate then geo-stationary satellites are not rotating either. If they are not rotating then there is nothing to stop them falling to earth unless they are held there by the combined faith of those who believe the earth rotates.

● On the subject of audio, I recall many years ago someone writing to say that he had added a switch in his speaker leads which reversed the polarity of both speakers (together). A loudspeaker will produce positive pressure when moving out and negative pressure when moving in.

He argued that in the case of an impulse such as may be produced by a symbol or a drum it is important that what started out as a positive pressure should come out of the loudspeaker as positive pressure and vice versa because the ear is not a linear transducer (and there is no reason why it should be).

If true then two amplifiers with same measurable quality could sound different if one was inverting relative to the other.

John Kennaugh
Cornwall

Catt's Difficulty

I wonder if Ivor Catt's conceptual difficulty (*EW + WW*, June) stems from a rather outdated picture of the electron, and of physics generally.

Around 1980, you published an interesting article by Professor Jennison, called "What is an electron". Jennison's team of researchers, recognising that the quantum mechanical picture of the electron is expressed in a rather high level language (in the sense that it does not say anything about the electron's physical structure), had been working on the idea that the electron is like a resonant cavity which contains energy that is oscillating back and forth at the velocity of light.

On the basis of such a picture, there might not be any problems with apparently slow-moving electrons transferring energy at velocities far in excess of their average velocity.

Catt might also be interested in learning that according to quantum electrodynamics (see for example "QED – the strange theory of light and matter" by Professor RP Feynman) electrons keep station by photon exchanges that take place at the velocity of light. So there would be no problems there with energy transferring very fast but electrons remaining relatively stationary.

Catt could respond by pointing out that he is concerned primarily with the removal of what to his mind seems to be an obvious contradiction within existing theory, but I think it would be far wiser to accept the theory in the form it is, rather than try to improve it on the basis of concepts that might not have a very long life expectancy.

And, after all, existing theory has served well, as evidenced by impressive technological achievements.

G Berzins
Camberley
Surrey

Pull of the aether

We are taught that energy may be stored in a capacitor by virtue of the strain in its dielectric; an electric field is the manifestation of this phenomenon. Duality exists with respect to the magnetic field. In both cases the dielectric can be a vacuum (that is space or absence of everything). Thus we have a device, a capacitor or inductor capable of storing energy by virtue of a field in nothing. This takes some believing!

It gets worse. If a device is constructed that creates such electric and magnetic fields alternating and in relative space quadrature, energy is radiated from such a device (for example a dipole). This phenomenon is described mathematically by James Clerk-Maxwell. Thus in this same nothingness (space) we have energy passing by virtue of electromagnetic fields.

Ever since the ancient Greek philosophers, the idea of an aether pervading space was established. Such hypothesis can explain the paradox of energy storage and transmission. However, when put to the test by the Michaelson-Morley experiment the scientific community agrees that aether drift effect of the earth moving through space not only is not proven but as the experiment has been refined shown not to exist.

I have always believed that this null result was due to a philosophical error in the interpretation of the experiment rather than in the negation of the existence of the aether per se. Strange that this experiment was being conducted at the time Einstein's theories were being expounded because if these are correct then a null result would be exactly what would be expected, aether or not.

Relativity theory predicts that there is no relative velocity between light emitted from moving bodies; everywhere in space light travels at its own speed irrespective of the speed of its source. Thus M & Ms counter-moving light sources somehow radiate light into the aether at this fixed speed so no Doppler effect can be measured by comparing the two returning beams.

We still have a paradox but at least M & M and Einstein are rendered mutually consistent and furthermore the aether is not ruled out. I have never wavered from the view that the universe is filled with a medium; how can a void have measurable properties? For the capacitor we have ε_0; the inductor μ_0.

What is more remarkable is that:
$\varepsilon_0 \times \mu_0 = c^{-2}$ (equation 1)

where c is the speed of light. So not only can space have properties that can be measured but these properties have dimensions which are non-rational (not simply ratios of classical dimensions). Though the aether's presence is not proven, there is overwhelming circumstantial evidence for it. It is even more so when engineers on earth assume it exists and design high speed logic circuit boards that prove that equation (1) holds when ε and μ are local values determined by materials and c is the local speed of transmission.

Radio engineers know that, $\sqrt{\varepsilon/\mu}$ has the dimensions of impedance and for space the value is $120\pi\Omega$. For circuit boards the same equation, but not value, holds.

Now for the clever part! Light is reputed to be bent in a gravitational field (here is yet another example of energy being represented by a field) and red shifted. The expression gravitational lens is used to describe the effect. Now we know that light bends when it passes through optical devices. We know why too. The waves slow down in the (optically) denser medium. Here again we accept the idea of a medium being involved. Perhaps then, for some reason, in areas of space where matter is concentrated, light slows just as in a glass lens. The only difference being that the transition is not abrupt but occurs gradually.

If ε_0 and μ_0 are not invariant throughout space but increase in areas of space where matter is concentrated we have a common sense explanation. Provided both constants increase at the same rate, ε/μ, and hence space impedance remains fixed so no mismatching occurs as the radiation enters or leaves regions of different aether density, no telltale reflections will be generated.

This is a common-sensical explanation of what others describe as distortion of the space-time continuum but leads to a different conclusion as to its cause.

We do have one conceptual problem to overcome. Speed (velocity) is defined as distance divided by time. My postulate is that the velocity of light is not constant throughout space while the passage of time is. I adopt this position because it follows more readily from the way we customarily think but for the purpose of this hypothesis it could just as well be vice versa.

If light slows down in areas of matter concentration, distances travelled in a given time are less, so any linear (distance) measurement based on light velocity and time will be distorted by this phenomenon (qv Lorenz compression). Thus wherever we are in space, then times, distances and speeds are related in the same way and thus we have no way of knowing if ε_0 and μ_0 have changed.

Because of this slowing, any modulation that light passing close by a heavy body possesses will be red shifted due to the Doppler effect. This is just what astronomers observe. Doppler shift is a fixed (offset) shift of all frequencies. Colour temperature is a scale change of frequencies. It is therefore possible to distinguish them.

But why should we get this aether compression? My hypothesis is that mass too is energy stored by virtue of a field as a strain of the aether. As this energy is located in a region of space the aether compresses to make room for it. Gravity is therefore the aether squeezing the matter together rather than matter particles attracting others towards them. Just as Maxwell stated "We reverse this", my hypothesis reverses the Newtonian principle of gravitational attraction though it doesn't alter its veracity as a tool.

While I imagine the above may be a little difficult to swallow, the *coup de grace* is much worse. Not only does the velocity of light change with proximity to matter, it also does so if its emitter is moving. Imagine a spherical body moving through the aether. In its direction of travel the aether is further compressed while in the opposite direction it is ratified. Because of the compression c is lower so the radiation is launched at a lower velocity than from a static source. Could it be that this exactly compensates for the relative forward motion? What basis exists for such a postulate? All forms of energy so far discussed can be explained as strains of the aether. We have not yet accounted for kinetic energy. With the aether distorted like the bow-wave and wake of a ship this is the manifestation of kinetic energy.

Lest readers think this is too esoteric, Steven Hawking has stated that matter and speed tell space how to bend. My hypothesis is consistent with this opinion but provides a better mental image of the process from which others may progress the science of space. One thing not explained is radioactive decay. It would seem that the aether is not homogenous but has the odd tear distributed randomly throughout it. It is their meeting with these tears that cause isotopes to revert to base. Could this process be the Sieve of Erasthenenes?

Yet more controversially, all these phenomena are fields in space. All establish themselves throughout space instantaneously (action at a distance). At least instantaneously in proportion to the energy they represent. However, such a process is rate limited. We can't change a capacitor's charge instantaneously. Thus a gravity field (not the same as a gravity wave) acts instantaneously throughout the whole universe. If this were not so, space scientists and astronomers would have to make allowance for the time taken for the pull of a body on another as it moved. Newton's force of attraction makes no such assumption.

If this hypothesis be correct then a true black hole can't exist. There is no event horizon. Light may be greatly slowed by the high aether density but it can still eventually escape. How much simpler this may make astrophysics! Not only that, but because aether pervades the smallest particle (maybe not superstrings), particle physicists may get a new perspective of their science and simplify their theories too. What appear to be short lived particles may be manifestations of the aether as energy changes form within it. Such physicists may in fact be observing the nature of the aether rather than of matter *per se*.

JS Churchill
Stroud

Einstein has the last laugh

Martin Berner may not have received many replies to his query (*EW + WW*, July), which I must say is surprising, do any physicists read *EW + WW*? Fortunately, the answers can be found in almost any text on special relativity, which will explain the relativistic Doppler shift. However, for the sake of completeness, there is no paradox regarding the invariance of the speed of light and the longitudinal Doppler shift.

Consider a source, in an inertial frame such that special relativity is valid, emitting pulses of light with frequency ν_0 as measured in that frame. To an observer moving away from this source at velocity u, or vice-versa, the situation is symmetric in this instance, the light pulses must cover an increasing distance to reach the observer and so an increased wavelength is observed.

A few hours careful working through decent introductory texts will introduce sufficient material to allow the derivation of the frequency measured by the observer, ν, to be:

$$\nu = \nu_0\sqrt{\frac{c-u}{c+u}}$$

If I can do it, and it's been a few years since this engineer did basic physics, anyone can. All that is required is the invariance of the velocity of light, as predicted by Maxwell ($1/\sqrt{\varepsilon_0\mu_0}$), and some careful thought (but no sleight of hand).

As with all special relativity results, this must be derived rigorously from postulates of special relativity. One cannot convert Newtonian mechanics to special relativity by changing $c + vs$ to cs and so on, this only generates self-inconsistent Newtonian mechanics, and has absolutely nothing to do with special relativity - and one should beware any such derivations which claim to be special relativity.

It is possible to derive Newtonian mechanics from special relativity when $u \ll c$. However, this is the correspondence principle, and is one of the strengths of special relativity - it does degenerate into the common-sense of very low velocity everyday experience at low velocities.

Please note that the above expression relies upon the second postulate and is only applicable to electromagnetic radiation. Stillwell and Ives confirmed this expression (as opposed to the Newtonian version, much to their disappointment) as early as 1938 using an ingenious experimental arrangement (see for example "Special relativity" by AP French).

In regard to John Ferguson's query (Letters, April) about the transverse Doppler shift, this too has been confirmed by experiment (for example to within 1.2% experimental error by W Kundig in 1968) to be in agreement with special relativity. Moreover, special relativity predicts a shift even when the source and observer are passing at 90°, which is not even predicted by classical theory, but which is observed. Again, French's introduction to special relativity discusses this effect mathematically and phenomenologically.

Moving on to David Chalmer's problem (Letters, July), acceleration cannot be ignored in the twin paradox no matter how little a fraction of the journey time it encompasses, and has nothing to do with quantum mechanics. Indeed, it has long been known that the acceleration effects are the key to the solution. Only one twin experiences real accelerating forces (the one who gets up, goes, turns around and returns then stops), so breaks the symmetry by changing reference frames, leading to the unequal time intervals predicted to special relativity theory, though obviously the proposed experiment cannot (easily) be performed.

No experimental evidence, only "common-sense", a "I think not" and a knowledge of electronics which seemingly gives insight into nature, is given to justify a statement that both clocks will read the same on return. However, accurately measured particle decay in nuclear accelerators is in agreement with Einstein's time dilation, so Albert has the hard experimental results from many closely related experiments in this instance.

Time is very well defined in special relativity - indeed any introduction to special relativity begins with a very careful examination of just what is meant by time and distance to an observer - an essential base for any rigorous study. This old paradox has been flogged to death in attempts to discredit special relativity, and repeating old arguments which have been resolved and hoping for non-relativistic experimental behaviour does not change the result. It does not matter if your clock is "Gone with the wind", a blob of plutonium, or came free with cereal. Nor does special relativity say anything about modifying nuclear decay, only the consequences of measuring it as an observer in relative motion.

If we engineers refuse, on the grounds of common-sense, to accept the experimentally tested answer, preferring to cling to Newton – nature, Einstein and the rest of the world are having a good laugh on us.

Andrew Myles
Edinburgh

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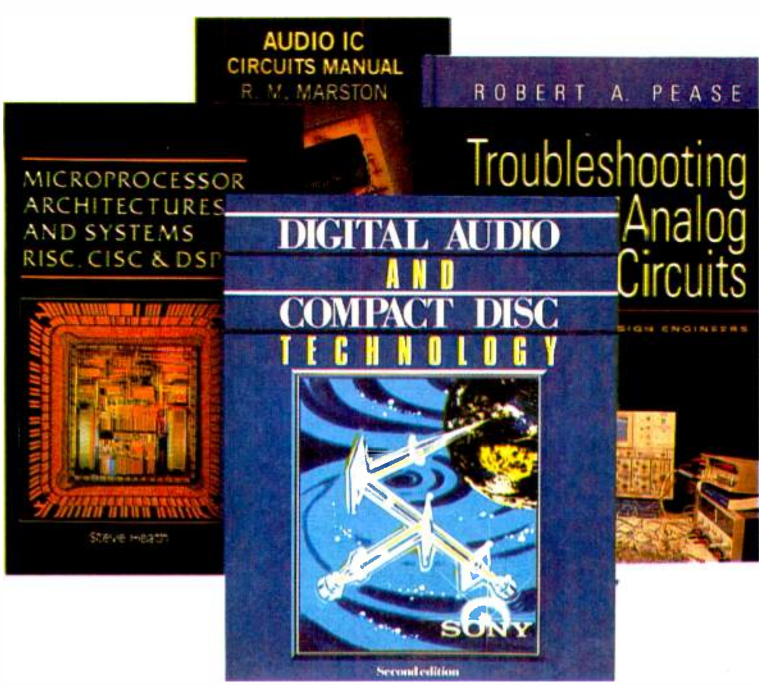

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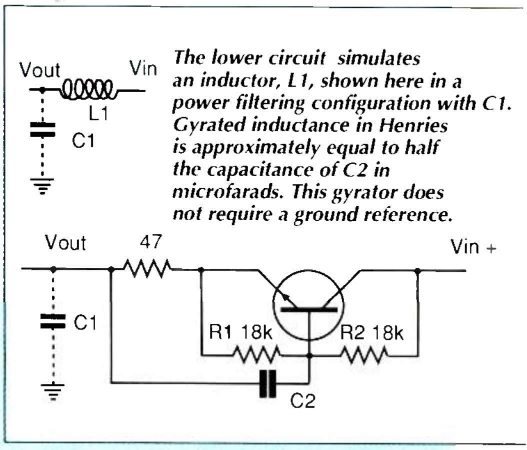
Gyrator acts as electronic choke

A gyrator can take the place of a straight resistor or inductor in filtering out noise and ripple on a power supply bus. Like the inductor which it simulates, it passes DC current with minimal voltage drop across its two terminals while providing a high impedance to AC.

The maximum level of AC noise and ripple which it can deal with is determined by the DC voltage drop across the transistor, itself determined by the ratio of R_1 to R_2. The simulated inductance relates directly to the size of C_2 and has a value in henries of about half the value of C_2 in µF.

The gyrator may also be used to hold down a PSTN line while providing a high impedance path to the 600Ω audio.

P Strict
Reigate
Surrey



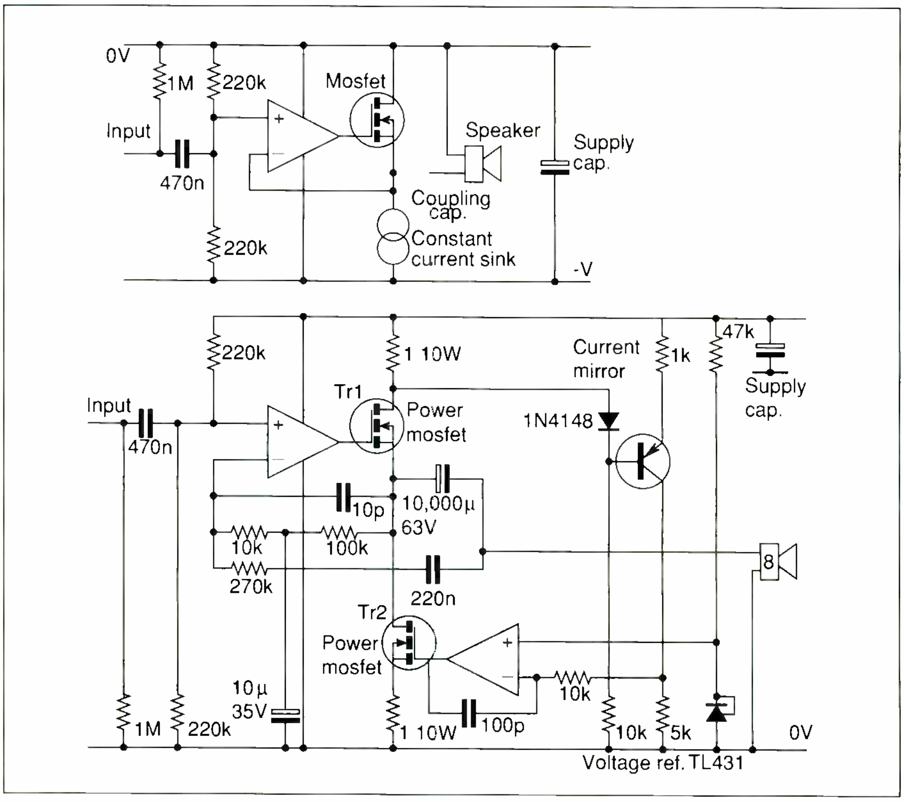
The lower circuit simulates an inductor, L1, shown here in a power filtering configuration with C1. Gyrated inductance in Henries is approximately equal to half the capacitance of C2 in microfarads. This gyrator does not require a ground reference.

High-power, class-A amplifier

To draw only direct current from the supply, to provide high power and to eliminate crossover distortion were the aims of this design.

Main circuitry is concentrated around IC_1, which has AC and DC feedback and provides a gain of 28 from 2Hz to 59kHz at a power output of 50W. Power transistor Tr_2 completes the DC feedback loop from the drain of Tr_1 to maintain constant current flow in the upper power transistor, taking as much current from the supply as may be needed to do that. The driver mosfet thereby acts as an ideal transistor.

A M Wilkes
Glasgow.



Class-A amplifier in which the driver mosfet operates in ideal mode; in which crossover distortion is negligible; and which becomes a class-AB type at higher powers

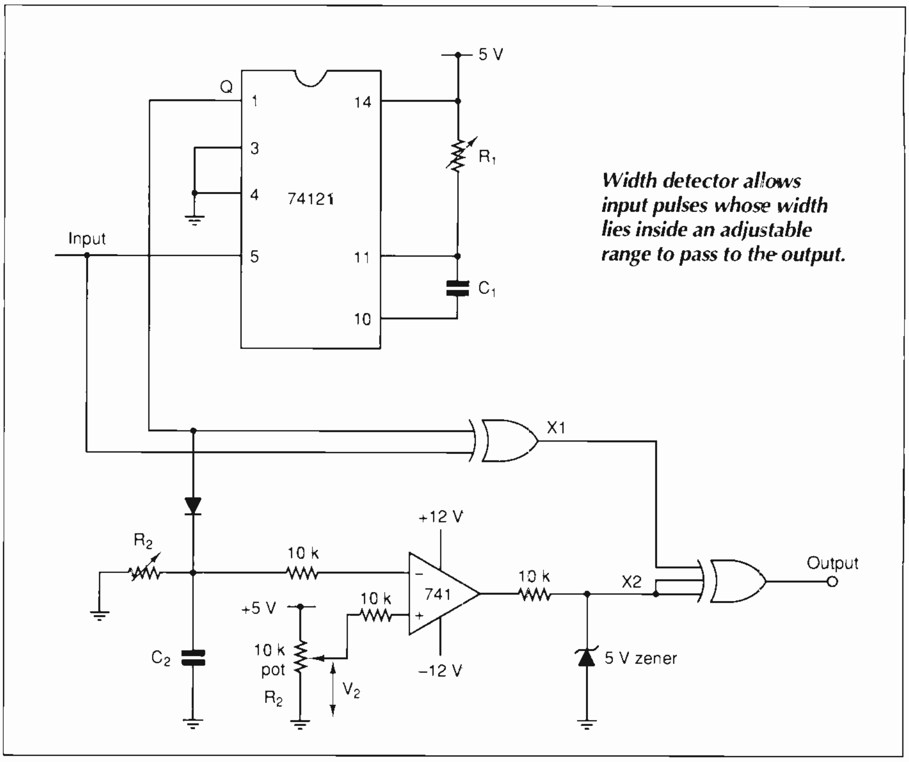
Pulse-width detector

Pulses whose width is within an adjustable window pass to the output of this circuit. Positive-going edges of input pulses trigger the 74121 monostable, output Q going high for a period $t_1 = 0.7R_1C_1$. This output and the input pulse go to the 2-input Xor, the monostable output also charging C_2 to 5V. Voltage V_2 is a variable reference between zero and 5V.

While Q is high, X1 is low, X2 is low and the circuit output remains low. When the monostable times out after t_1, X1 is in the same state as the input, this being passed to the circuit output via the 3-input Xor. Capacitor C_2 starts to discharge through R_2 and, at time $t_2 = R_2C_2\ln(5/V_2)$ after Q collapses, X2 goes high. Since two inputs of the 3-input Xor are high, circuit output is low.

Pulses of width greater than t_1 and less than $t_1 + t_2$ pass to the output, the limits being adhustable by R_1 and R_2.

KV Madanagopal
Madras
India



Width detector allows input pulses whose width lies inside an adjustable range to pass to the output.

Tweaking a D-to-A converter

It is possible to improve the linearity of a cheap digital-to-analogue converter by means of two resistors.

Ramping the input of the D-to-A from zero and viewing the output on an oscilloscope shows that the major non-linearity appears half-way, when the code changes from 0111...111 to 1000...000, secondary discontinuities coming at each quarter, **Fig. 1**. Since the end of the second quarter is the half-way point, it is simplest to start by correcting first and third quarters.

Ramp up the D-to-A and select R_m in **Fig. 2** to make the two halves linear; then choose R_n to align the halves with each other. Resistor R_n will probably need readjustment, but the procedure is simple – if a number of high-value resistors are available. Alternatively, feed static codes to the input and use a precise DVM in place of the oscilloscope; this may be more accurate, but the first method is visual and quick.

The offset resistor R_0 compensates for V^+ current through the two linearising resistors and is optional. Since linearity errors can be either positive or negative $R_{n,m}$ must pull up or down; hence the Xors or possibly Nands. Do not move the non-inverting op-amp input, since this would vary gain with input-code changes.

If the D-to-A has built-in latches, the state of the two MSBs must be stored separately in a dual flip-flop updated with the D-to-A.

CJD Catto
Cambridge

Fig. 1. In general, D-to-A non-linearities appear at quarter-scale major code changes

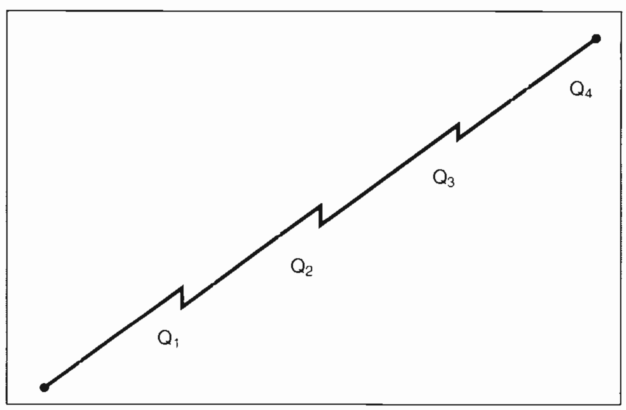
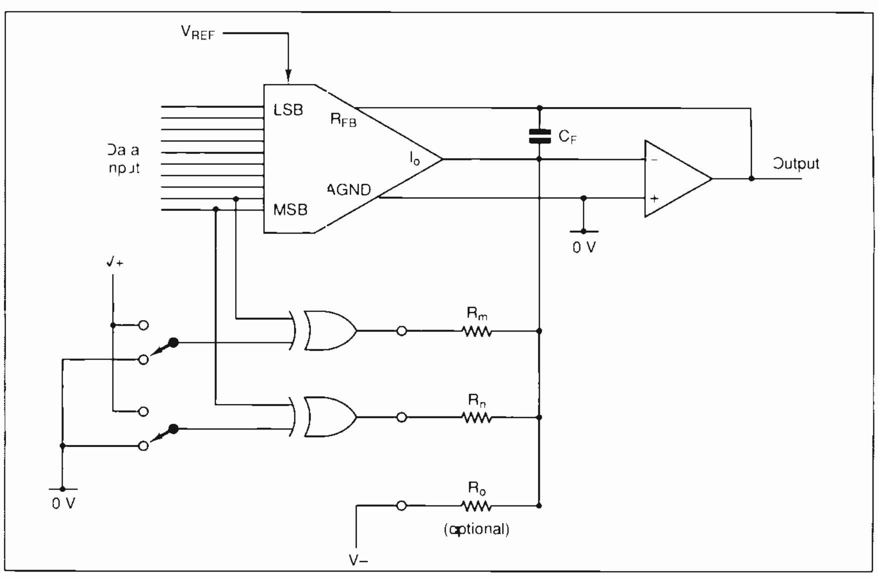
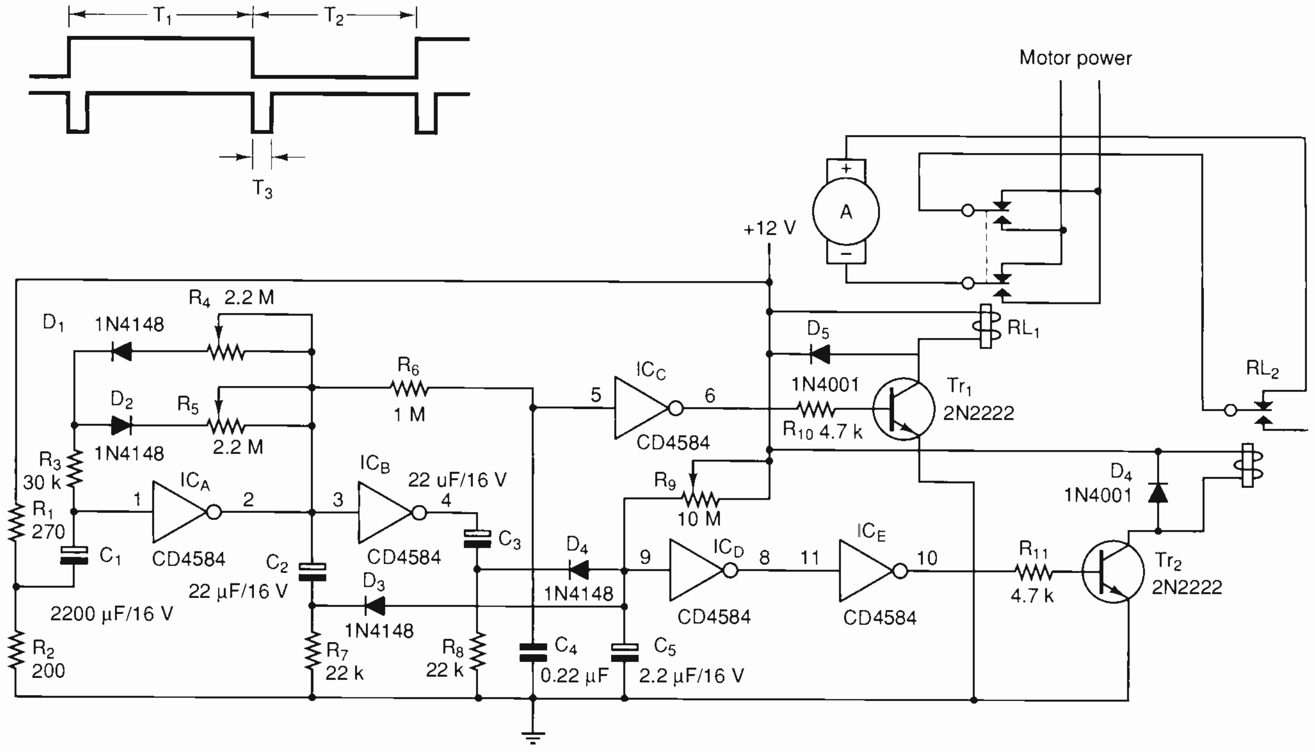


Fig. 2. Simple method of linearising D-to-A converter. Resistors Rm,n compensate for largest discontinuities.





Motor controller alternates motor direction for adjustable periods and guarantees that motor is stopped before a direction change.

Auto-reverse motor control

This one-chip circuit not only runs a motor in alternate directions for adjustable times, but stops it on reverse to avoid damage.

An oscillator based on IC_A is adjustable in period and duty cycle, R_4 controlling its output duration at high level and R_5 that at low level, both between 10s and 10min. The levels themselves control direction via IC_C, Tr_1 and RL_1. Resistors $R_{1,2}$ avoid the need for C_1 to charge from zero at switch-on, causing a longer high-level period.

Narrow pulses formed by $C_{2,3}$, $R_{7,8}$ and $D_{3,4}$ from the edges of the IC_A waveform discharge C_5 at each direction change, turning off Tr_2 and relay RL_2 to stop the motor for a time adjustable up to 10s by R_9. Resistor R_6 and C_4 delay direction changes until the motor has stopped. ■

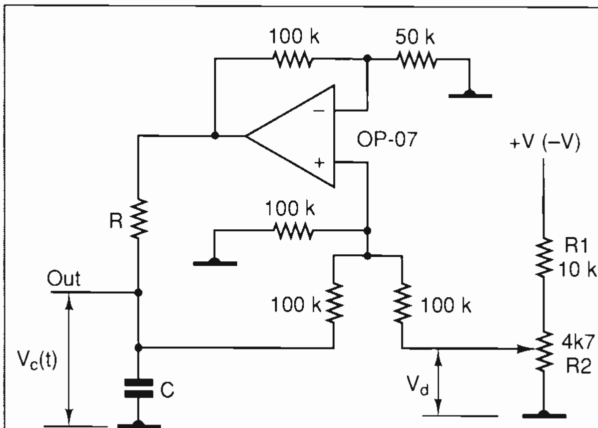
Yongping Xia
Torrance
California
USA

Linear ramp generator

Linearising an ordinary *RC* integrating circuit produces a long-period, adjustable ramp for use in timers.

As *C* charges, the voltage across it is applied to one input of the resistive summer, the other input being taken from the R_1R_2 tapping point. Voltage at the non-inverting op-amp input and, since the op-amp provides a gain of 2 to make good the loss in the summer, at the top of *R*, is therefore $V_d + V_{c(t)}$. Voltage at the lower end of *R* is $V_{c(t)}$, so that the voltage across it is $VR = V_d + V_{c(t)} - V_{c(t)} = Vd$, the bootstrap voltage providing constant current through *R* and therefore linear charging. This voltage sets the ramp time, with no *RC* timing circuit adjustment needed. A negative-going ramp is formed by a negative voltage on the voltage divider.

Valery Georg Chkalov
Oblinsk
Russia



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PC Operating Systems. Fully user documented and including software. MS-DOS 3.20, with 5" disk. **£5**, Order Ref: 5P2076: MS-DOS 3.3 with 3½" disk, **£5**, Order Ref: 3P208: MS-DOS 4.01, with 3½" disk, £10, Order Ref: 10P99.
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12V DC Brushless Axial Fan. Japanese made, battery operated. 93mm square, optimum is 12V but performs equally well at only 6V and its current then is only 100mA so it could be made into a hand-held dry battery-operated cooler. Or, on your desk operated by a PSU or in the car using the lighter socket. Snip price only **£4**, Order Ref 4P65. Mains power unit to operate this at variable speeds **£2**, Order Ref: 2P3
Movement Alarm. Goes off with the slightest touch. Ideal to protect car, cycle, doorway, window, stairway, etc. Complete with Piezo shrieker, ready to use, only **£2**, (PP3 battery not supplied), Order Ref: 2P282.
Project Box. A first-class, Japanese two-part moulding, size 95mmx66mmx23mm. Held together by 2 screws, this will hold a PP3 battery and a PCN and is ideal for many projects. To name just one, the washer bottle described in September's issue of E.E. This is nicely finished and very substantial. You get 2 for **£1**, Order Ref: 876.
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2, 3 and 4 Way Terminal Blocks. The usual grub screw types. Parcel containing a mixture of the 3 types, giving you 100 waves for **£1**, Order Ref: 875.
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2m 3-Core Lead. Terminating with flat pin instrument socket, **£1**, Order Ref: 879. Ditto but with plug on the other end so that you could use this to extend an instrument lead, **£1.50**, Order Ref 1.5P10.
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This is a multi range voltmeter/ammeter using the A-D converter chip 7106 to provide 5 ranges each of volts and amps. Supplied with full data sheet. Special snip price of **£12**, Order Ref: 12P19.

Solar Energy Educational Kit. It shows how to make solar circuits and electrical circuits, how to increase voltage or current, to work a radio, calculator, cassette player and to charge nicad batteries. The kit comprises 8 solar cells, one solar motor, fan blades to fit motor and metal frame to hold it to complete a free-standing electric fan. A really well written instruction manual. Price: **£8.00**, Order Ref 8P42B.
High Power Switch Mode PSU. Normal mains input, 3 outputs: +12V at 4A, +5V at 16A and −12V at ½A. Completely enclosed in plated steel case. Brand new. Our special offer price of **£9.50**, Order Ref: 9.5P1.
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Ultra Thin Drills, actually 0.3mm. To buy these regular costs a fortune. However, these are packed in half dozens and the price to you is **£1** per pack, Order Ref. 797B.
You Can Stand On It! Made to house GPO telephone equipment, this box is extremely tough and would be ideal for keeping your small tools in, internal size approx. 10½"x4½"x6" high. Complete with carrying strap, price **£2**, Order Ref: 2P283B.
Ultra Sonic Transducers. Two metal cased units, one transmits, one receives. Built to operate around 40kHz. Price **£1.50** the pair, Order Ref: 1.5P/4.

BARGAINS GALORE

Safety Leads. Curly coil so they contract but don't hang down. Could easily save a child from being scalded. 2 core, 5A, extends to 3m, **£1**, Order Ref: 846, 3 core, 13A, extends to 3m **£2** each, Order Ref: 2P290.
Power Supply with Extras. Mains input is fused and filtered and the 12V DC output is voltage regulated. Intended for high class equipment, this is mounted on a PCB and, also mounted on the board but easily removed, are two 12V relays and Piezo sounder, **£3**, Order Ref 3P80B.
100W Mains Transformers. Normal primaries 20-0-20 at 2.5A, or 30V at 3.5A, **£4**, Order Ref. 4P24, 40V at 2.5A, **£4**, Order Ref. 4P59, 50V at 2A **£4**, Order Ref: 4P60.
Philips 9" High Resolution Monitor. Black and white in metal frame for easy mounting. Brand new, still in maker's packing, offered at less than price of tube alone, only **£15**, Order Ref 15P1.
16 Character 2-line Display. Screen size 85mmx36mm, alphanumeric LCD dot matrix module with integral micro processor made by Epson, their ref: 16027AR, **£8**, Order Ref. 8P48.
Insulation Tester with Multimeter. Internally generates voltages which enable you to read insulation directly in megohms. The multimeter has four ranges, AC/DC volts, 3 ranges DC milliamps, 3 ranges resistance and 5 amp range. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, probably cost at least £50, yours for only **£7.50** with leads, carrying case **£2** extra, Order Ref: 7.5P/4.
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⅓hp 12V Motor - The Famous Sinclair C5 Brand new, **£15**, Order Ref: 15P8
Solar Charger. Holds 4AA nicads and recharges these in 8 hours, in very neat plastic case **£6**, Order Ref: 6P3.
Ferrite Aerial Rod. 8" long x ⅜" diameter, made by Mullard. Complete with two coils, 2 for **£1**, Order Ref: 832P
Air Spaced Trimmer Caps. 2-20pf, ideal for precision tuning UHF circuits, 4 for **£1**, Order Ref: 818B.
Mains Isolation Transformer. Stops you getting "to earth" shocks. 230V in and 230V out. 150 watt, **£7.50**, Order Ref 7.5P/5 and a 250W version is **£10**, Order Ref. 10P97
5 RPM Mains Driven. This is a shaded pole motor, **£5**, Order Ref: 5P54.
Amstrad Power Unit. 13.5V at 1.9A or 12V at 2A encased and with leads and output plug, normal mains input **£6**, Order Ref: 6P23.
Atari 65XE. At 65K this is quite powerful, so suitable for home or business, unused and in perfect order but less PSU, only **£19.50**, Order Ref 19.5P/5B.
80W Mains Transformer. Two available, good quality, both with normal primaries and upright mounting, one is 20V 4A, Order Ref 3P106, the other 40V 2A, Order Ref 3P107, only **£3** each.
Project Box. Size approx. 8"x4"x4½" metal, sprayed grey, louvred ends for ventilation otherwise undrilled. Made for GPO so best quality, only **£3** each, Order Ref 3P74.
Water Valve. 230V operated with hose connections, ideal for auto plant spray or would control air or gas into tanks etc. **£1** each, Order Ref 370.
BT Power Supply Unit. Output 9.5V AC at 600mA, in black plastic case with 13A plugs to go straight into socket, and approximately 3 metres of twin output lead. Price **£1.50**, Order Ref: 1.5P7
500V Bridge Megger. Developed for GPO technicians, the Ohmeter 18B is the modern equivalent of the bridge megger 9V battery operated, it incorporates a 500V generator for insulation testing and a null balance bridge for very accurate resistance measurement ex BT, **£45**, Order Ref: 45P2.
Experimenting with Valves. Don't spend a fortune on a mains transformer, we can supply one with standard mains input and secs. of 250-0-250V at 75mA and 6.3V at 3A, **£5**, Order Ref: 5P167.
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VU Meter. Illuminate this from behind becomes on/off indicator as well, 1½" square, **75** each, Order Ref: 366
Edge-Wise Panel Meter. Ideal when short of panel space, only 40x14mm, also have built-in LED, 500uAf sdd, scaled 0-5, **£1** each, Order Ref: 131.
Prices include VAT. Send cheque/postal order or ring and quote credit card number. Add £3 post and packing. Orders over £25 post free.

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CIRCLE NO. 130 ON REPLY CARD

THE REAL CHOICE FOR ACTIVE FILTERS

Op-amp parameters can have a drastic effect on filter response. Steve Winder shows how analysis of op-amp characteristics will give a better indication of filter performance.

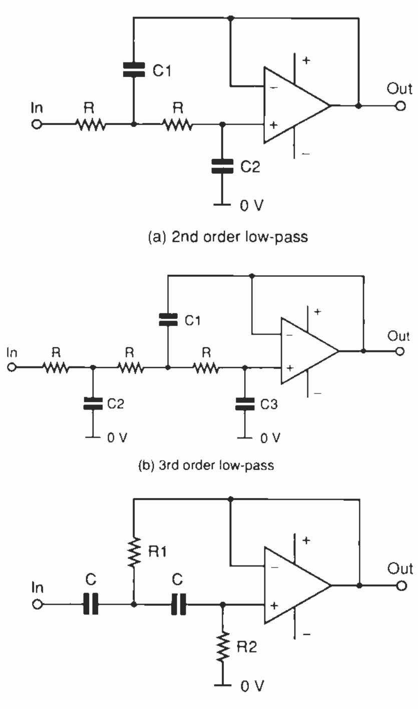


Fig. 1. Using op-amps connected as unity gain buffers. (a) 2nd order low-pass, (b) 3rd order low-pass, (c) 2nd order high-pass, (d) 3rd order high-pass.

Butterworth and Chebychev response filters are reasonably simple to design using tables given in a number of text books, including Williams[1]. Passive component values obtained using these tables should give the desired response. But identifying the correct passive component is only part of the story: the active device can also play an important part. Using the wrong op-amp for a filter can result in poor performance, high insertion loss, excessive ripple in the pass band or an incorrect cut-off frequency.

Basic op-amp theory says that a device connected to form a unity gain buffer, with its output tied to its negative input pin, has the characteristics of high input impedance, low output impedance and a bandwidth of typically 1MHz or more.

In reality devices have input resistance and capacitance. They also have an output impedance which rises with frequency and approaches the open-circuit output resistance at the unity gain bandwidth.

Operational amplifiers have a very high open-loop gain but also an open-loop bandwidth of a few hertz. Generally devices with higher open-loop gains have lower bandwidths deliberately applied by the manufacturer to ensure stability. All these characteristics have an effect on the filter response.

Examples of op-amp characteristics are given in **Table 1**. Butterworth and Chebychev filters use op-amps that are connected as unity gain buffers (**Fig. 1**). But it would be wrong to assume that the cut-off frequency of a filter using these devices could be as high as the unity gain bandwidth. Positive feedback is also present due to the capacitor which connects the op-amp output to the *RC* network at the input.

Computer analysis

The effect of op-amp parameters on the overall filter performance has been simulated by a computer program. The program calculates component values and creates a netlist which can be read by the proprietary software *ECA*[2].

Filter modelling is necessary because of the large number of designs and frequencies involved.

Butterworth and Chebychev filters in high-pass and low-pass configurations have been modelled, covering all orders from two to nine. Each of the designs has been tried with the four op-amps described, so that 128 designs must be tested at several frequencies to find the limit of acceptable performance.

The limit of acceptable performance has been arbitrarily chosen as the frequency where pass-band ripple or insertion loss is not greater than 2dB. Performance is unacceptable if the cut-off frequency is not at its design frequency – even if the loss or ripple is less than the

Table. 1. Examples of op-amp characteristics.

Device type	*741*	*OP-42*	*NE5532*	*TLE2027*
Input resistance	2MΩ	1TΩ	100kΩ	2MΩ
Input capacitance	2pF	5pF	2pF	8pF
Open-loop bandwidth	10Hz	45Hz	200Hz	1Hz
Open-loop gain	200k	250k	100k	40M
Closed-loop bandwidth	1MHz	10MHz	10MHz	15MHz
Open-loop output resistance	75Ω	45Ω	100Ω	50Ω

The *TLE2027* is available from Texas Instruments and is an improved *OP-27*.

Table 2. Results obtained for Butterworth filters.

Butterworth Order	*741* LPF	*741* HPF	*OP42* LPF	*OP42* HPF	*5532* LPF	*5532* HPF	*2027* LPF	*2027* HPF
2	700k	500k	3.5M	2M	5M	4M	5M	4M
3	100k	100k	400k	400k	800k	800k	2.5M	1M
4	200k	100k	1M	700k	2M	2M	2M	800k
5	150k	80k	600k	400k	1M	1M	1.5M	750k
6	100k	60k	500k	300k	800k	800k	1.2M	700k
7	80k	50k	300k	250k	600k	500k	1M	700k
8	60k	40k	250k	200k	500k	400k	800k	600k
9	40k	30k	180k	150k	400k	350k	600k	500k

CIRCLE NO. 131 ON REPLY CARD

CIRCLE NO. 132 ON REPLY CARD

CIRCLE NO. 133 ON REPLY CARD

2dB limit. Clearly the results obtained are subjective, but errors are minimised by double checking.

Butterworth filters

Results show (**Table 2**) that the filter cut-off frequency range increases with increasing amplifier open-loop gain and open-loop bandwidth. The cut-off frequency range falls as the square of the filter order. High-pass filters have a lower cut-off frequency range when compared with low-pass filters of the same order and which use the same op-amp. Filters of the third order often have a lower frequency range than fourth order designs. As a guide, the following empirical formula gives the acceptable bandwidth:

Butterworth frequency range =

$$\frac{\text{open-loop gain} \times \text{open-loop bandwidth}}{(\text{filter order})^2}$$

Butterworth example 1: 7th order filter using *741* op-amp

Frequency range limit =
200k x 10Hz/49 = 40.8kHz.
Limits using Table
2: 80kHz for LPF and 50kHz for HPF.

Butterworth example 2: 5th order filter using an *OP42* op-amp.

Frequency range limit
= 250k x 45Hz/25 = 450kHz
Limits using Table 2 =
600kHz for LPF and 400kHz for HPF

The formula given for working out the frequency range is moderately accurate in both examples – particularly for the high-pass filter. To find the frequency range limit for third order filter designs, which do not agree with the general pattern, determine the second order filter limit and divide it by five.

Chebychev filters

Chebychev designs have a lower acceptable frequency range than the comparable Butterworth filters (**Table 3**). Again the frequency range is approximately proportional to the product of open-loop gain and open-loop bandwidth, and inversely proportional to more than the cube of the filter order. But unlike the Butterworth designs, Chebychev high-pass filters generally have a higher acceptable cut-off frequency range than their low-pass counterparts. An empirical formula for determining the acceptable frequency range of Chebychev filters is given by:

Chebychev frequency range =

$$\frac{\text{open-loop gain} \times \text{open-loop bandwidth}}{(\text{filter order})^{3.2}}$$

Chebychev example 1: 6th order filter using *NE5532* op-amp

Frequency range =
100k x 200Hz/309 = 64.7kHz
Limits using Table 3:
40kHz for LPF and 100kHz for HPF.

Chebychev example 2: 9th order filter using *TLE2027* op-amp

Frequency range
= 40M x 1Hz/1131 = 35.4kHz.
Limits using Table 3
= 30kHz for both HPF and LPF.

The formula given for determining the Chebychev frequency range limit is also reasonably accurate.

Chebychev third order filters do not follow the general pattern, and their limit is found by dividing the second order limit by twenty.

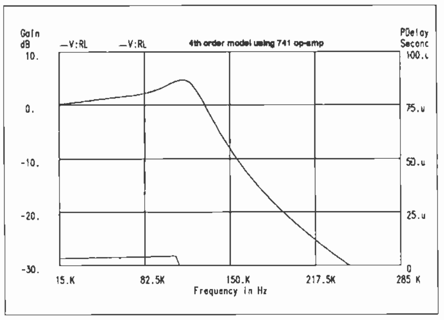


Fig. 2. 4th order model using 741 op amp.

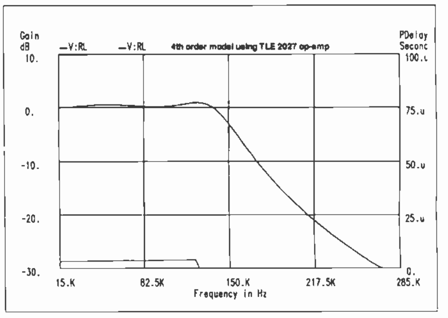


Fig. 3. 4th order model using TLE2027 op amp

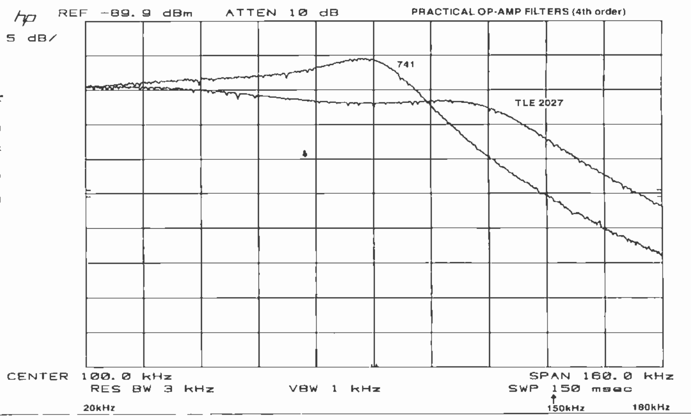


Fig. 4. Results of practical op amp filters from built models (4th order)

Testing validity of models

The results give an idea of what characteristics an operational amplifier must have to provide the expected performance of an active filter. The limits of acceptable performance were arbitrarily chosen for my own purposes, and if better performance is needed the frequency ranges could be much lower than those tabulated. Choice is really a case of balancing performance against bandwidth. The performance unacceptable by the criterion used here, may be satisfactory in some applications.

Validity of the filter models was tested against the results of built designs. A 150kHz low-pass filter was designed using both *741* and *TLE2027* op-amps. The practical results of built designs (**Figs. 2, 3, 4**) show slightly worse performance than the modelled response in both cases. ■

References

1. "Handbook of Filter Design", A B Williams and F J Taylor, McGraw-Hill, ISBN 0-07-070434-1
2. ECA (Electronic Circuit Analysis), Those Engineers Ltd.

Chebychev Order	*741*		*OP42 LPF*		*5532 LPF*		*2027*	
2	500k	500k	2M	2M	3M	3M	3M	5M
3	30k	30k	40k	50k	100k	150k	300k	300k
4	25k	30k	120k	200k	200k	500k	250k	300k
5	10k	25k	50k	100k	50k	150k	150k	250k
6	5k	10k	40k	60k	40k	100k	60k	200k
7	4k	5k	15k	25k	20k	50k	50k	100k
8	2k	3k	10k	20k	15k	35k	40k	60k
9	1.5k	2k	6k	8k	10k	15k	30k	30k

Table 3. Results obtained with Chebychev filter designs.

Filter characteristics

Filters have a pass band, which is the range of frequencies that should be passed without attenuation. They also have a skirt response, which is where the attenuation increases as the frequency moves further from the cut-off point, outside the pass band.

Butterworth filters have a frequency response which is flat within the pass band.

Chebychev filters have a small amount of pass band ripple which can be defined at the design stage. The filter skirt response is steeper if more pass band ripple is allowed in the design.

Simulating capacitor ripple

Are you about to design a linear regulator circuit, switched mode power supply or amplifier power pack? Take a look at a simple program from A M Wilkes first.

My program calculates the peak and trough voltages on the dc rail of an ac-to-dc mains supply, simulating the reservoir capacitor ripple. A sinusoidal supply is assumed. Full wave rectification is simulated and the output is smoothed by a capacitor.

Load may be a constant current, a constant resistance or a constant power and so the program can be useful in designing linear regulator circuits, switched mode power supply front ends and amplifier power supplies.

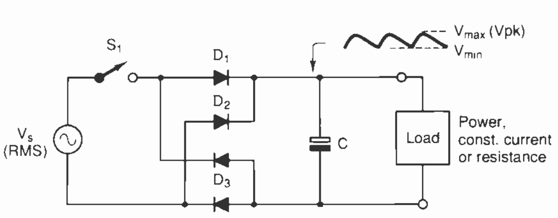
Coding is in Pascal and should be easy to follow for non-Pascal users since it is heavily commented, remarks enclosed between curly brackets.

The program body is a sequence of procedure calls at the end of the listing enclosed between begin and end statements.

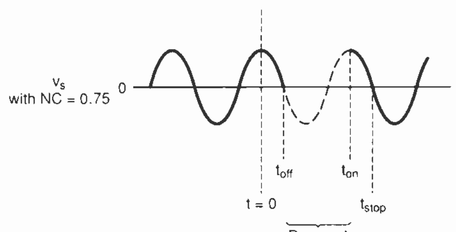
Seven variables may be edited by the user to suit a problem. To simulate half-wave rectification, the value of NC (number of missing cycles) should be set to 0.5, and as the diode drop will be one so V_d should be set to, say, 0.8

When the program is run it simply lists the adjustable parameters and the result – peak voltage and trough voltage across the reservoir capacitor. ■

General form of the simulated circuit.



FULL WAVE $V_d = V_{forward}$ of $(D_1 + D_4)$ or $V_{forward}$ of $(D_2 + D_3)$
HALF WAVE $V_d = V_{forward}$ of D_1 or D_2
S_1 = missing cycles (drop-out) switch



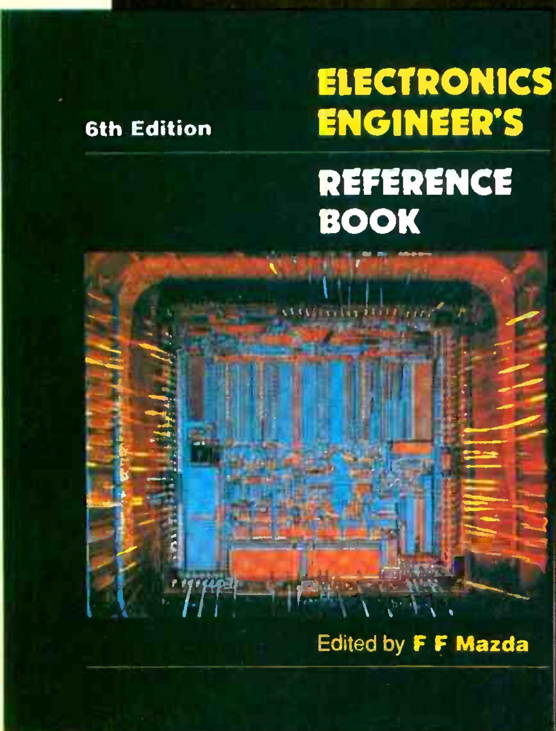

```
program CapacitorRipple; { Simulates the capacitor ripple voltage of
a                              bridge rectifier circuit. }
uses Crt;
type
   LoadType = ( Power , Current , Resistive );
var    { Global variables }
   C, Vs, F, Value, NC, Vpk, Vd : Real;
   Load : LoadType;

procedure InitialiseValues;
{ Edit these values to your liking }
begin
   C := 1500; { Reservoir capacitor value in microfarads }
   Vs := 15; { Source voltage (Vrms) }
   F := 50; { Frequency of source voltage in hertz }
   Load := Current; { Type of load: Power, Current or Resistive (All
constant)}
   Value := 1; { Load value in Watts, Amps or Ohms }
   NC := 0; { Number of cycles to skip ( 0.5 for half-wave rectification )
}
   Vd := 1.6 { Total of diode drops }
end;

procedure ListValues;
begin
   ClrScr; { Clear the screen }
   WriteLn('Capacitive supply filter simulator. By A.M. Wilkes.
1993');
   WriteLn;
   WriteLn;
   WriteLn('Capacitor Value in Microfarads = ',C :6 :0);
   WriteLn('Input Voltage in Volts = ',Vs :6 :0);
   WriteLn('Supply Frequency in Hertz = ',F :6 :0);
   Write('Load value in ');
   case Load of
      Power : Write('Watts');
      Current : Write('Amps ');
      Resistive : Write('Ohms ');
   end;
   WriteLn(' = ', Value :6 :1);
   WriteLn('Number of cycles to skip = ',NC :6 :1);
   WriteLn('Total of diode drops in volts = ',Vd :6 :1);
   WriteLn;
end;

procedure Calculate; { Do the work }
const dT : Real = 0.0001;  { Time step = 0.1 milli seconds }
var{ Local variables }
   Kv, Ke, P, dE, Ecap, Vcap, Vmin, Vsine, Period, T, Toff, Ton, Tstop :
Real;
begin
   Period := 1 / F;  { 1 / Frequency }
   Kv := 2 * Pi * F;{ Constant used for calculating sine wave }
   Vpk := Sqrt(2) * Vs - Vd;   Peak source voltage minus diode drop
}
   Ke := 0.5 * C * 1e-6; { Const used in calculating capacitor
energy }
   Vcap := 0; { Initial capacitor voltage }
   Vmin := Vpk; { Initialise trough voltage }
   Toff := Period / 4; { Start of missing cycles }
   Ton := Toff + Period * NC; { End of interval of missing cycles }
   if Period > Ton then { Set stop time for calculations }
      Tstop := Period { 1 cycle }
   else Tstop := Ton + Toff; { Resumption of supply + 1/4 cycle }
   T := 0; { Initialise start time }
   repeat { *** Start of loop *** }
      { Calculate change in capacitor energy for time step dT }
      case Load of { Find load power (P) }
         Power     : P := Value; { Power = Watts }
         Current   : P := Vcap * Value;  { Power = V x I }
         Resistive : P := Sqr(Vcap) / Value; { Power = V x V / R }
      end;
      dE := P * dT; { Energy change = power x time change }
      { Discharge cap }
      Ecap := Ke * Sqr(Vcap) - dE;
      if Ecap < 0 then Ecap := 0; { Test for complete discharge }
      Vcap := Sqrt(Ecap / Ke); { Calculate new cap voltage }
      { Get value of source voltage at time T }
      if (T < Toff) OR (T >= Ton) then { If supply is present }
         Vsine := Vpk * Abs( Cos(Kv * T) ) { Full wave rectified cosine
wave }
      else
         Vsine := 0;   { Cycle has been cut so supply voltage = 0 }
      if Vsine > Vcap then Vcap := Vsine; { Charge cap }
      if Vmin > Vcap  then Vmin := Vcap;
{ Detect minimum cap voltage }
      T := T + dT;  { Increment time
}
   until T > Tstop; { *** Loop then
display result *** }
```

A M Wilkes, *70 Arundel Road, Harwood Park, Bromsgrove, Worcestershire B60 2HN.*

ELECTRONIC ENGINEERS REFERENCE BOOK

6th Edition
F F Mazda

This reference book is divided into five parts: techniques, physical phenomena, materials and components; electronic design and applications. The sixth edition was updated throughout to take into account changes in standards and materials as well as advances in techniques, and was expanded to include new chapters on surface mount technology, hardware and software design techniques, semi-custom electronics and data communications.



Fraidoon Mazda has worked in the electronics and telecommunications industry for over twenty years, and is currently Product and Operations Manager, Generic Network Management, with Northern Telecom. He is the author of six technical books (translated into four languages) and the editor of the Communications Engineers Reference Book published by Butterworth-Heinemann.

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The MCT combines the versatility of a transistor, the low forward conduction losses of a thyristor and the gate characteristics of a mosfet. Ian Hickman puts a new type of high power switching device into a test bed.

THE MOS CONTROLLED THYRISTOR

Thyristors and triacs have developed to the pointwhere they can handle hundreds of amps and volts, but can need quite a heft pulse of current to trigger them on. The exceptions are the mos based devices. One type is similar to an N channel power mosfet but with an additional P layer in series with the drain, resulting in a four layer device. Thus when conducting, the usual fet majority carriers are augmented by the injection of minority carriers resulting in a lower bottoming voltage. These devices are variously known as comfets, gemfets etc, depending on the manufacturer and, like the power mosfets from which they are derived, can be turned on or off by means of the gate.

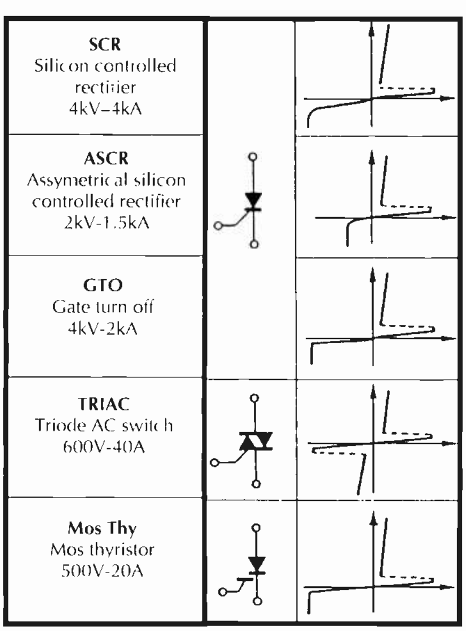


Fig. 1 Variations on the Silicon Controlled Rectifier theme. (Reproduced by courtesy of Motorola Inc.)

Not so the mos thyristor, which has the usual four layer structure of an SCR with its very low forward volt drop when conducting, and like them must be turned off by reducing the current through it to zero by external means. However, unlike SCRs, it does not require a sizeable current pulse to turn it on. The GTO (gate turn-off) thyristor can be switched off again by means of the gate, but the drive power needed to do so is considerable. The main characteristics are summarised in **Fig. 1**.

A recent development has resulted in yet another variation on the thyristor theme, possessing many of the best points of all the various device types mentioned so far – this is the MCT (mos *controlled* thyristor: not to be confused with the mos thyristor). As **Fig. 2a** shows, this is basically an SCR, but instead of the base of the NPN section being brought out as the gate terminal the device is controlled by two mosfets, one n-channel and one p-channel. These are connected to the anode of the

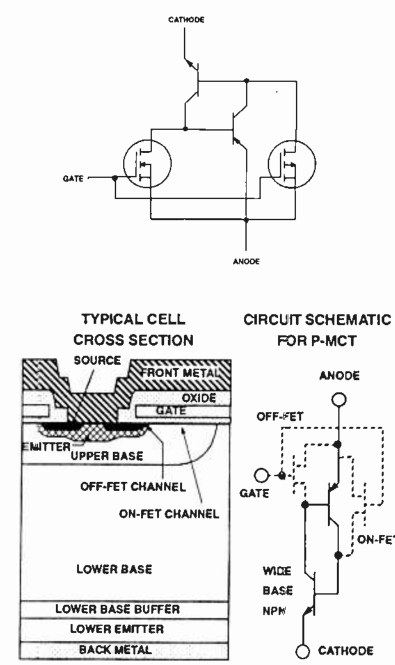
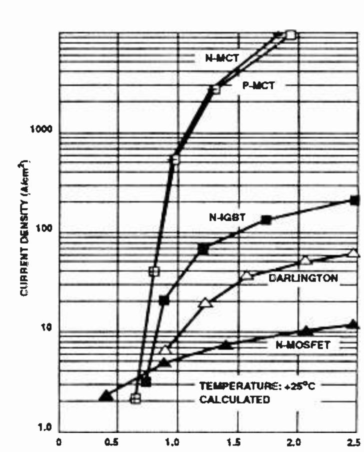


Fig. 2a. Equivalent circuit of the MCT, showing the complementary bipolar latch which forms the main current path, the n-channel "off" mosfet which shorts the base-emitter junction of the pnp section, and the p-channel "on" mosfet which feeds base current into the npn section. b) Cross section and equivalent circuit of one of the cells of an MCT; there are tens of thousands of these cells in a typical device. c) Comparison of current capability of the MCT and other devices for a given chip size.



MCT, making it a p-MCT and in effect a high side switch. The p-channel mosfet can turn the device on by feeding current into the base of the npn section of the complementary latch, while the n-channel mosfet can turn it off again by shorting the base of the pnp section to its emitter. To turn the device on, the p-channel mosfet has only to feed enough current into the base of the npn section to cause the loop gain of the npn-pnp pair to exceed unity, consequently it does not need a very low on resistance. But to turn the device off, the n-channel mosfet needs to take over the main current, and pass it with a volt-drop lower than the forward V_{be} of the pnp section. This description of the operation applies not only to the device as a whole, but also to each and every one of the many thousands of constituent cells, Fig. **2b**. If carrying a heavy current, the base-emitter shorting fets must be turned on uniformly and rapidly to ensure that all MCT cells turn off essentially the same current. If the gate voltage rises slowly, the current will redistribute among the cells, reaching a value in some cells that cannot be turned off.

Taking the simplest possible view, the main current path via the four layer pnp-npn latch should be either on or off, depending upon which of the controlling mosfets was last in conduction.

An *MCTV75P60E1* in its five lead TO-247 package was connected up as in **Fig. 3a**, the base connections and circuit symbol being shown in **b**. Now the device's input capacitance C_{iss}, that is to say the capacitance looking in at the gate pin with respect to the gate return pin, is listed as the not inconsiderable figure of 10nF, so to ensure that the gate received almost the full ±18V pulses which are recommended, the value of C_3 in Fig. 3a was set at 100nF. When the supplies were switched on, the device did not conduct. Momentarily connecting point *X* to the –15V rail switched it on, and likewise connecting point *X* to the +15V rail switched it off again.

The device's holding current (the minimum needed to keep the device in conduction, below which the loop gain falls below unity and the device turns off) is not stated on the data sheet and is merely indicated in the applications notes as being "mA". With the device switched on, the voltage of the +24V supply was slowly reduced. At 12V, the voltage across the 1k resistor suddenly collapsed to zero, indicating a holding current of 12mA for this particular sample at room temperature.

Since the drive was obtained via a capacitor, the drive circuit did not need to be referenced to the gate return pin – this was verified by breaking the circuit at point K and returning the junction of the two 10uF capacitors to the negative end of the 24V supply. Thus in certain relatively low power applications, the device could be used as a high side switch without the need for any auxiliary supplies referenced to the high side voltage. It is true that spikes on the main supply could then be coupled to the gate, but due to the large ratio of the 100Ω gate resistor to the 8.2kΩ recharging resistor, unintentional switching from this cause is not likely, nor is it likely from stray capacitive coupling given the very large internal gate capacitance. However, this is not the recommended mode of operation for the following reason. The circuit of Fig. 3a barely tickles the device, given its 600V blocking capability and 75A continuous cathode current rating (at 90°C). Therefore the device leakage current was only microamps, way below the current at which the loop gain exceeds unity. Thus the off condition could persist, despite the fact that the bases of the two internal bipolar devices were floating. However, at a case temperature T_c=150°C, the peak off-state blocking current I_{DRM} (with V_{KA} = –600V) could be as much as 3mA, even with the n-channel mosfet fully enhanced (V_{GA} = +18V). If the n-channel mosfet were not fully enhanced, or even off completely, the collector leakage current of the npn bipolar section flowing into the base of the pnp section could result in the loop gain exceeding unity; the device would turn on, its blocking ability would have failed. For this reason, the recommended switching and steady state gate voltages are as shown in **Fig. 4**.

To meet these requirements, the circuit of **Fig. 5a** was sketched out, using a *2N5859* (npn) and *2N4406* (pnp). Both types are switching transistors, rated at 2A and 1.5A

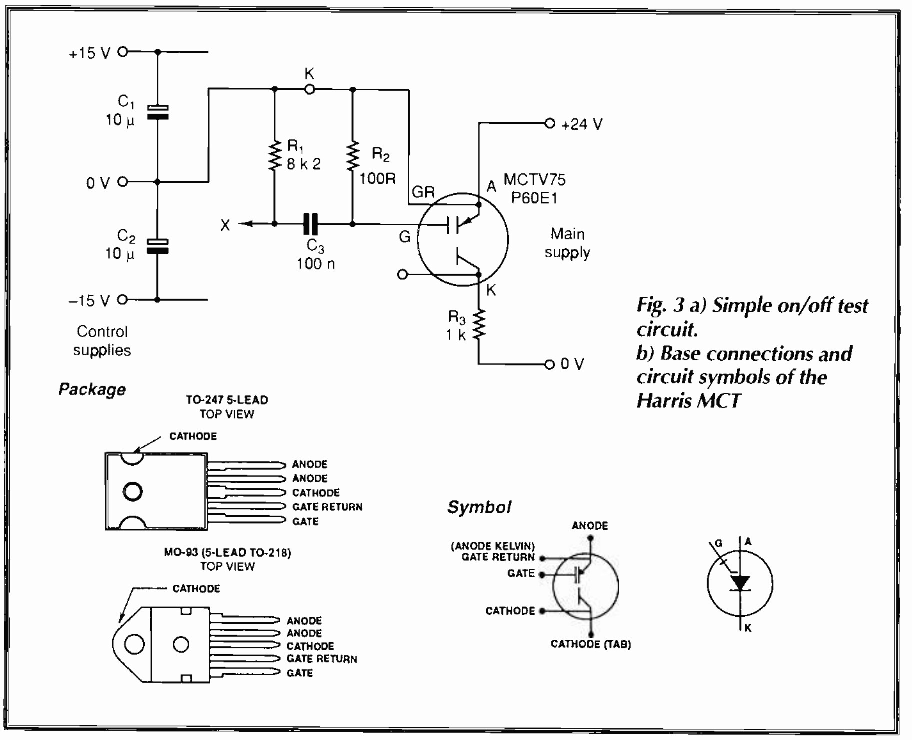


Fig. 3 a) Simple on/off test circuit.
b) Base connections and circuit symbols of the Harris MCT

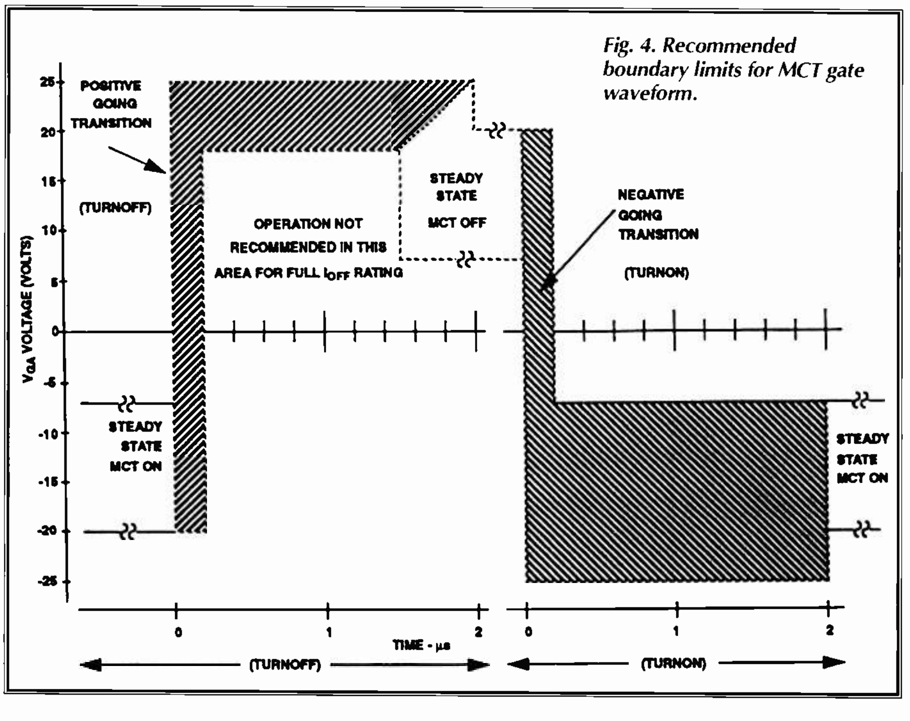
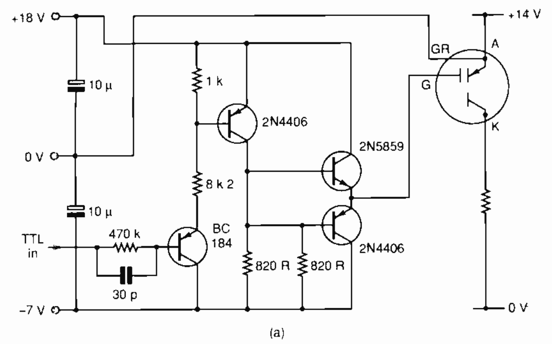


Fig. 4. Recommended boundary limits for MCT gate waveform.



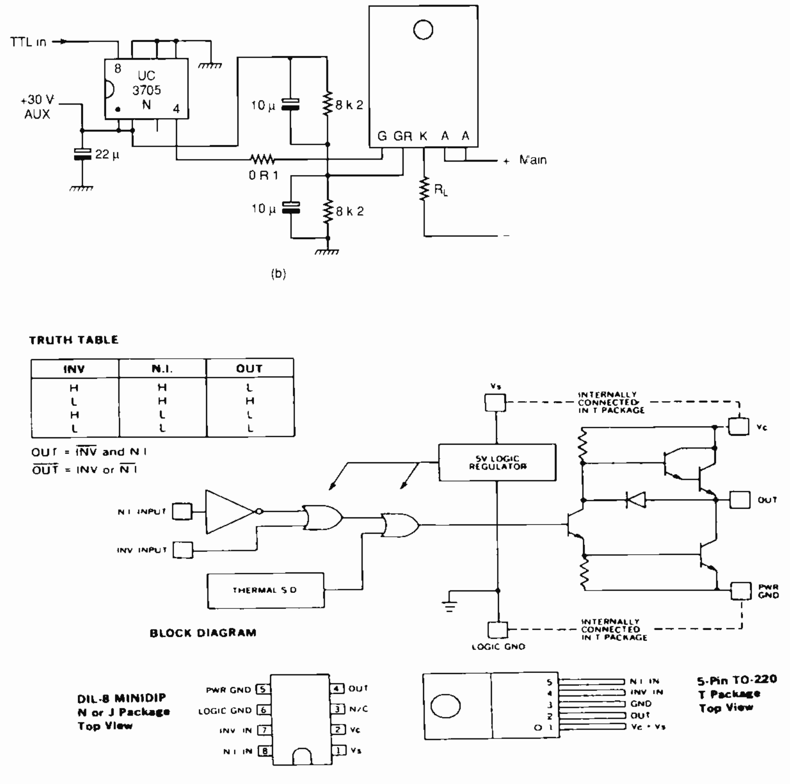


Fig. 5 a) Useless gate driver circuit MKI b) Gate driver circuit using the Unitrode UC3705N c) Internal circuit

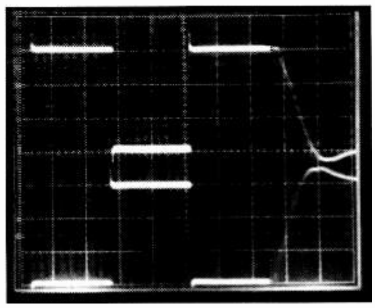
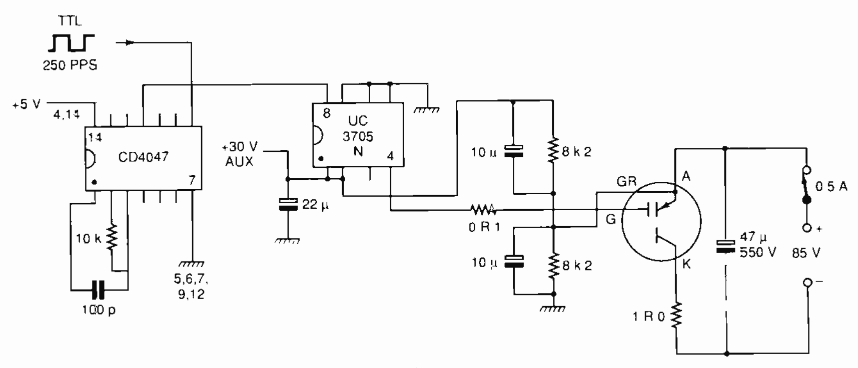


Fig. 6. Waveform at MCT gate driven by a 10kHz squarewave using the UC3705N, double exposure showing both the positive and negative going transitions; 10V/div vertical, 20µs/div switching to 200ns/div horizontal.

continuous collector current respectively, so they seemed at first sight a plausible choice since to charge a C_{iss} of 10nF through 25V in 200ns requires just 1.25A. (Note that the MCT's C_{iss} is relatively constant; it is not augmented during switching by the Miller effect unlike a power mosfet). The circuit was a resounding failure, being quite incapable of swinging the MCT's gate through 25V in 200ns. This was presumably due to the fall of current gain of the driver transistors with increasing collector current, and the absence of suitable speed-up capacitors.

Changing from a discrete driver approach to a Unitrode minidip *UC3705N* High Speed Power Driver (also available in a 5-pin TO-220 package) in the circuit of Fig. **5b**) rectified the problem; **5c** shows this device's internal arrangement. **Fig. 6** shows the gate waveform with a 10kHz squarewave applied to the input of the driver chip, the double exposure showing both positive and negative transitions on mix timebase (10V/div vertical, 20µs/div switching to 200ns/div horizontal.) A 30V swing across 10nF results in the 4.5µJ stored energy being dissipated in the *UC3705N* switch, well within the 20µJ rating of the n-package and with the 200ns rise/fall time in Fig. 6, the peak current is within the n-package's ±1.5A peak rating. At 10kHz the average dissipation is 20000 x 4.5µJ = 90mW, again well within the 1W (25°C) rating.

Note that while the *UC3705X* series are specified for operation over the range 0 to 70°C, it incorporates an internal over-temperature shutdown operating at 155°C typical. Shutdown drives the output low, which would turn the MCT on – this will usually be undesirable if not fatal. There are various possible solutions, such as making sure that an external shutdown (perhaps associated with the MCT's heatsink) shuts the whole system down before the driver nears its shutdown limit. A simpler solution is to use one of the other devices in the series such as the *UC3706X* which has complimentary outputs: using the inverted output will result in shutdown turning the MCT off.



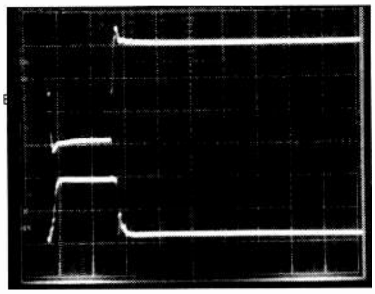


Fig. 7a Circuit used to pulse the MCT at 80A. Note the 100 milliohm gate drive damping resistor. b) Gate drive waveform, 10V/div vertical, 2µs/div horizontal (upper trace), voltage across 1 ohm load, 50V/div (lower trace)

A satisfactory driver circuit allowed operation of the MCT nearer its limits. With its 600V 85A rating, it is capable of controlling over 50kW and indeed the manufacturer has produced modules containing 12 paralleled devices with a megawatt capability. To keep the average power within bounds, the device was pulsed on for 4μs at a 250pps rate – a 0.1% duty cycle – as in **Fig. 7a**. Messing about with 600V on the lab bench is not a thing to be undertaken lightly, so I settled for a modest +85V from raw supplies. With the mains to the supplies was wound up with a Variac, the MCT happily passed pulses of current through the 1Ω load resistor, the voltage across which is shown in Fig. **7b**, lower trace, the upper trace being the gate drive waveform.

My experiments showed that the *MCTX75P60E1* is reliable and easy to use. In applying these devices, one must seek to obtain maximum advantage from their good points, which include a very low forward voltage drop even compared to other minority carrier devices such as IGBTs - let alone mosfets - while working within their limitations. As a double injection device - both p-and n-emitters - the MCT conduction drop is well below that of the insulated gate bipolar transistor, especially at high peak currents (**Fig. 8a**). Clearly their turn-off time will be longer than a mosfet which conducts purely by majority carrier action, although they can be used at higher frequencies than power Darlingtons.

Spice models for the devices, Fig. **8b**, show the close agreement between measured and predicted turn-off dissipation. With the present models, a notional snubber network may be needed to reduce numerical noise in the simulation, but then a snubber may be required for real, depending on the application. This is because the p-MCT's safe operating area is rated at half the device's breakdown voltage rather than 80% typical of an n-type power device. If an application involves hard switched inductive turn-off above the SOA and a snubber is not cost effective, then the MCT is not the best choice. Furthermore, if with a snubber the switching losses now approach the conduction loss, there may be little advantage in using an MCT.

On the other hand, with their minimal conduction losses, these devices are ideal in soft switched or resistive load circuits and above all in zero current switched applications such as resonant circuits. The maximum operating frequency F_{max} depends upon both the conduction and switching losses, and can be defined in more than one way, Fig. **8c** (note that "E" here indicates energy, not emf). From this it will appear that in most applications, the operating frequency will be 30kHz or lower. A point to bear in mind is that the peak reverse V_{KA} is +5V, so that in a bridge or half bridge circuit with an inductive load, anti-parallel commutation diodes should be fitted to provide a path for the magnetising current at the start of each half cycle, when operating at low loads.

References

MCTV75P60E1, MCTA75P60E1, Harris Semiconductor, File Number 3374 MCT User's Guide, Harris Semiconductor, Ref. DB307A.

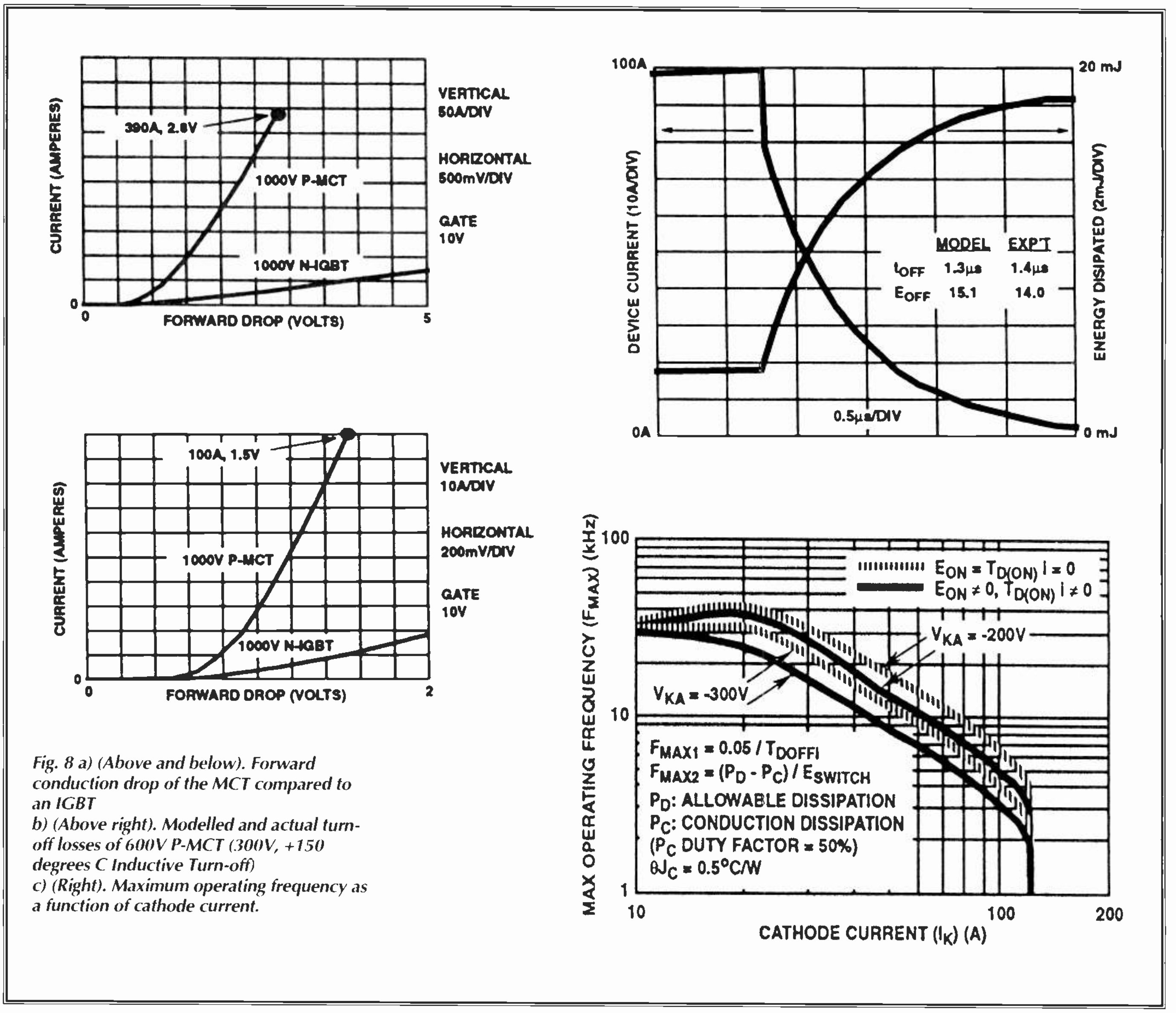


Fig. 8 a) (Above and below). Forward conduction drop of the MCT compared to an IGBT
b) (Above right). Modelled and actual turn-off losses of 600V P-MCT (300V, +150 degrees C Inductive Turn-off)
c) (Right). Maximum operating frequency as a function of cathode current.

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Four-channel A-to-D. National's *ADC08234CIMF* is a 20mW, 2μs serial 8-bit analogue-to-digital converter with four channels in a thin shrink small outline package intended for the PCMCIA disk-drive application. Its four-channel multiplexer operates in single-ended, differential and pseudo-diff. modes, the device also containing a 2.5V reference. National Semiconductor, 0793 697428.

Low-power A-to-D converter. *CS5389* stereo 18-bit delta-sigma A-to-D converter has an S:N ratio of 107dB and sinad better than100dB. Crystal's new chip needs no extra components and includes digital anti-aliasing filtering, sample-and-hold and a voltage reference. Phase and magnitude responses of the filter are flat from 0-22kHz, stop-band rejection being more than 80dB and ripple in the pass-band ±0.01dB. Sequoia Technology Ltd, 0734 311822.

Discrete active devices

Dual-gate mosfet. *BF904* from Philips is a 12V dual-gate mosfet with a 25mS transfer admittance, 2.2pF input and 2dB noise figure. It also has an internal bias circuit that removes the need for external components while allowing adjustment of quiescent drain current. It can be turned off at any electrode. *BF908* has 35mS transfer admittance and a 1.5dB noise figure at 800MHz, but no bias circuit. Philips Semiconductors, 071-436 4144.

Power transistors. Zetex claims its *FZT850/950* power transistors to be the world's best performers in SOT223 packages. Saturation voltage is 33mV at a continuous current of 7A and the devices exhibit a gain of 100. The range includes n-p-n and p-n-p types,some with collector ratings to 60V and all handling 20A peak. Zetex plc, 061-627 4963.

Hyperabrupt varactors. Zetex's range of SM voltage-controlled capacitors will tune frequencies in the 0-2GHz range. Control voltages of 4-20V or 0-60V tune over an octave. Devices in the 22V ZC840 series vary from 0.7pF to 5pF and in the 12V *ZC930* range the variation is 3-95pF. At a reverse voltage of 4V and at 50MHz, Q is 600 minimum. Zetex plc, 061-627 4963.

Digital signal processor

Audio processor. All the filtering, companding and analogue control circuitry needed by an analogue cellular telephone fit into TI's new *TCM 8000* audio processor chip. Current consumption from the single supply is 14mA. Filters are programmable to comply with AMPS, TACS or NMT standards. Texas Instruments, 0234 223252.

Linear integrated circuits

Video difference amplifier. For use in systems where high common-mode and noise must be rejected, Analog's *AD830* video difference amplifier has a unity-gain bandwidth of 100MHz, CMRR of 100dB at DC and 60dB at 4MHz and ±2.3V clipping. Common-mode range is +13V to −11.5V, settling time of 35ns to 0.1%, diff. gain phase error of 0.05%/0.08% and gain flatness of 0.1dB to 15MHz. Analog Devices Ltd, 0932 253320.

10V reference. *REF01* by Burr-Brown is an improved version of the standard *REF01*, giving a 30% accuracy enhancement to ±0.2% and 75% lower noise at 5μV pk-pk from 0.1Hz to 10Hz. Stabilisation and regulation are 0.002% and 0.001%. Burr-Brown International Ltd, 0923 233837.

Variable-gain amp. Comlinear's *CLC522* is a DC-coupled two-quadrant multiplier with differential voltage input and single-ended output, with two input buffers and an op-amp output. Gain control is by way of a high-impedance voltage input. Maximum gain is set by two resistors from 2 to 100 with control over a 40dB range. Bandwidth is 165MHz. Comlinear Europe Ltd, 0203 422958.

850MHz buffer. Harris's current-feedback, closed-loop buffer, the *HFA1113*, exhibits an 850MHz -3dB bandwidth, 2050V/μs slewing rate, 11ns settling time to within 0.1% and 0.075dB gain flatness over 200MHz. There is a programmable output clamp to protect succeeding circuitry and programmable gain of +2, +1 and −1. Output current is 60mA and third-harmonic distortion −80dBc. Harris Semiconductor (UK), 0276 686886.

Analogue multipliers. Two high-speed, four-quadrant multipliers by Harris for use in mixer and AGC application are 65MHz (*HA-2556*) voltage output and 100MHz (*HA-2557*) current output devices, the latter needing an off-chip amplifier. *HA-2556* offers 420V/μs slewing, 0.2dB gain tolerance to 8.5MHz, −50dB feedthrough, 0.1% error and 0.1 differential phase error. Harris Semiconductor (UK), 0276 686886.

DC converter. Maxim's *MAX1743* is a 5V in, ±12V or ±15V out power supply module that needs no extra components. Output voltage is within 4% of the strap-selected value for all specified input, output and temperature conditions and current is 125mA or 100mA, depending on output voltage. Protection is included. Maxim Integrated Products Ltd, 0734 845255.

RF amplifiers. In six-pin SOT23 packages, NEC's μPC27XX wide-band RF amplifiers cover the 1GHz-3GHz range and use the MMIC technique. The amplifiers are meant for use in low-cost gain and buffer stages in cellular and PCM telephones, GPS receivers, DBS tuners and test gear. The range comprises 3.4V, 15.3mW types working at 1.8GHZ and 1.2GHz; low-noise 5V amplifiers, producing 3dB-12dB noise figures at 1GHz; and medium-power 5V types at 1.5GHz-3GHz with saturated power outputs of 10dBm-13.5dBm. NEC Electronics (UK) Ltd, 0908 691133.

FM IF amplifiers. Two FM chips by Sony are in SOP and VSOP packages with a view to reducing space and parts count. *CXA1474* is for use in single-conversion pagers and the *CXA1484* has a second on-chip mixer and oscillator for use in double-conversion systems. Both devices use a single 1-4V supply with current drains of 920μA and 1.4mA. Sensitivities are 17dBμV and 7dBμV with input bandwidths of 1MHz and 20MHz. Sony Semiconductor Europe, 0784 466660.

4-Mbit flash memory. Atmel has a 3V, 4-Mbit flash memory, claimed to the world's first of its type. *AT29LV040* needs only the 3V supply for both read and write and, with an 83mW requirement, offers a 70% power saving over a 5V-only flash. It is organised as 512K by 8-bit and individual sectors can be written to in 20ms. Atmel (UK) Ltd, 0276 686677.

Logic building blocks

Programming module. A 14-pin module which contains a complete flash-memory programming supply, the Maxim *MAX1732* occupies only 0.25in^2 and provides 120mA at 12V from 4.5-6V input. Load regulation is ±4%. Normal 1.7mA quiescent current reduces to 70μA in digitally actuated shutdown mode. Maxim Integrated Products Ltd, 0734 845255.

Reset monitors. The *MAX709* supervises a microprocessor's supply voltage and issues resets if it falls below a trip threshold, versions to handle 3V, 3.3V and 5V systems being available. The reset output remains low for 200ms after the supply is restored. Devices are in 8-pin dip and SO packages and need no extra components. Maxim Integrated Products Ltd, 0734 845255.

SCSI termination. TI has a single-ended terminator for SCSI-based computer systems, which contains the external components on one chip and will handle the proposed Fast SCSI III 100Mbyte/s speed.The nine-channel *TL2218-285* uses current-mode termination, in which a constant high current is supplied to the SCSI cable

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during transitions to give a faster digital signal with fewer distortions. Output capacitance is 6pF. Texas Instruments, 0234 223252.

Memory chips

Eeproms. New technique used by Silicon Storage Technology to make their *28EE010/1* eeproms offers sector erasing, a single 3.3V or 5V supply and fast erasing, while retaining Jedec pinouts for byte-wide memories. Both are 128K by 8 devices with 10-year data retention, access times down to 120ns and standby current of 15µA. Byte-write time is 39µs and pre-loading of data enables the whole memory to be written in 5.2s. Microelectronics Technology, 0844 278781.

Video rams. Two three-port rams for television use are availablefrom Sony. *CXK1206AM* is a 1.2Mbit ram with a 4-bit word, while *CXK4832Q* is a 2.4Mbit device with 8-bit organisation to make it capable of storing an 8-bit Pal or NTSC field. Each has one write port and two read ports, all transfers between i/o and memory blocks being controlled internally. Both recursive and non-recursive modes are available. *CXK4832Q* has write and read times of 50ns and 30ns. Sony Semiconductor Europe, 0784 466660.

Microprocessors and controllers

Micros for portables. Three 32-bit microprocessors from Motorola, *68341,68349* and *68040*, are meant for low-power, high-performance portable equipment, all having 3.3V (v) versions. 341 is for the CD-I market, working up to 16MHz and having additional instructions to provide up to six VAX Mips of performance. *68040* is for lap-top and notebook computers with a speed of 33MHz and a dissipation of 1.5W. *68349* dissipates 300mW and has a 32-bit core processor, 32-bit DMA controllers, dual serial comms port, power management and a system interface. This is the highest performing device of the three. Motorola Ltd, 0908 614614.

2V, 4-bit controllers. New members of the NEC *µCOM75X* family of cmos single-chip microcontrollers operate from supplies down to 2V. The 74004/6/8 series have 4, 6 or 8K of rom and 512 byte of ram. There are 34 i/o lines, four external and four internal interrupts, three 8-bit timers and a serial comms port. Clock speed is 1-5MHz, giving an instruction cycle time of 0.95µs. Devices using LCDs have on-chip drivers for 34 by 4 segment displays. Sunrise Electronics Ltd, 0908 263999.

Mixed-signal ICs.
GSM synthesisers. Dual bicmos PLL synthesisers for the GSM and CT1/CT1+ telephone market are the first devices in the AMS 1.2µm bicmos process. *AS3520* has two PLL synthesisers with VCO, RF buffer, prescaler and filter amplifier and are meant for the 900MHz range, although the synthesiser spans 800-1100MHz. Both 5V and 3V versions are available. Current drain is 35mA. Austria Mikro Systeme Int Ltd, 0276 29353.

Video analogue input interface. The GPS *VP8708* is intended for use in PC cards to perform video overlays on graphics displays in multi-media systems, but can also be used in frame grabbing, digital picture processing etc. Output is selectable between binary and twos-complement. The device is compatible with the Philips *TDA8708*. GEC Plessey Semiconductors, 0793 518510.

Teletext decoder. GEC Plessey's *MV1815* single-chip teletext 625-line standard. The cmos chip has an on-board data slicer, dual page acquisition, direct memory addressing and up to 254 display pages stored in external dram. It has an IIC bus and multi-language capability. Gothic Crellon Ltd, 0734 788878.

Digital video processing. Digital Transient Improvement ICs from ITT make television and computer systems compatible for multimedia work and are also suitable for high-quality, multi-standard and multi-format television receivers. *DTI2250/1* versions are usable as 4:1:1 YUV systems with software-selected function. *DTI2260* improves picture quality by interpolating chroma signals from 4:1:1 to 4:2:2 and processing via a digital colour transient improvement filter. The devices' skew compensation allows the *DIGIT2000* television system to produce computer-compatible "square" pixels. ITT Semiconductors, 0932 336116.

CT2 processor. *VP23070* is a CT2 processor providing a full Common Air Interface base-band function but using only 15mW at 3V. VLSI's design has a burst-mode controller, data clock and sync extractor with a fully compliant G721 ADPCM transcoder and interfaces for most handset and base-station use in domestic cordless telephone and Telepoint application. VLSI Technology Ltd, 0908 667595.

Optical devices

Blue leds. Temic-Telefunken's *TLHB* range are blue silicon-carbide leds emitting at 470nm. Measuring 3mm or 5mm, they are clear or diffused with luminous intensities of 3.5-15mcd. ITT Multicomponents, 0753 824212.

Oscillators

Directly heated crystal osc. Contained in one cubic inch, Anglia's DHXO has its heater deposited on the crystal blank itself to provide rapid warm-up. The technique also improves ageing, phase noise and vulnerability to vibration compared with larger, oven oscillators. Frequency range is 7-20MHz at a stability of 2 parts in 10^7 from –20 to 70°C, with 1 part in 10^7 per year ageing. Phase noise is –153dBc/Hz at 10kHz. Anglia Microwaves Ltd, 0277 630000.

SM oscillators. Surface-mounted oscillators in a new range by Murata are 40% smaller than earlier ones. MQE series of voltage-controlled oscillators cover frequencies for EAMPS, ETACS, NMT and GSM carriers, with more types in the pipe-line. Carrier-to-noise ratio is 73dB and output is –2dBm minimum. Murata Electronics (UK) Ltd, 0252 811666.

Small rubidium oscillator. Steatite's System Electronics Division believes its *FE-5650* rubidium frequency standard to be the smallest atomic oscillator available. Measuring 3in by 3in by 1.4in, it consumes less than 7.5W, warming up in less than four minutes, exhibiting low phase noise with low spurious content and harmonics. Frequencies are factory-set in the range 10kHz-20MHz to within 2 parts in 10^{12}. Steatite Group, 0630 873571.

Capacitance meter. Boonton's *7200* capacitance meter calculates and displays equivalent parallel or series resistance, series C,dissipation factor and Q in the range 0-2000pF, or to 4000pF with auto-zero, with strays compensated. Accuracy is 0.25% of reading plus 0.2% FSD. Internal 100V or external 200V bias voltages can be used for biased devices and capacitance can be displayed as a deviation from a preset reference in percentage or pF. Aspen Electronics Ltd, 081-868 1311.

Power semiconductors

Low-R Hexfets. *HEX 6* power mosfets from IR range from 60V devices with an on resistance of 9mΩ to 600V types offering 400mΩ. Drain current for the 60V type is 70A at case temperature of 130°C. International Rectifier, 0883 713215.

PASSIVE

Passive components

SM inductors. Waycom's range of surface-mounted inductors includes low-profile coils, transformers and power inductors made by Sumida. The *CLS63* DC-to-DC converter transformer has a maximum inductance of 1.8mH, works up to 500kHz and 200mW. CDR power inductors cover the 1µH-820µH range at 3.8A to 0.36A, with resistances of 0.033-2Ω. Cases are 3-5.4mm high and 4-12.6mm diameter. Acal Electronics Ltd, 0344 727272.

Electrolytic capacitors. Philips' *PLL-SI 058/059* power electrolytics offer a 33-150,000µF range of values, operating at temperatures of –40°C to 105°C, and affording a life of 10,000h at the higher temperature. Diameters are 22mm to 33mm and cases are between 25mm and 50mm long, with snap-in terminals. Gothic Crellon Ltd, 0734 788878.

Electrolytics. KL series electrolytics by Nichicon exhibit a leakage current of 0.2µA at working voltages of 6.3V-100V, in values from 0.1µF to 10,000µF. Ripple is 1.9A and load life 32,000 hours at 55°C. Nichicon (Europe) Ltd, 0276 685393.

Film chip capacitors. In the capacitance range 0.47pF-0.047µF, Panasonic's *ECH-U* components provide better than 0.5%/year stability. Size is 3.2 by 2.5 by 1.6mm and the capacitors can be flow or reflow soldered. Panasonic Industrial UK Ltd, 0344 853827.

Filters

2.5GHz filter. For front-end filtering in GPS, cellular telephones and RF data exchange, Toko's 2.5GHz surface-mounted filter measures 9.4mm by 4mm by 4mm and, in spot frequencies between 1.3GHz and 2.5GHz offers a 100MHz –1dB bandwidth, less than 0.5dB ripple and 1.5dB insertion loss. Impedances are 50Ω. Cirkit Distribution Ltd, 0992 444111.

Hardware

EMC cabinet. Eurorack HF2 from Schroff is an electromagnetic compatibility cabinet with individually plugged stainless steel contact springs, mounted at any interval, to tailor the characteristic for any application. Widths and depths are 600mm to 800mm and heights from 16U to 43U, the units being protected to IP20. Schroff UK Ltd, 0442 240471.

Instrumentation

Field-strength meter. ITT's *VX600* television field-strength meter performs measurements in all VHF and UHF TV bands, including satellite, and the FM band: acts as a TV monitor for sound and vision testing: and performs spectrum analysis. Sensitivity is 20dBμV and there is a scart connector for an external D2mac or video. The *VX600* meets both IEC and VDE safety and EMC standards. Amplicon Liveline Ltd, 0800 525 335.

Dielectric measurement. H-P's *HP 85070M* is a software/hardware system designed to perform dielectric measurement for the food and chemical industries. *HP 85071B* is the software used to control a 3GHz HP 8752A or 20GHz *HP 8720C* network analyser, which makes swept, high-frequency stimulus/response measurements, then translated into the relevant terminology and format. Measurements include dielectric constant, permeability, loss factor and loss tangent. Software runs under Windows in MS-dos format for PCs or HP Basic for HP workstations. The system includes all peripherals, including a 486 computer. Hewlett-Packard Ltd, 0344 362277.

Universal counter. Hewlett-Packard's *HP 53131A* counter uses a technique developed by H-P for modulation-domain analysers to provide extremely high resolution at very high speeds, displaying 10 digits in 1s. Bandwidth is 225MHz or 3GHz with an optional channel and facilities include 500ps single-shot time interval; all standard counter functions including phase angle, peak voltage and rise time; an analogue display; measurement statistics; and single-key recall for measurement set-ups. Hewlett-Packard Ltd, 0344 362277.

Microwave power meter. Although a portable, cordless instrument, Marconi's *6970* RF power meter provides benchtop functions in the range 30kHz-40GHz at power levels of –70dBm to 35dBm (100pW-3W). The optional 0dBm 50MHz power reference is traceable to national standards and gives a ±0.2dB accuracy. Marconi Instruments Ltd, 0727 59292

Dialled port access. Multilog from Mutek allows dial-in access to multiple serial ports in PABX or computer systems. It is battery-backed and there is an optional internal modem and large buffer for data capture or remote access. Dialling selects one of five serial ports and several isolated single-line inputs and outputs. Mutek Ltd, 0225 866501.

Digital oscilloscope. Hitachi's *VC7104* DSO has 150MHz analogue bandwidth and samples at 100Ms/s on four channels simultaneously. Memory cards up to 2Mbyte are accepted to provide storage of up to 200 waveforms of 8K each in dos format for PC use. The built-in printer automatically records waveforms and there is a plotter output. Programming is by way of GPIB and RS 232 interfaces. Thurlby-Thandar Instruments, 0480 412451.

10-trace oscilloscope. A 10-trace, four-channel 100MHz oscilloscope from Kenwood has 100-step programming and Pal/NTSC line counter. The *CS6030* offers on-screen readout and a delayed timebase allowing independent A and B sweep trigger setting. Vertical sensitivity is 1mV/division at a sweep speed of 20ns-50ms/div on B and 20ns-500ms on A. Accelerating voltage is 17kV. Trio-Kenwood UK Ltd, 0923 816444.

Pulse generator. Models *240* and *233* pulse generators by Levell are 0.5Hz-50MHz instruments, the *233* being a dual type with independent rate and width control and the facility of running the two outputs independently, paralleled, summed, in series or with one channel running as an oscillator to give a burst function. Rise and fall times are independently adjustable in the *240*. Levell Electronics Ltd, 0992 501231.

Multimeters. Escort *EDM-88/89* offer dynamic recording in both auto ranging and manual modes. Accuracy is within –0.1% on direct volts, bandwidth 20kHz AC is true RMS. The display is a 5000-count type and includes a 53-segment bar graph. Other features include a 10MHz counter, capacitance measurement and dBm with selected reference impedance. Feedback Instruments Ltd, 0892 653322.

Literature

Data acquisition. Features of Amplicon Liveline's *200* series data acquisition systems are described in a new brochure. Amplicon Liveline Ltd, (Free)0800 525 335.

SM leds Dialight has a colour guide to their range of surface-mounted led, which includes top-view and right-angle configurations in colours from blue to infrared, and photodetectors. The *microLED 597* series are claimed to be the smallest available leds and the *PRISM CBI* the first true right-angle mounted SM led with integral optics. BLP Components Ltd, 0638 665161.

SM devices. Murata has a new catalogue detailing the company's range of surface-mounting components such as chip ceramic capacitors, trimmer pots, EMI suppression devices, ceramic filters, coax. connectors, isolators and VCOs. There is a section on a bulk feed system for the components. Murata Electronics (UK) Ltd, 0252 811666.

Power supplies

200W DC-to-DC modules. Single and triple output converters from Advanced Power Conversion use a current-fed push-pull converter circuit switching at a fixed 500kHz rate, the units being usable alone or in series and parallel and can be synchronised to a clock. The units are fully protected and are made to ISO 9000 QC in chassis or PCB mountings. Advanced Power Conversion Ltd, 0252 371036.

Long-life cells. Lithium coin cells from Fuji, the CR series are meant for battery backup, the *CR2450*, for example, providing five years of life at 10μA drain. All cells give 3V nominal

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and capacities are in the 70mAh-550mAh range. Smallest in the range measures 20mm by 1.6mm. Price is about one-sixth that of thionyl chloride cells. Suvicon Ltd, 021-643 6999.

Bench power supply. Trio-Kenwood's *PD 110-5* PSU gives 0-110V at 0-5A, having a phase-control circuit with a pre-regulator to give rapid response and high-stability large currents. Remote sensing is used and remote control of outputs is included, as is over-voltage protection. Trio-Kenwood UK Ltd, 0923 816444.

DC-to-DC converter. 15W and 30W DC-to-DC converters from Computer Products in the *WR15* and *WR30* series are intended for three particular markets: telecomms; industrial electronics; and test/mobile equipment. They are pin-compatible with standard WR units, but smaller. Outputs are in three ranges: 9-18V, 18-36V and 36-75V. The modules meet the relevant international standards in the three classes. XP plc, 0734 845515.

Radio communications

Miniature radio receiver. For remote-control and alarm applications, the Celm hybrid regenerative receivers measure 38.1mm by 13.7mm in a 15-pin sil package. They are self-quenching and modules are either fixed or tuneable in the range 200-450MHz. Sensitivity is –105dB and supply is 5V or 8V at 4mA. Acal Electronics Ltd, 0344 727272.

SM VCO. A surface-mounted voltage-controlled oscillator by Z-Comm is only 0.5in by 0.5in by 0.2in and covers the 1.2-2.4GHz band in response to a 0-26V control voltage. Drawing 35mA from 5V, *C-600M* puts out 3dBm into 50Ω, with second-harmonic 10dB down. Phase noise at 1kHz from carrier is –76dBc/Hz and –98dBc at 10kHz. Eurosource Electronics Ltd, 081 977 1105.

Chirp synthesiser. Improving on the often non-linear FM chirp signals used in various forms of radar, Sciteq's *DCP-1* chirp synthesiser provides a linear sweep, wide bandwidth and excellent spectral purity. Frequency range is 1-230MHz, step size less than 30Hz, spurious signals –55dB and 2ns update. Lyons Instruments Ltd, 0992 467161.

Keyfob transmitter. Quantelec's *SPTXM-418/RS* is a small FM transmitter working at 418MHz for telemetry and control in both domestic and industrial applications. It is UK type-approved. Radiated power is –8dBm from one *MN21/GP23A* alkaline battery to give a range of 100m outdoors and 50m in buildings. A positive data bit is transmitted if battery voltage falls below 7.5V to warn that only 200 operations are left. Quantelec Ltd, 0993 776488.

Switches and relays

Tough PCB connectors. Two-part PCB connectors in the SPF range from Hypertac were developed for aerospace and military use and are suitable for use in hostile surroundings. A moulded top shroud protects the pins and guides ensure accurate connection. The units are available in two or three row versions with up to 160 contacts rated at 170V at 4A .Hypertac Ltd, 081-450 8033.

Transducers and sensors

Load cell. A load cell measuring 13mm high and between 15mm and 25mm diameter, the *Mini-UTC* by Control Transducers is for both tension and compression loads in ranges from 50g to 5000kg to within ±0.3%. Optional spherical bearings avoid off-axis loading and overload protection is 150% of full scale. Output from the 10V bridge is 2mV/V. Control Transducers, 0234 217704.

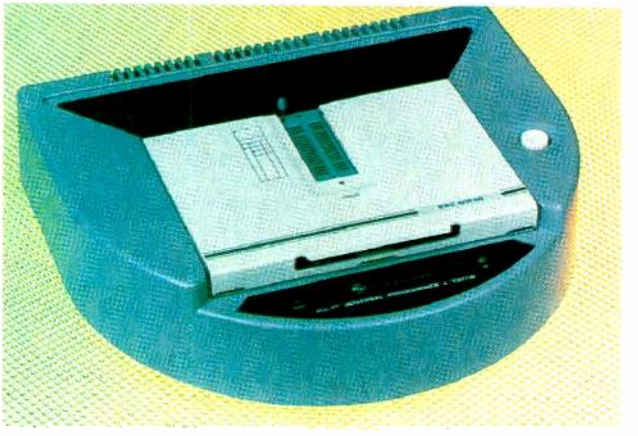
COMPUTER

Computer board level products

Virtual voltmeter for PCs. Operating as a virtual voltmeter on a PC, CIL Microsystems's PC-Precise comes in single or dual channel versions and is essentially an A-to-D converter plug-in card providing up to 21-bit resolution from 20mV to 20V analogue input. The virtual instrument software and other software for calibration and sampling rate variation are included. CIL Micro Systems Ltd, 0903 765225.

Software

Schematic capture. *TopNET*, introduced by CRaG Systems, is a schematic capture program for Spice, running from the control shell of *TopSPICE* and generating a *Spice* netlist. Symbols for standard *Spice* components and *TopSPICE* digital elements plus a few others are available; an extended library is to come. A PC with VGA is needed. CRaG Systems, 0635 868557.■



Filter design. *FILDES* software from CRaG assists in the design of low-pass, high-pass, band-pass, band-stop and GP filters using Butterworth, Tchebychev, Cauer, Bessel, general-purpose biquad and other functions. After menu-assisted specification entry, the program displays magnitude, phase and delay against frequency. Component values are shown and the design is output in ascii format. CRaG Systems, 0635 868557.

Development and evaluation
Universal programmer. Latest addition to Smart's range of programmers is the truly universal *ALL-07* which, connected to a standard PC printer port, programs all current and, says Smart, future devices; it drives up to 256 pins. In addition to memory chips, it also handles memory cards, logic arrays including MACH, MAX and MAPL families, and a range of microcontrollers including Motorola's new *PIC17C42*. An eight-gang adaptor and single-key operation make it suitable for low-to-medium volume production use. Smart Communications, 081-441 3890.

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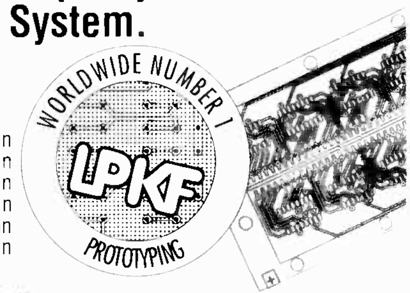

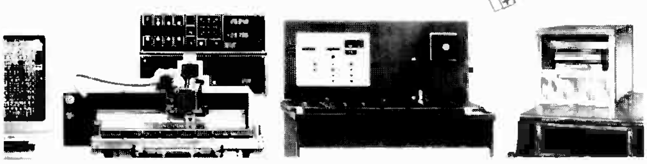

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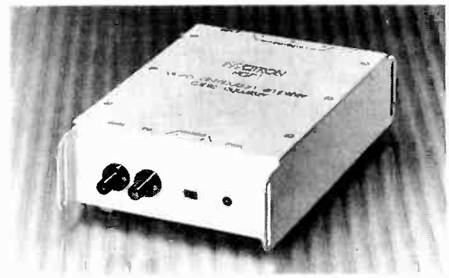

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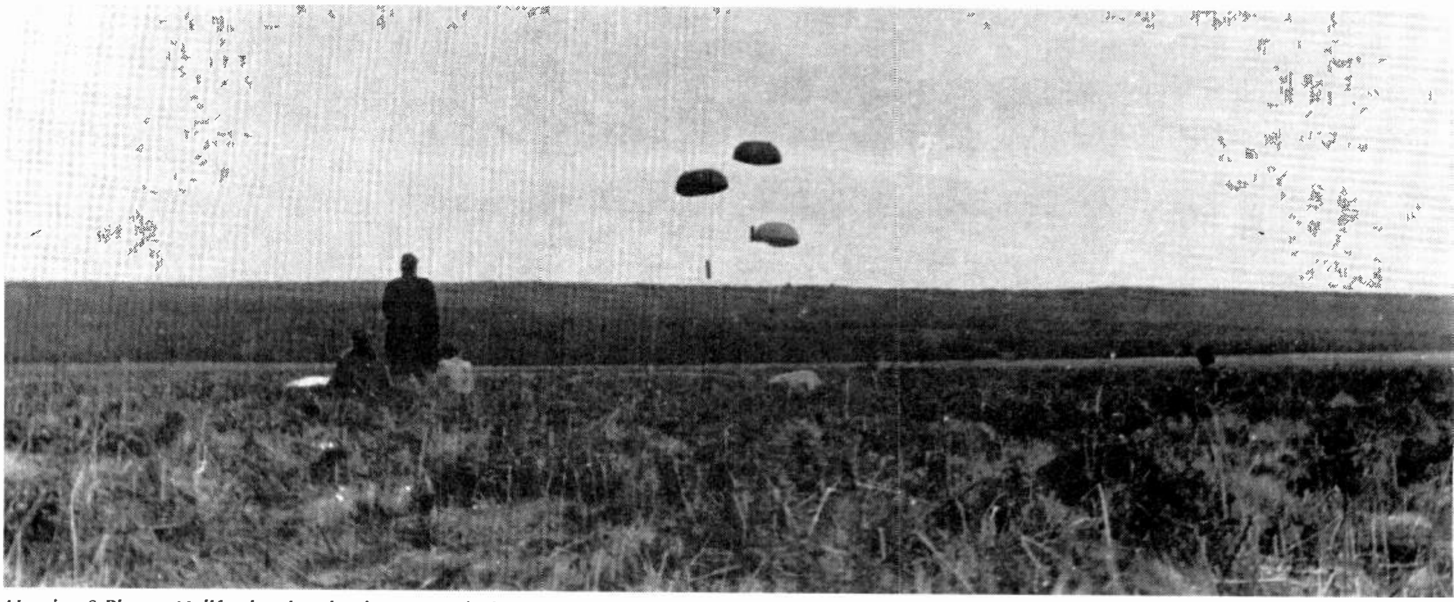


Homing S-Phone: Halifax leaving the drop zone during an actual operation.

The secret radio that kept Resistance lifelines open

Good communication and reliable parachute drops of supplies were vital for coordinating Resistance fighters in occupied Europe. Charles Bovill describes how the S-Phone met both needs – and the enemy never knew.

In a Europe occupied by the German Army, and a Britain under threat, Winston Churchill issued a directive to "Set Europe ablaze". Until the return of the Allies to Europe, that was an instruction that could only by accomplished by formation of a Resistance movement, organised by patriotic nationals – often in conjunction with agents from Britain who infiltrated occupied countries. Armaments, explosives and agents were parachuted in by the RAF, and the work of the Resistance was to harass the Occupying Forces, mainly by sabotage.

But for the work to be effective, good communications between Resistance Groups and allied agents was essential.

Low-powered HF equipment was in use – and was entirely successful. But for parachute drops, a specially designed communication system with a homing component was needed. The S-Phone, developed by Captain H Lane, was the answer.

Captain Lane, of Royal Signals, was engaged in radio work for the Inter-Service Research Bureau, later to become the Special Operations Executive (SOE). He knew that suitable equipment had to be small and very simple to operate. Reliability was an extremely high priority too, as equipment repair was practically impossible in the field.

Lane's basic idea was to use a new approach to secure communications built on the line of sight performance of UHF, with operational range depending on the relative heights of the sending and receiving stations. So an aircraft flying thousands of feet above the ground station could communicate over considerable distances. The generally used formula for the horizon distance, upon which the idea was based is $D = \sqrt{(H_1 + H_2)}$ where D = distance of the horizon in miles, H_1 is the height in ft of the aircraft and H_2 is the height in ft of the ground equipment.

In a typical case the horizon distance between an aircraft flying at 3000ft and a ground station would be about 50 miles for an S-Phone at 100 feet ASL. In practice, this meant that with the low power available from the ground station the range, under favourable conditions, would be about 20 miles – an adequate range for its intended use. But as a by-product, the system was extended to intelligence work communications where it was extensively used almost as soon as the system became operational.

At short ranges, various effects severely restricted ground-to-ground communication. Over normal terrain, the range was not more than a maximum of one mile, with a power output of 200mW. Experiment indicated that the S-Phone should operate in the 400-450MHz band. But why did SOE not use the already developed VHF? The answer is that communications equipment had to be compact. It was also known that the enemy carried out extensive monitoring on the VHF band, but very little on UHF – though they did operate communication links on UHF.

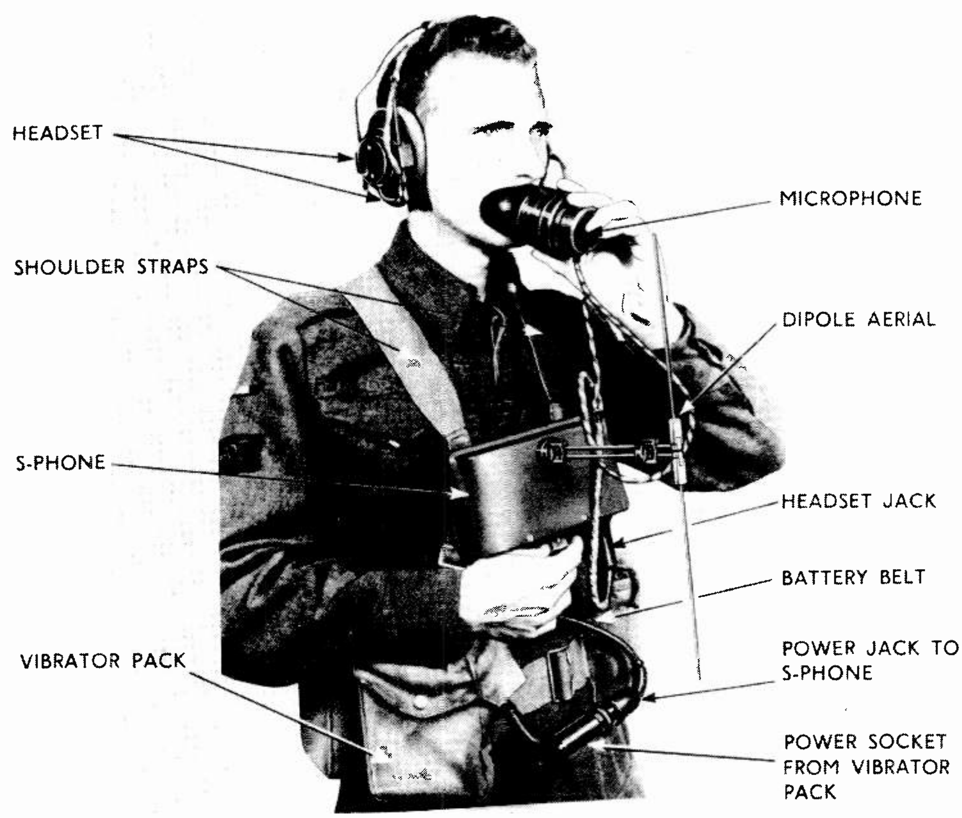
For the period in question, fifty years ago, miniaturisation was hardly an option. Only valves were available and for VHF, suitable types were rare and mostly absorbed for radar development.

Ground S-Phone

The ground S-Phone prototype hardly changed throughout the war. It consists of the transmitter-receiver unit, in a contoured metal case, a dipole antenna plugged in and a belt to which the unit was clipped and which also contained rechargeable batteries and a vibrator HT generator.

By present day standards the circuit arrangement used is very simple and consists of a free-running UHF oscillator and Heising modulator for the transmitter. The oscillator valve, an *RL18* is fed into the antenna inductively and provides an output of about 200mW. The vibrator, driven by 6V from the battery belt, provides 200V for the HT of all valves in the

The lightweight self-contained SPhone enabled communication between ground and air while minimising the chance of transmissions being picked up on the ground.



transmitter and receiver sections. Batteries provide about 4h of continuous operation and a charger operating from the 110 or 220V mains was supplied.

The receiver uses a super-regenerative detector, also an *RL18*-type of valve, and audio is fed to an amplifier, using *Hivac* valves. A tuning control provides an adjustment of ±5MHz to take up transmitter and receiver frequency drift.

The detector is connected to the antenna inductively. Closeness of the transmitter circuits to the receiver input results in a side-tone signal.

The microphone is a normal RAF air crew type and gave good quality. Intelligibility was deemed essential during the experimental period as, in many cases, the ground operator and opposite number on the aircraft did not always share the same first language. Repeating signals were not desirable, because of the risk of night fighter activity.

Overall, the S-Phone, using duplex, had been conceived to resemble a normal telephone as far as possible. With correct operation on the part of the aircraft and ground operators it went near to fulfilling the task.

Crash setback

The airborne equipment presented less development difficulty in and, in the first days of trials, consisted of a transmitter of similar type to the ground model but using a superheterodyne receiver. Within a few days of the completion of the prototype, the Whitley aircraft in which it was installed crashed at Stradishall, with the loss of the crew and total destruction of the S-Phone equipment

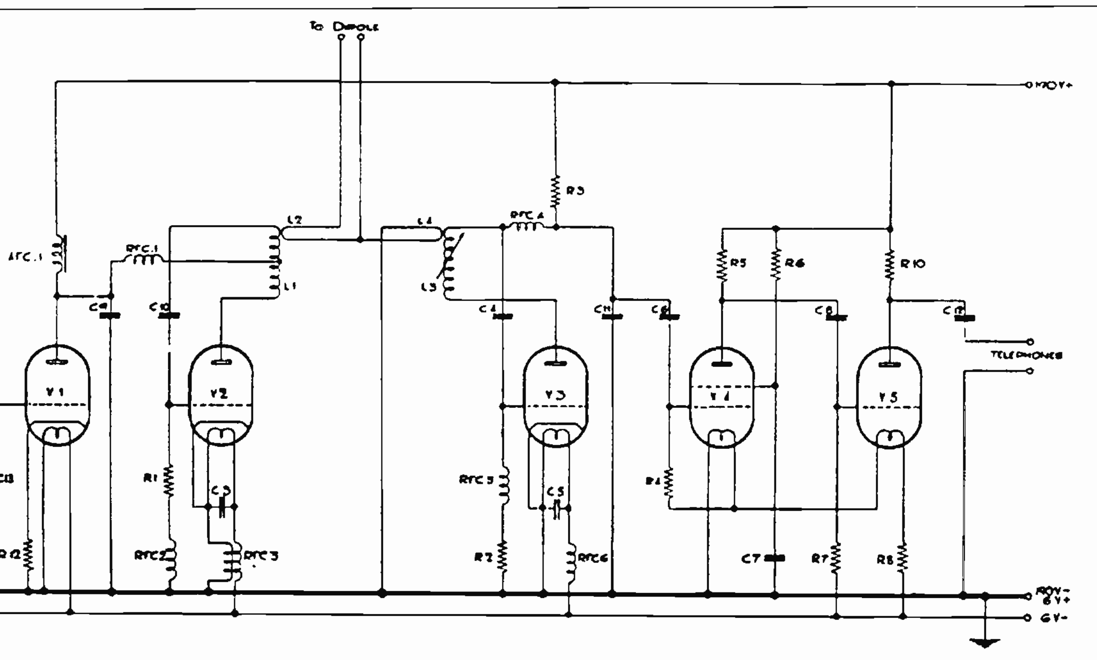
The situation was particularly serious because the S-Phone was urgently needed and the equipment destroyed had been the only one in existence. Worse, it was then discovered that no drawings of circuits had been prepared.

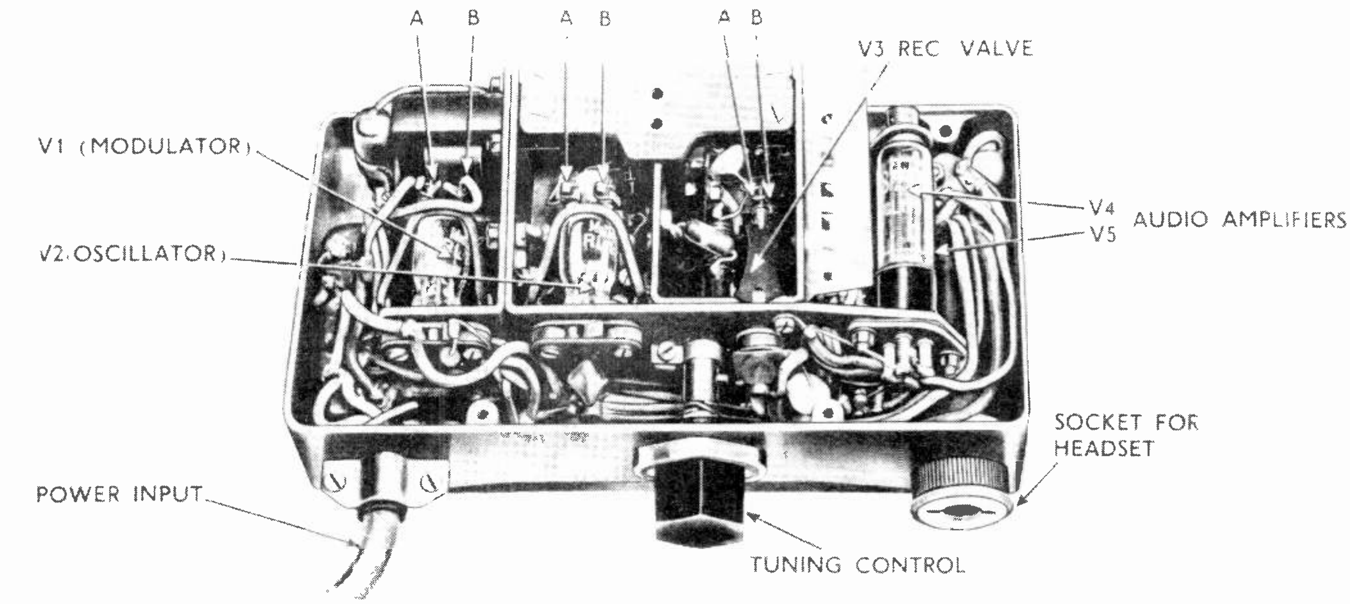
But such was the attitude and the "press on" spirit during the war that, on the evening of the crash, work was immediately put into hand and new equipment was available for airborne tests within three days.

The new airborne unit altered the receiver to a super-regenerative type using tuned lines, as did the transmitter, both with good performance – the receiver had a sensitivity of the order of 5μV for "a loud and clear signal". Transmitter power was also increased.

Because of the unusual conditions attached to parachute dropping, the speech output from the transmitter and the receiver were connected to the intercommunication circuits of the aircraft, facilitating operations and eventually saving several aircraft and crew on dangerous missions.

The simple ground S-Phone circuit was built around a free-running UHF oscillator and Heising modulator for the transmitter. The receiver and transmitter operated simultaneously with a frequency separation of about 50MHz allowing full duplex speech transmission.





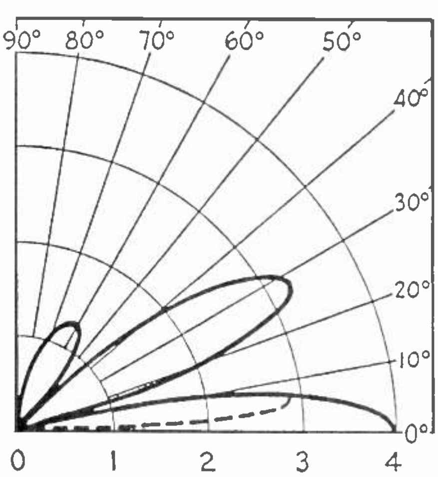
Inside the ground S-Phone.


(Right). Many Halifaxes were fitted with the S-Phone. Inset shows a close up of the S-Phone antenna, poking out from under the fuselage. The three-quarter wave antenna provided a bearing facility onto a ground S-Phone set.

Antenna fine-tuning

The airborne installations – in the first instance on Whitley, Wellington and Halifax bombers, converted for dropping parachutes – hit problems with the antennas. Fitting the antennas on the lower surface of the fuselage seemed to be the most suitable solution for ground-to-air communication.

But on the first test flight, with the aircraft at a low altitude, received signals experienced severe distortion from the ground, due to the inherent radiation of a super-regenerative receiver reflected back from the ground below.



Lobes of radiation from the ground S-Phone were not as expected. The gaps were used to guide aircraft to a drop.

Further experiments showed that the difficulty could be overcome by mounting the antenna – a quarter wave type – on top of the fuselage.

The best position was not determined until several flight tests has been made, because, at some angles of flight, such as steep banking and climbing, the antenna was shielded.

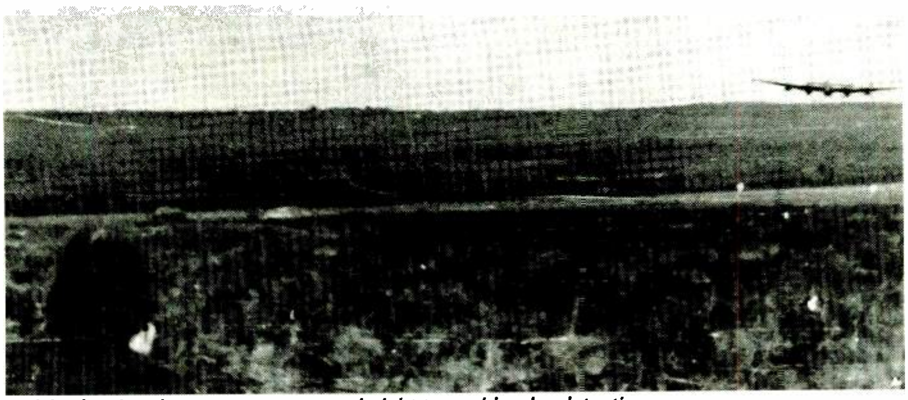
During these experiments developers noted that in some positions of the antenna, distortion of signals occurred, only to be eliminated when the aircraft was flying directly towards the ground transmitter. The effect was in fact due to reflections from the airscrews, an unsophisticated but practical homing system. It was never adopted and better solutions were to come into service later.

The combined characteristics of the ground and airborne antennas added together in quite a fortunate manner. Lobes of radiation from the ground S-Phone were not what is found in textbooks, mainly because of the position, and basic nature of the antennas. The result was several radiation lobes at low angles, causing gaps which, when flown through at relatively low altitudes, were distinctly noticeable by the drop in signal strength, followed by a clear "cone of silence" when signals were not heard.

These special conditions were exploited in dropping operations. The aircraft would fly towards the DZ (drop zone) and the levels of signal strength would be noted by the pilots and the dispatcher – the crew member responsible for the release of the parachutes. Although crude by today's standards, the method was frequently used and was, in its way, successful. When the S-Phone homing system was developed and in operational use, the pilots and the dispatcher were assisted by a signal strength meter which gave accurate indications for a precise drop.

Receiver and DF units were far more advanced than the super-regenerative receiver which had been used on S-Phone operations for the previous years – the super-regenerative receiver being unsuitable for a homing system.

The transmitter remained the same, but by this time, successful UHF superheterodyne designs were available and a reliable sensitive



Halifax leaving drop zone at tree top height to avoid radar detection.

Pregnant technology

Trials and operations re-commenced and included demonstrations at night. On one of these tests, to a most secret military organisation, Colonel Lord Sandhurst was critical that, when worn under an overcoat, the operator looked pregnant. The quick-witted SOE Flight Lieutenant handling the presentation, instantly replied that this was an advantage as it was a standing order that, in the presence of pregnancy, a German soldier must avert his eyes and salute.

receiver was produced. In essence, the homing receiver was associated with a phase comparison unit, signals being received on three spaced dipole antennas located below the nose of the aircraft

Examination of the equipment reveals some strange techniques in implementation. But the extreme shortage of components and time available had to be taken into consideration. The main consideration was that it all worked.

Transmitting and receiving antenna

During development of the S-Phone ground equipment, one of the main difficulties was the antenna. Position of the dipole made it necessary to use vertical polarisation. Tip of the lower element was about a quarter of a wavelength from the ground, producing a slightly abnormal radiation in the vertical plane which was actually an operational advantage. In addition, the antenna – being forward of the operator – had poor back to front performance, with considerable loss of signal if the operator was not facing towards the transmitting-and-receiving aircraft.

Attempts were made to rectify this operational weakness but, short of mounting a quarter wave antenna on the operator's head, no practical solution was found and the original antenna layout was retained until the end of the war.

The weakness did lead to some operational failures. An operator knew beforehand the direction from which the aircraft should arrive at the DZ. But in many cases enemy action caused the aircraft to make a detour and probably arrive on a reciprocal bearing. In this case it would not be contacted until it was almost overhead. Usually, the operator placed stones on the ground indicating the cardinal points of N, S, E and W. While waiting for the arrival of the aircraft, the operator searching for signals by pointing the antenna in various directions. When the signals were heard, directional characteristics of the S-Phone would guide the aircraft to the DZ.

How secure were S-Phone operations?

Air-ground S-Phone operations do not seem to have been detected or seriously interfered with by the enemy – which is surprising, because Germany did have UHF systems. Clearly the aircraft transmissions would be detectable over an area of at least 400 square miles. But they were not heard, or were not felt to be of significance to the very well organised German Abwehr. Finding the ground sets, unless sought by detection units on the ground or in the air, would have involved a considerable organisation.

A reference[2] to S-Phones is made – though not by name – by the former Chief of Military Counter Espionage in Holland, Belgium and Northern France, Major H J Giskes, author of "London Calling North Pole".

Although primarily engaged in the "English Game" operation, he states that "he had heard from Berlin that progress had been made in the design of VHF sets for agents' use. It is quite possible that the enemy is using them and our normal interception service can't pick them up".

Later in his book, he reports the capture of a Dutch SOE agent with an S-Phone, although again not specified as such, who reported that the radio telephone was for communication with English ships at sea. He reports later that tests showed the equipment was capable of: "... communicating over 5km – quite a good performance at the time".

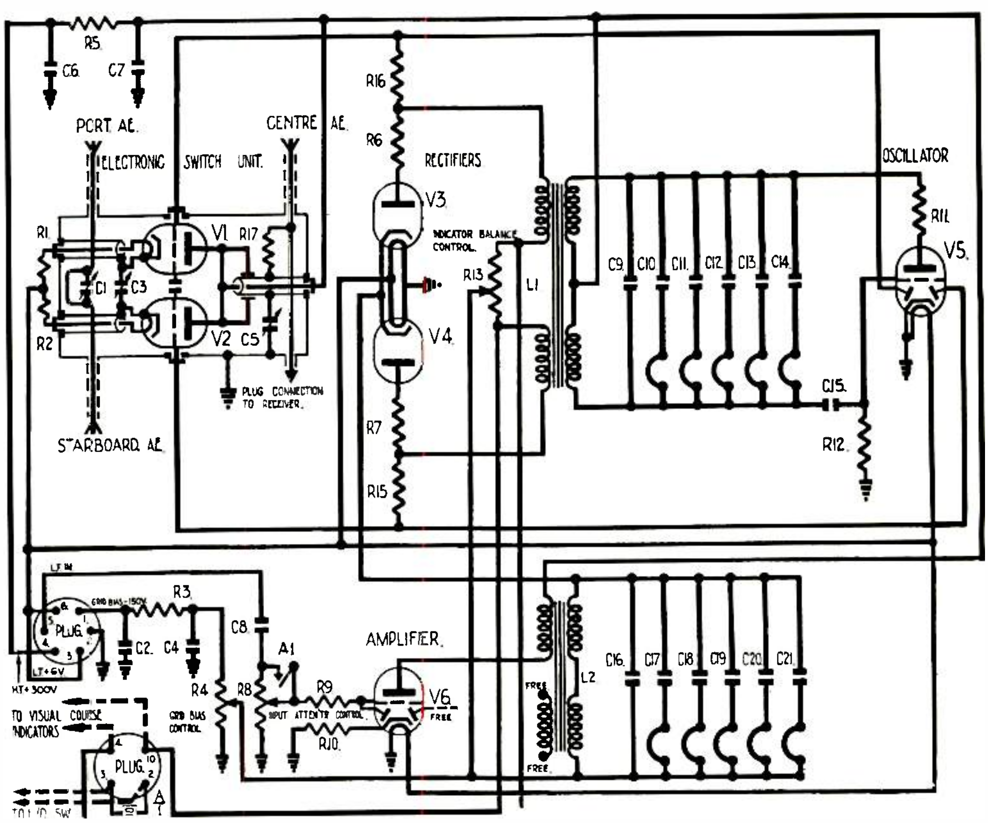
There does not seem to be a record of the capture of agents or saboteurs while using S-Phones, except in the case mentioned.

Proved by history

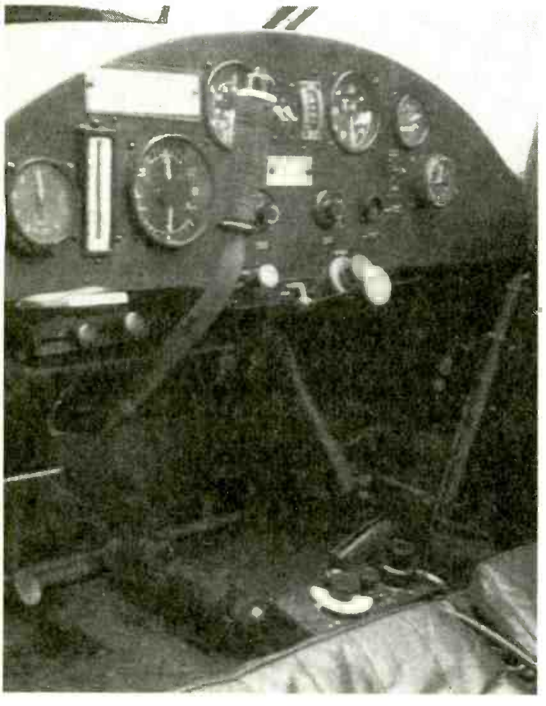
In these days there is a rather unfortunate tendency for authors and journalists to find fault with military operations. But the S-Phone has not yet suffered in this way and it can be concluded that the development and operations were worth the effort.

The system saved lives and was of great assistance to the valiant agents and Resistance groups in many countries.

In Holland, when the Germans had retreated to the north of the Maas river, an air-ground



Airborne S-Phone homing unit making use of phase difference between three nose-mounted aerials. In operational use pilots were aided by a signal strength meter.



The Auster was normally used for spotting artillery, but the SOE had them fitted with the S-Phone (in front of seat).

Intelligence gathering network was set up and operated for the period leading up to the last day of the war.

Necessary ground equipment for the activities were smuggled into enemy occupied territory by a few courageous Dutch men and women. Aircraft used were of two types: DH Mosquitoes and the smallest plane flying with the RAF – the Auster.

Normal role of the Auster was artillery spotting, but for the SOE they were fitted with the S-Phone. The aircraft only operated at short ranges and were mainly employed in "orchestrating" and organising the crossing of the Maas and other rivers, by people leaving the Arnhem battle.

The deep-penetrating intelligence-gathering Mosquitoes flew over Germany at great altitudes collecting valuable information at speeds which made them difficult for the Luftwaffe to intercept.

Airborne equipment was the normal type but the antenna arrangements were unusual. Tests showed that attenuation from the wooden fuselage was negligible at 450MHz, and for aerodynamic and concealments reasons, the antenna was placed inside the fuselage and towards the tail.

Polar diagrams of this arrangement were satisfactory and the range over which communication was possible – theoretically about 150 miles, but in practice nearer to 100 miles – adequately covered the whole area of Occupied Holland and into Germany.

10,000 in use

Estimating how many S-Phone operations were carried out in all of the theatres of war during the years of conflict is difficult, largely due to the very strict security maintained by the RAF, USAF and SOE. Keeping personal diaries was a court martial offence and few existed. Official records – and equipment – were efficiently destroyed, especially by SOE, in 1946.

From the small amount of information available, mainly from the memories of persons actually involved, the number is of the order of 10,000 in Europe and Asia.

The aircraft equipped were Wellingtons, Halifaxes, Whitleys, Hudsons, C47, Fortresses, Liberators, Mosquitoes, Stirlings and Austers. Sorties were made very frequently so the 10,000 estimate seems reasonable.

Operations were, in the main, successful and were, from the beginning of 1944, assisted by the Eureka-Rebecca 200MHz guidance system which provided a homing and distance facility.

The marine activity using S-Phones was considerable in all theatres of war and assisted in many clandestine landings of agents from small boats and submarines.The only comparable system to the S-Phone was the American Joan Eleanor, first used in late 1943. An operation with this system is described in detail by V J Layton in an article "Above Intercept" which appeared in "73 for Radio Amateurs" during October 1985. ■

Tangible proof of drop accuracy

S-Phone homing and "blind" dropping was demonstrated in the winter of 1943 before a distinguished assembly of officers. The night chosen was considered to have the worst weather that even an English winter could produce, with zero visibility, driving rain and low cloud.

The airborne operator, having complete belief in the system's ability to act as a beacon for the drop, warned observers not to remain closer to the S-Phone than 200 yards. In the event, the bad weather prompted the observers to stay in their cars – which were very close to the S-Phone.The S-phone was simply switched on, without the operator so that the drop could be automatic, and the homing run started some 30 miles from the DZ. Entering the cone of silence, the dispatcher released six containers, and this was followed by a cessation of signals.

The outcome was that the containers, having landed within a few yards of the S-Phone, had inflicted alarm and expensive damage on the distinguished gathering sheltering in their cars.

Accuracy of the homing system was also demonstrated to the US Air Force with a DC3 aircraft of the 60th Group Troop Carriers. The aircraft carried out an initial drop followed at half-hour intervals by further drops. At the end of the exercise, the parachutes from each drop were lying together in an impressive heap.

S-Phone in action

One spectacular operation using the S-Phone was when an enemy headquarters was – to use the present day term – bugged.

Ground equipment was infiltrated into the building and a remote microphone installed in an office where discussions of interest to the Allies were to take place.

For the remainder of the war, an aircraft carrying out routine flights was able to cover conversations through the S-Phone link.

In Denmark, valuable use was made of the S-Phone in establishing a link between Helsingfors and a listening post on the adjacent coast of Sweden.

The Resistance realised that an ancient high tower near Helsingfors could provide an S-Phone transmitter and receiver site for direct communication with Sweden. To meet the requirement special mains-operated equipment was designed and air dropped complete with all associated accessories. After installation on the tower, it was put into operation and regular communication was carried out until the cessation of hostilities. The tower's already-existing telephone-system was connected to the S-Phone enabling information to be passed at will and without interception. After the war, the general excitement and relief of peace resulted in the installation being completely forgotten and it was not until some years after that an ex-SOE radio engineer, who had designed the equipment, discussed the system with an ex-Danish Resistance operator. The tower was later visited and the S-Phone was found to be in perfect working order. Now the equipment is still serving a useful purpose – in a museum in Copenhagen.

Considerable use was made of S-Phones for secret landings from small boats on enemy coasts. For several years the "Shetland Express" transferred agents to and from Norway with the aid of the system. Similarly, a service was in operation between Devon and the north coast of France. In this instance, not only were the ships kept in contact with each other, but also with the aircraft which maintained a watch over them. The antennas on the ships were concealed at the top of the masts and the S-Phone equipment in the bilges. The S-Phone range over the sea from the 25ft masts was well within the horizon distance, owing to the favourable over-sea path.

Further reading

1. "Clandestine Armament" (Also entitled in USA "Secret Warfare"), by Col P Lorain, published by Orbis Publishing, London.
2. "London Calling North Pole", by Major Giskes, published by W. Kimber, 40 Wilton Place, London.

As F/Lt. Bovill, Charles Bovill designed and tested the first widely used airborne homing S-Phone set. He remained intimately involved with clandestine radio operations throughout the war. Charles Bovill is still active as a counter surveillance consultant.

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RJ3

Fast 10-bit converter with power-down mode

In power-down mode, the 10-bit analogue-to-digital converter used in this battery-monitor for lap-top computers consumes only 20μW.

In a lap-top computer, battery parameters that need to be measured are positive and negative terminal voltages, average current drain and battery-case temperature. Once digitised, these parameters can be used by the keyboard microcontroller to control battery charging circuits. They also provide a means of indicating battery-charge status.

Battery-case temperature rises rapidly when an NiCd or nickel-metal hydride cell reaches full charge. In this circuit, temperature is sensed by an *LM34*. Resistor R_3 provides a voltage representing battery current drain. To prevent false readings, this voltage is averaged by a low-power op-amp.

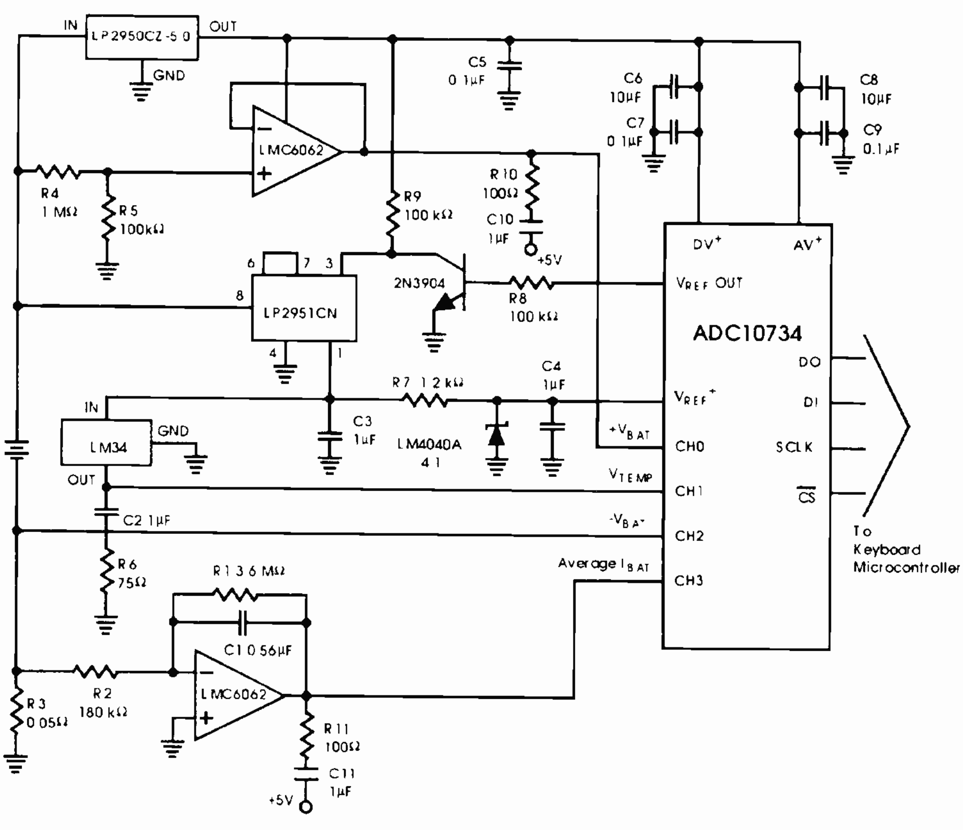
Communication with the keyboard microcontroller is serial via a four-wire link. Power-down mode is initiated by the controller via this link. Since battery parameters are only needed once a second, the converter spends most of its time powered down so battery drain is minimised.

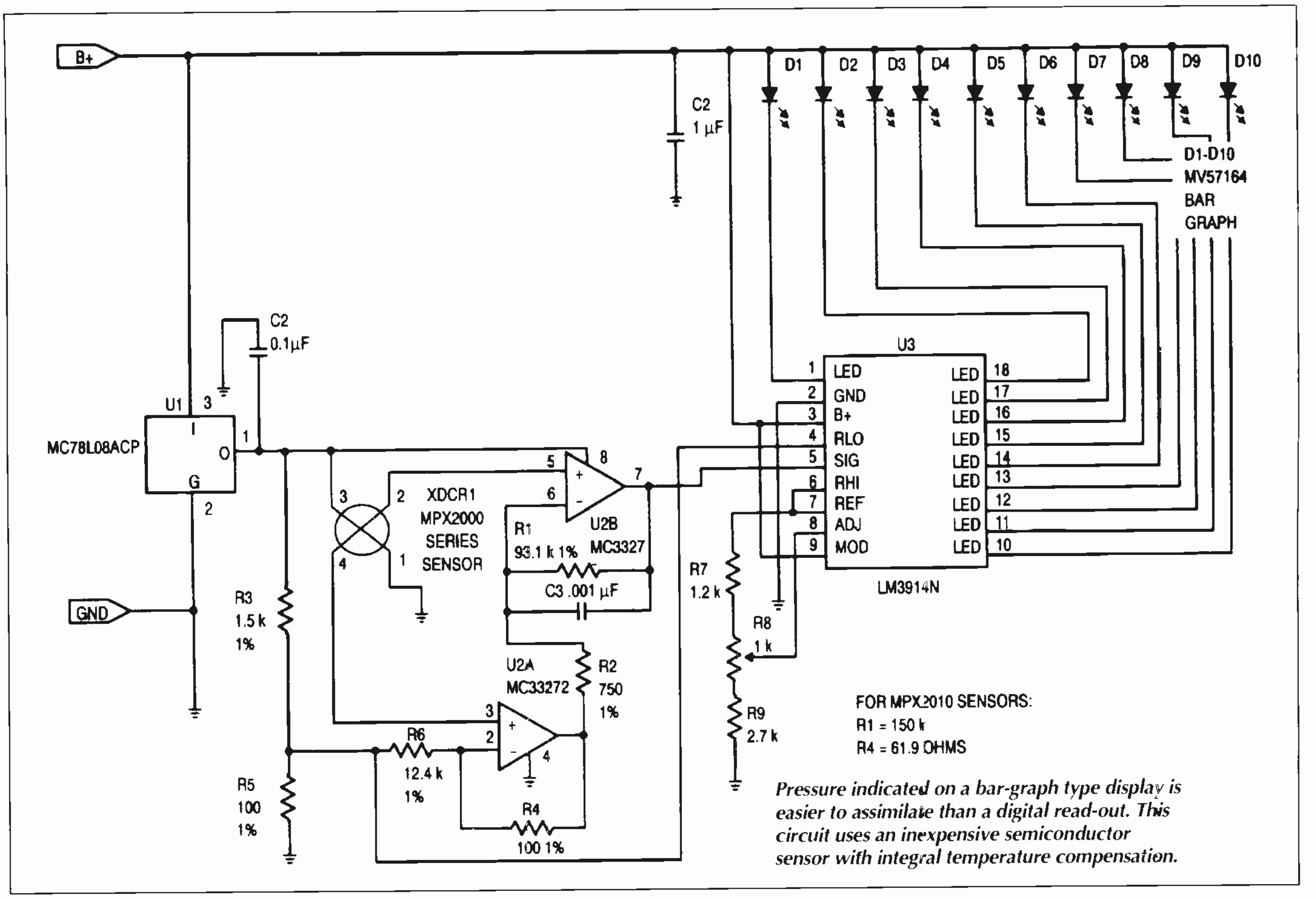
Powering down the data converter also shuts down its 2.5 reference output. This in turn powers down the *LP2951* voltage regulator, the temperature sensor and the *LM4040* reference. Because the battery current reading is averaged, the *LMC6062* cannot be shut down.

Conversion time of the *ADC10734* is 5μs maximum. The design is from National Semiconductor's *Leading Edge* bulletin. Also outlined in the bulletin are circuits including a four-channel data acquisition system, a MIL specification analogue monitor, rail-to-rail op-amps, a shunt reference for portables and a high-performance modulator, demodulator and synthesizer. There is also a description of a low component count 3.3V switching IC, the *LM2574M*.

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

In a lap-top computer, precise battery monitoring is essential. This circuit provides the lap-top keyboard controller with full battery voltage information and cell-case temperature to indicate end of charge.





Pressure indicated on a bar-graph type display is easier to assimilate than a digital read-out. This circuit uses an inexpensive semiconductor sensor with integral temperature compensation.

Pressure gauge with bar indicator

According to application note *AN1322* from Motorola, interfacing pressure sensors to bar-graph display drivers, microcomputers and voltage monitors is straightforward. Called *Applying Semiconductor Sensors to Bar Graph Pressure Gauges*, the note outlines all three type of interface.

Temperature compensation is provided by the bar-graph pressure gauge shown but the note also contains a non-compensated option involving no additional op-amps. This simpler circuit uses a different sensor, an *MPX5100*.

Drive to the bar-graph IC is 0.5 to 4.5V, proportional with pressure. The op-amps provide gain and level-shifting. Reference input R_{LO} of the bar-graph IC is held at 0.5V, the zero-pressure output voltage, by tying it to reference divider R_3/R_5. Full scale is set via potentiometer R_8.

Full details of how the op-amp circuit works are given in the note. There is also a block diagram of the bar driver IC, a microcomputer bar pressure guage circuit and a three-segment pressure indicator for at-a-glance OK, high and low display.

Motorola Ltd, *European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP. Telephone 0628 585000.*

Slotted ferrites for non-contact current measurement

On their own, Hall effect sensors are not usually sensitive enough for detecting current carried in a cable. It is however possible to obtain toroidal ferrites with a radial slot cut into them, although there are few sources. Passing the conductor through such a ferrite ring and placing the detector in the slot greatly increases the flux density available to the Hall effect sensor. Winding the conductor around the core increases effectiveness even further.

Neosid's note *Slotted Ferrite Ring Cores for use with Hall Effect Devices in Current Sensing Applications* describes how to design such non-contact current sensors. As the following example illustrates, there is enough detail in the booklet to allow engineers to choose the right ferrite – selecting the right ferrite is normally a complex procedure. Tabular data for a small number of appropriate cores however makes selection a relatively simple task.

In this example, maximum anticipated current in the cable is 12A. Space available is 40mm by 40mm and the conductor diameter is 1.5mm. For the Hall-effect device, maximum flux density is 30mT (300 gauss).

Best results are obtained when the gap is as small as possible. Some sensors currently available are 1.69mm thick, so a gap of 2mm is acceptable.

For the number of turns N of the conductor around the core there is a central equation,

$$N=(B.10^3/\mu_0 I).({}_e/\mu_e)$$

where μ_0 is the permeability of free space ($4\pi.10^{-7}$), B is maximum flux density in teslas, I is maximum trip current in amps, $_e$ is effective path length of the core in millimetres and μ_e is the effective permeability of the core.

For a *631* core the following holds good:

$$_e/\mu_e=2.091$$

and the winding area W_a is $81mm^2$. As a result, the equation for the number of turns is now

$$N=(0.03/4\pi 10^{-7}x12)x2.091x10^{-3}$$

$$=1989.44x2.091x10^{-3}.$$

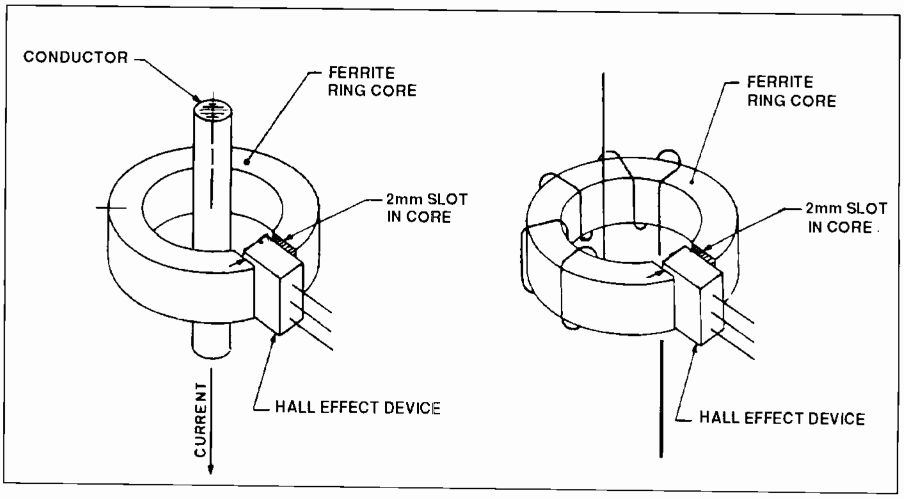
This reduces to 4.16 turns.

To calculate A_c, the number of square millimetres of copper winding area in the core,

$$A_c=(\pi d^2N)/4$$

where d is the conductor diameter millimetres. ie 1.5mm. This equates to $7.07mm^2$, which is considerably lower than the figure for the winding area W_a at $81mm^2$.

Further information in the booklet describes how the effects of rounding off the number of turns can be calculated. The basis of the central equation is also explained.



In most applications, Hall-effect sensors alone are not sensitive enough to provide a useful indication of cable current. Adding a ferrite core with a slot focuses the magnetic field produced by the current in the cable on the sensor. Winding the cable around the core increases the field intensity even further.

MMG Neosid, Icknield Way West, Letchworth, Hertfordshire SG6 4AS. Telephone 0462 481 000.

Planar power inductors – lower profile and higher

Theoretically, the physical size of DC-to-DC converter and switch-mode power supply circuits decreases proportionally with switching frequency. In the past, transistor switching time usually limited the practical operating speed of power switching circuits. Now that power transistors capable of efficient switching at well above 100kHz are common, losses from inductive components become increasingly significant.

Higher operating frequencies increase the rate of flux change in the inductor. This in turn increases eddy and hysteresis losses in the inductor core. Winding losses due to proximity and skin effect increase too. Common solutions to these problems include twisted pair windings, Litz wire and other elaborate methods.

At powers to 250W and switching frequencies to 2MHz, planar magnetics could well offer an alternative solution, as suggested in Magdev's Planar Magnetics *Technical Bulletin* TB/001.

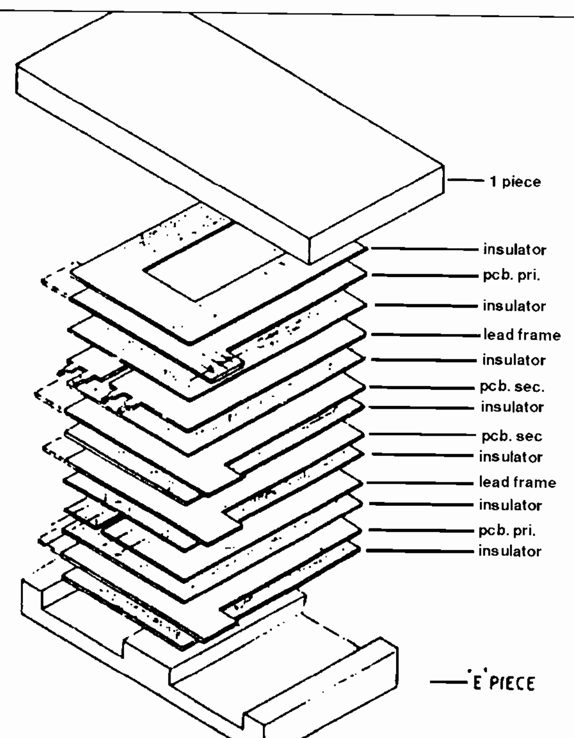
Planar transformers can have a very low profile since their windings are printed on double-sided PCB. Core material is chosen to combine high permeability with high flux density. Material for the winding PCB is selected for its dielectric permittivity to minimise high-frequency losses.

With planar technology, square-section winding geometry results in increased magnetic coupling and lower losses due to skin effect relative to conventional transformers. Leakage inductance is claimed to be low because of improved magnetic coupling and the ease of connecting windings in parallel.

Having a well defined construction, planar transformers are also said to offer consistent and easily determined inductance, interwinding capacitance, flux linkage and losses. The ability to increase operating frequency reduces winding resistance and subsequently copper losses.

Being physically a low, flat block, planar transformers offer the opportunity for mounting in direct contact with the host circuit board. This improves their ability to

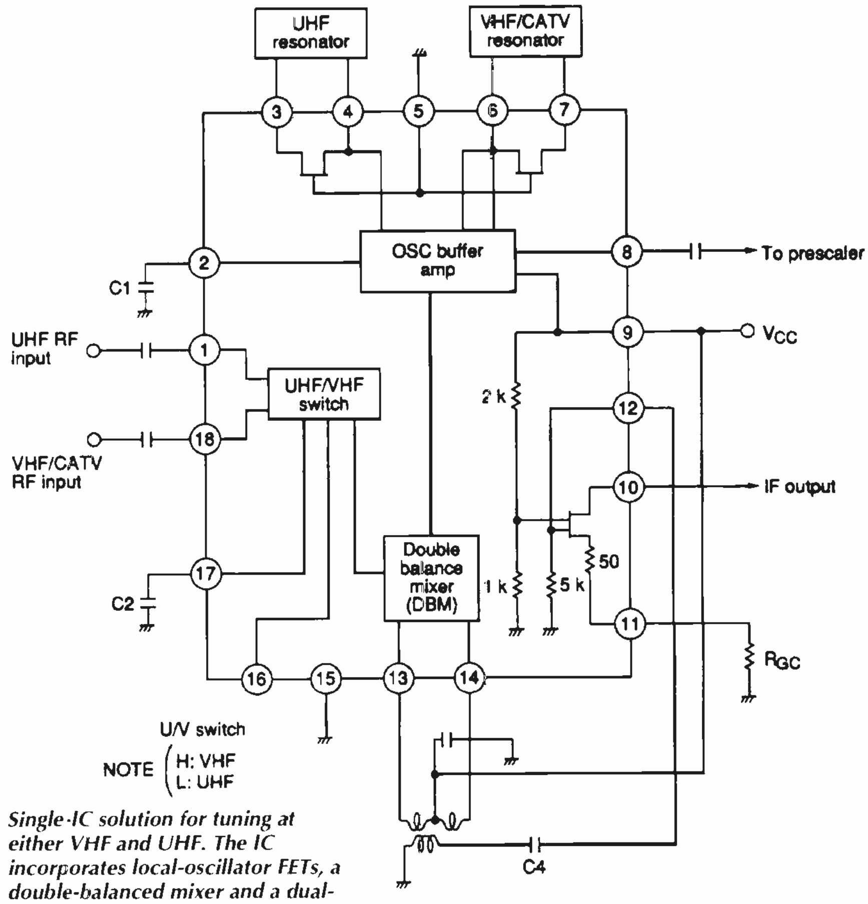
Windings in a planar transformer or inductor are spiral tracks on a PCB. Circuit board tracks can be reproduced more accurately than wire windings on a conventional magnetic core. As a result, planar transformers and inductors offer the potential for cost-effective mass production.



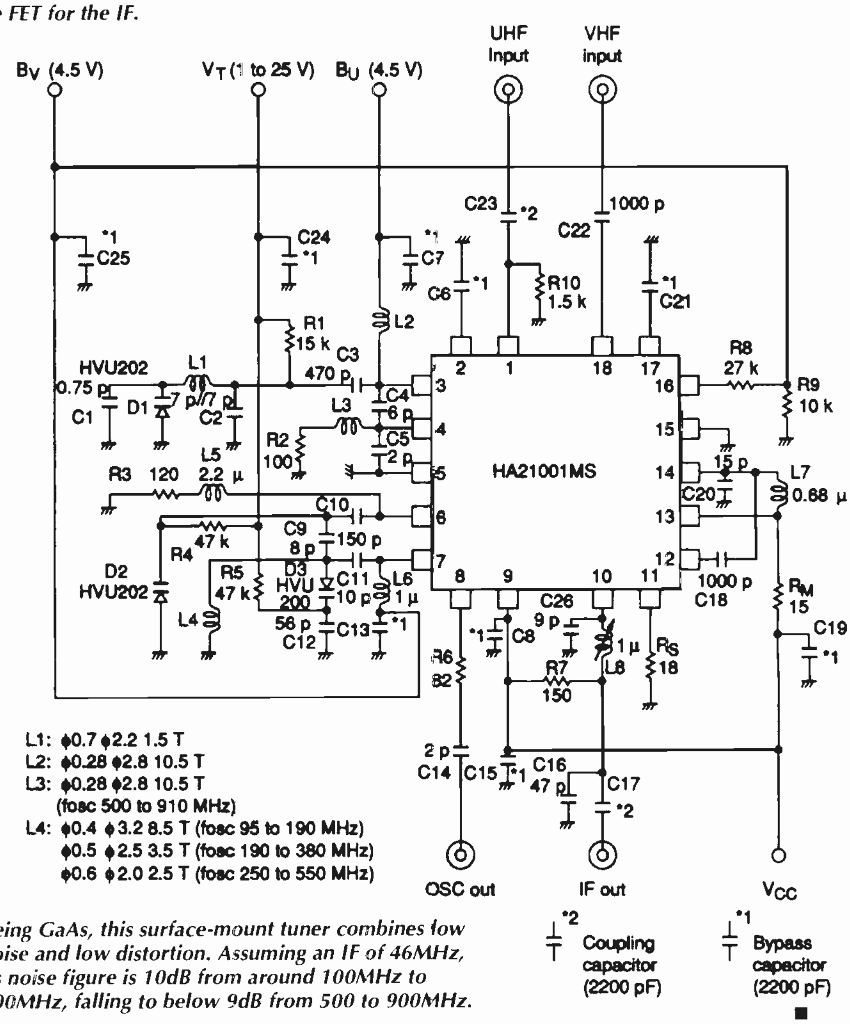
GaAs tuner for VHF and UHF

This is a complete 95 to 550MHz tuner system using a single GaAs chip, the *HA21001*. It is an evaluation circuit from Hitachi's Ultra-High Frequency Devices data book. Specifications for the IC are given but apart from a few performance curves there are no further details on this particular circuit.

***Hitachi Europe Ltd**, Electronic Components Division, Whitebrook Park, Lower Cookham Road, Maidenhead, Berkshire SL6 8YA. Telephone 0628 585000.*



Single-IC solution for tuning at either VHF and UHF. The IC incorporates local-oscillator FETs, a double-balanced mixer and a dual-gate FET for the IF.



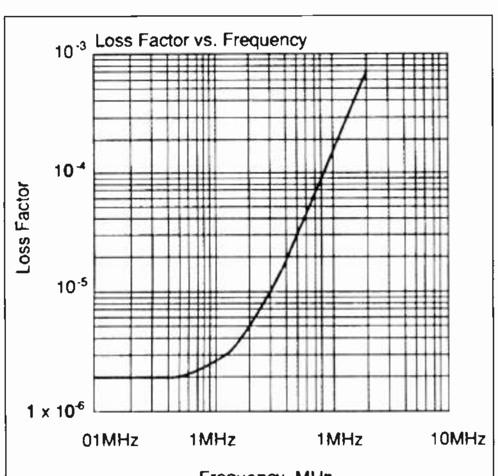
Being GaAs, this surface-mount tuner combines low noise and low distortion. Assuming an IF of 46MHz, its noise figure is 10dB from around 100MHz to 400MHz, falling to below 9dB from 500 to 900MHz.

efficiency?

withstand physical shock relative to conventional PCB-mounting inductors and transformers, which usually need raising off the PCB.

In addition to an outline on planar transformer technology, the bulletin contains technical specifications for evaluation kits that allow designers to prototype 50, 125 or 250W inductors or transformers.

***Magdev**, Unit 26, Ketley Business Park, Ketley, Telford. Telephone 0952 243822.*



Low-profile planar transformers and inductors can reduce SMPS losses at high SMPS switching frequencies. Ferrite and winding materials resulting in this graph were optimised for operating frequencies to 2MHz.

SUMMING IT UP: a guide to integration

From totalling the charge accumulating on a capacitor to analysing the waveform of signals, integration is fundamental to many aspects of electronics. In this extract from his book* Understand Electrical and Electronics Maths, *Owen Bishop shows how to go about it.

Let's look at the relationship that exists between the curves of a function and of its derivative. Take as an example: $y = x^2 + 10$. This is the upper curve in **Fig. 1**. Below it is the curve for its derivative: $dy/dx = 2x$. The derivative is also a function and we call this function u: $dy/dx = u$. There is a region ADCD beneath the graph of u, from $x_1 = 3$ to $x_2 = 5$. The aim is to calculate the area A of this region. If the graph is a straight line, as it is here, the area is easily calculated by using the formula for a trapezium:

$$A = CD \times \frac{(AD + BC)}{2} = 2 \times \frac{(6+10)}{2} = 16$$

This gives us the result we are aiming for, but we need a more general method for finding A, which works with a graph of any function. Think of the area as being divided into a large number of narrow vertical strips. In the diagram these are alternatively black and white to make them show up clearly. Given that the width of a strip is Δx (a very small distance in the x direction) and that its height is u, the area of the strip is about $u\Delta x$.

The total area of ABCD is the sum of the areas of all the strips. In maths this is written:

$$A = \sum_{x_1}^{x_2} u\Delta x \qquad (1)$$

The symbol Σ means the sum of all terms similar to the following term. The x_1 and x_2 indicate that this is to be done for the area starting at x_1 and finishing at x_2.

Now we leave the strips for the moment and look at the line EF at the top left of the figure. This is divided into line segments, alternately black and white. The segments in order from E to F correspond with the strips in order from AD to BC. The figure shows the correspondence for one of the strips. Its width is projected up on to the function curve, and then across on to EF to give the length of the segment. The length of the segment is Δy, a very small distance in the y direction. Since they correspond with the segments of varying widths and since the curve is not straight, the segments are not necessarily of equal length.

The total length of the line EF is the sum of the lengths of all the segments. This is written:

$$EF = \sum_{y_1}^{y_2} \Delta y \qquad (2)$$

At this stage there are two equations, (1) for the total area ABCD and (2) for the total length EF. The final step is to link these together. **Figure 2** shows how this is done. This is an enlargement of the part of the curve circled in **Fig. 1**.

The gradient of the curve is approximately that of the straight line NL and equals LM/NM $= \Delta y/\Delta x$. But the gradient of the curve is also given by the value of the derivative, u:

$$\Rightarrow \quad \frac{\Delta y}{\Delta x} = u \qquad \Rightarrow \quad \Delta y = u\Delta x$$

Summing both sides of this equation for all segments and strips:

$$\sum_{y_1}^{y_2} \Delta y = \sum_{x_1}^{x_2} u\Delta x$$

Looking back at the summing equations (1) and (2), we see that this equation means that the length of EF is equal to the area of ABCD. This is an extremely important result. To show that it works in this case, for an area from $x_1 = 3$ to $x_2 = 5$, we use the function $y = x^2 + 10$ to calculate the corresponding values of $y_1 = 19$ and $y_2 = 35$. The length of EF $= y_2 - y_1 = 35 - 19 = 16$. This is equal to the result calculated from the trapezium formula.

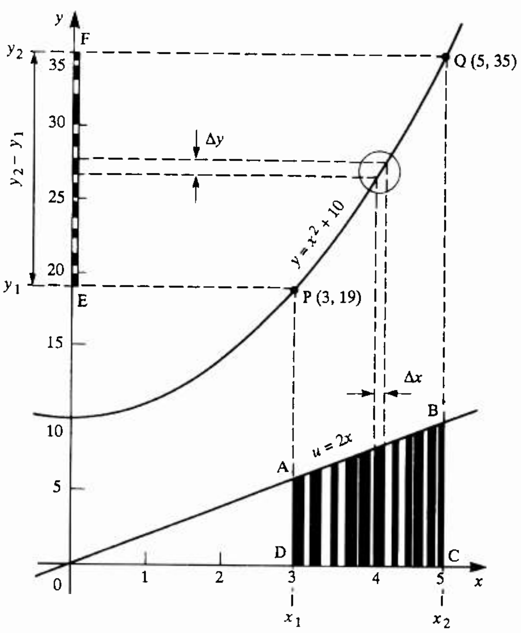


Fig. 1. The curve for y = x^2 + 10 (top)) and the curve for its derivative (bottom).

Tidying up

Two approximations were made in the above discussion. First, the area of the strips was calculated as if they were rectangular, but they are not. Secondly, the gradient of the curve in **Fig. 2** was calculated as if it is the same as the straight line LN, which it is not.

These approximations gradually disappear as Δx and Δy are made smaller and smaller. As the strips become narrower they become less and less different from rectangles. The line LN becomes less and less different from the curve. Taking the calculations to the limit, as Δx and Δy approach zero, removes the errors due to the approximation. When working at the limit, with Δx and Δy infinitely small, the Greek letter S, or sigma Σ, which stands for sum, is replaced by the long S, $\int$. Equation (2) becomes:

$$A = \int_{y_1}^{y_2} dy$$

The Δy is replaced by dy, as in differentiation, to indicate that limiting values are involved. Another word meaning almost the same as summation is integration. This is done to individual components when an integrated circuit is made. We have done it here, putting the strips together to make a whole area, or putting the segments together to make a whole line. The expression above is called an integral. It is the integral with respect to y between the limits y_1 and y_2. Here the term limit is used to mean the lower and upper values of y.

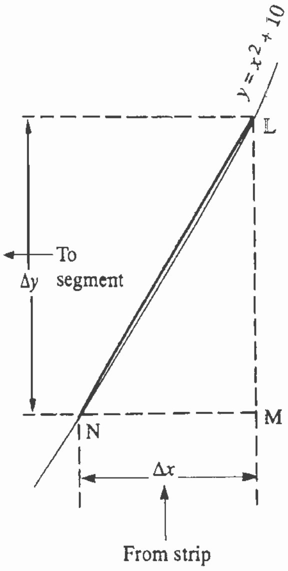


Fig. 2. Enlargement of the circled part of Fig. 1.

Working in reverse

The result of this can be expressed as follows: Given the curves of the two functions, one of which is the derivative of the other, the area under the curve of the derivative from x_1 to x_2 is given by the difference of the y coordinates $(y_2 - y_1)$ of the other curve.

In practice, this is usually looked at from another viewpoint. We are given a function and want to know the area under part of its curve. The function we are given is the derivative. Before we can calculate y_2 and y_1 we have to find a function with this derivative. In other words we have to differentiate in reverse. Integration is sometimes called anti-differentiation.

On the other hand, anti-differentiation implies that the process is one based on the reverse of differentiation. The box shows how to integrate a simple expression of the form ax^n.

If the function to be integrated has a constant as a multiplier or divisor, that constant applies to every one of the strips that are being integrated. It therefore applies to the whole area and so may be written in front of the integral sign. For example:

$$\int 5x^2 dx = 5\int x^2 dx$$

$$\int \frac{x^3}{2} dx = \frac{1}{2}\int x^3 dx$$

The rules for integration are simply the inverse of the rules for differentiation with the extra condition that we have to add a constant c, the constant of integration. Given a polynomial with a constant term not involving x, we lose that term when differentiating. For example, the following terms all differentiate to $dy/dx = 4x + 3$: $y = 2x^2 + 3x$; $y = 2x^2 + 3x + 4$; $y = 2x^2 + 3x + 7$; and $y = 2x^2 + 3x + 99$.

The constant makes no difference to the value of the derivative. When reverse differentiating $4x + 3$ there is no way of knowing whether the constant in the original function was 4, 7, 99, or any other value, or if there was a constant at all. We just call it c with the possibility that $c = 0$. Here are some examples of using the rules for integration:

Function	Integral
$2x$	$x^2 + c$
$4x^2$	$(4x^3/3) + c$
$6x^2 + 7x$	$2x^3 + (7x^2/2) + c$
$5/x^2$ $(= 5x^{-2})$	$-5/x$ $(= -5x^{-1}) + c$
$2/x^4$ $(= 2x^{-4})$	$-2/3x^3$ $[= -2x^{-3}/3] + c$
$3\sqrt{x}$ $(= 3x^{1/2})$	$2(\sqrt{x})^3$ $(= 2x^{3/2}) + c$

These examples can be checked by differentiating the functions in the right column to yield the functions in the left column. Fractional and negative indices follow the rules, the only exception being the index -1, in a term such as x^{-1} $(= 1/x)$. Applying the rules, the new index is 0, and the term has to be divided by zero, giving an indeterminate result. The function which has $1/x$ as its derivative is $\ln x$. Therefore the integral of $1/x$ is $\ln x + c$.

Standard integrals

The box lists common functions and their integrals. When integrating a function, examine it to see if it is a standard integral. The examples above are all variations of the standard form. The terms of a polynomial are integrated individually, as in an examples above. If an expression (or integrand, as we call a function that is to be integrated) is not standard, it may be possible to make it standard before integrating it. For example, take $\int x(2x - 6)dx$. The integrand is the product of the two functions. If the expression is multiplied out, we obtain a polynomial, the terms of which can be integrated individually as standard integrals:

$$\int x(2x-6)dx = \int (2x^2 - 6x)dx = \frac{2x^3}{3} - 3x^2 + c$$

Rules for integrating simple functions

Provided that the index of x is not -1: Add 1 to the index, divide the term by the new index, and add c, the constant of integration. Summarising:

$$y = ax^n \Rightarrow \int y dx = \frac{ax^{n+1}}{n+1} + c \quad (n \neq -1)$$

Standard integrals

(add c to all integrals)

Funct.	Integral	Example Funct.	Example Integral
ax^n	$(ax^{n+1})/(n+1)$	$3x^4$	$(3x^5)/5$
a/x	$a\ln x$	$5/x$	$5\ln x$
$\sin ax$	$(-\cos ax)/a$	$\sin 5x$	$(-\cos 5x)/5$
$\cos ax$	$(\sin ax)/a$	$\cos 3x$	$(\sin 3x)/3$
e^{ax}	e^{ax}/a	e^{2x}	$e^{2x}/2$

Integrating with time

A constant current I flows into a capacitor, capacitance C, for a time t. Assuming that the capacitor has no charge when timing begins, the charge q stored in the capacitor is given by $q = It$.

In words, the charge is the product of the current and the length of time for which it has been flowing. We can represent this as a graph (**Fig. 3a**) in which charge, being the product of current and time, is represented by the area beneath the curve. This idea can be extended to a varying current i since, for any short instant of time Δt, the accumulating charge Δq equals $i\Delta t$ (**Fig. 3b**); compare with the strips of **Fig. 1**.

Suppose that we pass a current which varies according to a given function in which t is the independent variable. The area under the current-time graph represents the accumulated charge. This area is found by evaluating the definite integral of the function for the period of time concerned.

For example, a capacitor begins uncharged, but is then charged by a current i for which $i = \sin 20t$. How much charge accumulates on the capacitor in a period of 1.2s? Integrate the function i with respect to t from $t_1 = 0$ to $t_2 = 1.2$ (4dp):

$$q = \int_{t_1}^{t_2} \sin 20t\,dt = \left[\frac{-\cos 20t}{20}\right]_{t_1}^{t_2}$$

$$= \left[\frac{-\cos(20 \times 1.2)}{20}\right] - \left[\frac{-\cos 0}{20}\right]$$

$$= -0.0212 - (-0.0500) = 0.0288$$

The charge is 0.0288C. Note that the angle $20t$ after 1.2s is 24rad. This is $24/2\pi = 3.82$ cycles. The capacitor is subject to charging and discharging three times, finishing with 0.0288C when 0.82 of the way through the fourth cycle.

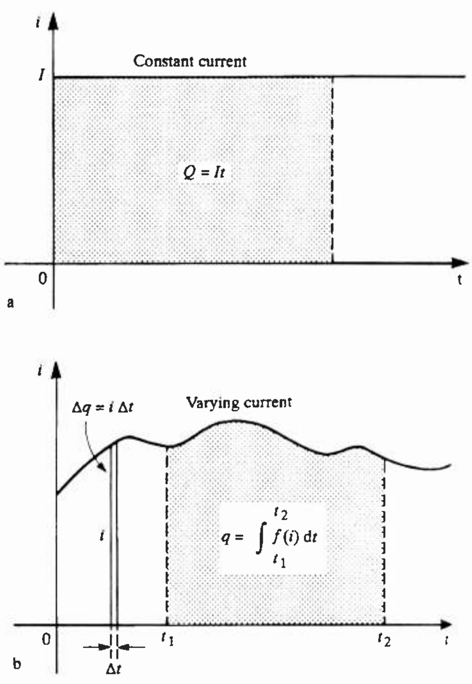


Fig. 3. Graph showing constant current (top) and varying current (bottom).

The integral of a quotient may sometimes be found by first dividing out the integrand:

$$\int \frac{x^3+1}{x^2}dx = \int\left(x + \frac{1}{x^2}\right)dx = \frac{x^2}{2} - \frac{1}{x} + c$$

Not all integrals lend themselves to this approach. Other methods are described later.

Dealing with the constant of integration

In the example above, the integral has had no limits attached to it. Such an integral is called an indefinite integral. It is evaluated by substituting a given value of x, or other variable that the integral is in respect to. But there is still the constant of integration. To find this, more information is needed such as the value of the integral for a given value of x. For example, let us evaluate the integral of $4x + 3$, given that, when $x = 2$, the value of the integral is 10:

$$\int(4x+3)dx = 2x^2 + 3x + c$$

When $x = 2$:

$$\int(4x+3)dx = 2 \times 2^2 + 3 \times 2 + c = 14 + c$$

Put this equal to the given value so $14 + c = 10$, giving $c = -4$. The integral is $2x^2 + 3x - 4$

In the earlier discussion of integration, the area under the curve (**Fig. 1**) was to be evaluated between x_1 and x_2. Such an integral with limits is called a definite integral:

$$A = \int_{x_1}^{x_2} 2x\,dx = \left[x^2 + c\right]_{x_1}^{x_2}$$

The integral is written in square brackets with the limits outside the right bracket. Evaluating the contents for $x = x_1$ and $x = x_2$ gives y_1 and y_2; their difference, $y_2 - y_1$, is the area:

$$A = \left[x_2^2 + c\right] - \left[x_1^2 + c\right] = x_2^2 - x_1^2$$

Given $x_1 = 3$ and $x_2 = 5$, then $A = 5^2 - 3^2 = 25 - 9 = 16$.

Note that c appears in both brackets and so cancels out. Consequently, when we are evaluating definite integrals, the constant of integration can be ignored. In **Fig. 1** it can be seen that the value of c is 10, this being the y intercept of the curve $y = x^2 + 10$. However, it does not matter what it is. Giving c a different value merely shifts the parabola vertically up or down the page without affecting the length of EF.

When integrating $1/x$, the constant of integration can be expressed differently. Normally we would write $\int 1/x = \ln x + c$. Using an alternative expression, we write $\int 1/x = \ln kx$. The constant, now called k, is included in the logarithm. Addition of logarithms is equivalent to the multiplication of ordinary numbers: $\ln kx = \ln k + \ln x$. Differentiating:

$$\frac{d}{dx}(\ln kx) = \frac{d}{dx}(\ln k + \ln x) = 0 + \frac{1}{x} = \frac{1}{x}$$

The integral of $1/x$ can be considered to be $\ln kx$. This is useful in differential equations.

Integrating ratios

If the integrand is in the form of a quotient, it may be possible to integrate it after dividing out the quotient. For example, find:

$$\int \frac{2x+3}{x+2}dx$$

Divide $(2x + 3)$ by $(x + 2)$:

$$\begin{array}{r} 2 \\ x+2\overline{)2x+3} \\ \underline{2x+4} \\ -1 \end{array}$$

$$\frac{2x+3}{x+2} = 2 - \frac{1}{x+2}$$

$$\int\left(2 - \frac{1}{x+2}\right)dx = 2x - \ln(x+2) + c$$

Note that the logarithm of a negative number is indeterminate. If the expression $(x + 2)$ has a negative value, the logarithm cannot be found. For this reason it is the absolute value of the expression which must be used when evaluating the logarithm. The result of the integration should be written: $2x - \ln|x + 2| + c$.

Integration by substitution

Substitution should be tried when an integrand is not standard, and can't be simplified or multiplied out to make it standard. The idea is to put everything in terms of a different variable, to make it easier. For example finding $\int(4x - 3)^3dx$. This could be integrated by expanding it and then integrating the terms individually, but we will use substitution instead. The variable of the new integral is to be u. First we replace the integrand by u, by making:

$$u = 4x - 3 \qquad (3)$$

The choice of what to make u is straightforward in this example, though it is not always as easy. Usually it is best to try substituting for the most complicated part of the integrand and, if this fails to give a solution, to try other parts. The original integral also has dx in it, so we must find a substitute for this in terms of u. Differentiating equation (3) gives du/dx = 4.

Although dy/dx (or du/dx in this case) is a symbol expressing limiting rates of change, implying that it must always be written as a whole, we find in practice that we can separate the dx from the du, treating them as individual quantities. This is why we can change the subject of the equation to give dx = du/4. Now we are ready to assemble the new integral by substituting the equivalents of $(4x-3)^3$ and dx:

$$\int(4x-3)^3\mathrm{d}x=\int u^3\frac{\mathrm{d}u}{4}=\frac{1}{4}\int u^3\mathrm{d}u=\frac{u^4}{4\times4}+c=\frac{u^4}{16}+c$$

This gives the integral in terms of u but we need it in terms of the original variable x. Use equation (3) to replace u by $(4x-3)$:

$$\int(4x-3)^3\mathrm{d}x=\frac{(4x-3)^4+c}{16}$$

This integral has the form of $ax+b$, with $a=4$ and $b=-3$. The box shows a general rule which the result above confirms. This rule applies to any of the standard forms. Examples are:

$$\int\sin(3x+2)\mathrm{d}x=-\frac{1}{3}\cos(3x+2)+c$$

$$\int e^{5x-2}\mathrm{d}x=\frac{1}{5}e^{5x-2}+c$$

$$\int\frac{1}{6x+2}\mathrm{d}x=\frac{1}{6}\ln|6x+2|+c$$

More examples of substitution

The next example is slightly different and involves finding $\int x(2x+3)^4\mathrm{d}x$. We have two functions in the integrand, x and $(2x+3)^4$. As stated above, the best approach is to try putting u equal to the more complicated function:

$$u=2x+3 \qquad (4)$$

Find a substitute for dx: du/dx = 2, which gives dx = du/2. In this example we also need a substitute for the first function of the integrand, the x. This can be done by changing the subject of equation (4) to give $x=(u-3)/2$. Now assemble the new integrand by substituting the equivalents of x, $(2x+3)^4$, and dx:

$$\int x(2x+3)^4\mathrm{d}x=\int\left(\frac{u-3}{2}\right)u^4\frac{\mathrm{d}u}{2}=\frac{1}{4}\int(u-3)u^4\mathrm{d}u$$

Multiplying out:

$$=\frac{1}{4}\int(u^5-3u^4)\mathrm{d}u=\frac{1}{4}\left(\frac{u^6}{6}-\frac{3u^5}{5}\right)+c=\frac{u^6}{24}-\frac{3u^5}{20}+c$$

Replacing terms in u with their equivalents in x:

$$=\frac{(2x+3)^6}{24}-\frac{3(2x+3)^5}{20}+c$$

Now it is a matter of simplifying the expression, starting by taking out $(2x+3)^5$:

$$=(2x+3)^5\left(\frac{2x+3}{24}-\frac{3}{20}\right)+c$$

Add the fractions, over the HCF of their denominators, 120:

$$=(2x+3)^5\left(\frac{5(2x+3)-18}{120}\right)+c=\frac{(2x+3)^5(10x-3)}{120}+c$$

Integrating by parts

This is another technique to be tried when the integrand is not standard. The technique is based on the rule for differentiating a product. Under this rule, if the function to be differentiated is the product of u and v, both of which are functions of x, then:

$$\frac{\mathrm{d}}{\mathrm{d}x}(uv)=\left(\frac{\mathrm{d}u}{\mathrm{d}x}\times v\right)+\left(\frac{\mathrm{d}v}{\mathrm{d}x}\times u\right)$$

Reversing the order of the factors on the right makes no difference to the values of the terms:

$$\frac{\mathrm{d}}{\mathrm{d}x}(uv)=\left(v\times\frac{\mathrm{d}u}{\mathrm{d}x}\right)+\left(u\times\frac{\mathrm{d}v}{\mathrm{d}x}\right)$$

Integrating by substitution

Put u equal to (one of) the function(s) of x. Find du/dx or dx/du (whichever is easier), then change subject to get substitute for du. If necessary find a substitute for other term in x.
Assemble the new integral by substitution and simplify if possible. Integrate.
Replace u with original function of x.
Simplify if possible.

Putting (ax + b) into the standard form

Instead of x, write $ax+b$ in the standard integral. Multiply the result by $1/a$.

Changing the subject:

$$u \times \frac{dv}{dx} = \frac{d}{dx}(uv) - \left(v \times \frac{du}{dx}\right)$$

Integrating both sides:

$$\int u \times \frac{dv}{dx}dx = \int \frac{d(uv)}{dx}dx - \int v \times \frac{du}{dx}dx$$

But:

$$\int \frac{d(uv)}{dx}dx = uv + c$$

So:

$$\int u \times \frac{dv}{dx}dx = uv - \int v \times \frac{du}{dx}dx$$

Where is c, the constant of integration obtained when we integrate uv? This is amalgamated with the c which we will obtain when integrating v. We have to consider the integrand as being made up of two parts, one corresponding to u and the other to dv/dx. For example, let us find $\int x\cos x dx$. The integrand has two parts, x and $\cos x$. Make x equal to u, and $\cos x$ equal to dv/dx. As well as u and dv/dx, the equation contains du/dx and v, which we must calculate. If u equals x, then du/dx equals 1. If dv/dx equals $\cos x$, then v equals $\sin x$ (integrating or anti-differentiating with respect to x). Now substitute these values in the equation:

$$\int x\cos x dx = \int u\frac{dv}{dx}dx = uv - \int v\frac{du}{dx}dx$$

$$= x\sin x - \int \sin x dx = x\sin x - \cos x + c$$

Another example is to find $\int x^2 \ln x dx$. If u equals x^2, then du/dx equals $2x$. If dv/dx equals $\ln x$, there are problems; this is not a standard form which can be integrated easily. Trying the alternative approach, if u equals $\ln x$, then du/dx equals $1/x$. If dv/dx equals x^2, then v equals $x^3/3$ (a standard integral). Substituting:

$$\int x^2 \ln x dx = \int u\frac{dv}{dx}dx = uv - \int v\frac{du}{dx}dx$$

$$= \frac{x^3}{3}\ln x - \int \frac{x^3}{3} \times \frac{1}{x}dx = \frac{x^3}{3}\ln x - \frac{x^3}{9}$$

A third example is to find $(1/L)\int mte^{Rt/L}dt$, where L, m, and R are constants. First bring m before the integral sign, then integrate by parts with u equal to t, du/dt equal to 1, dv/dt equal to $e^{Rt/L}$, and v equal to $(L/R)e^{Rt/L}$. Substituting:

$$\frac{m}{L}\int te^{\frac{Rt}{L}}dt = \frac{m}{L}\left(t\frac{L}{R}e^{\frac{Rt}{L}} - \int \frac{L}{R}e^{\frac{Rt}{L}}dt\right) = \frac{m}{L}\left(t\frac{L}{R}e^{\frac{Rt}{L}} - \frac{L}{R} \times \frac{L}{R}e^{\frac{Rt}{L}}\right)$$

$$= \frac{m}{L}\left(t\frac{L}{R}e^{\frac{Rt}{L}} - \frac{L^2}{R^2}e^{\frac{Rt}{L}}\right) = \frac{m}{R^2}e^{\frac{Rt}{L}}(Rt - L)$$

Integration and averages

Currents and voltages often vary with time. The voltage v in **Fig. 4a** falls steadily with time. At t_1 the voltage is v_1 and at t_2 it is v_2. Since v is falling at an average rate we can say that the average voltage v_{av} is $(v_1 + v_2)/2$. The area under the graph of **Fig. 4a** from t_1 to t_2 is the same as the area of ABDC of **Fig. 4b**; the shaded areas above and below AB being exactly equal. The area of a rectangle is its height multiplied by its base. In the case of ABDC this area equals $v_{av}(t_2 - t_1)$. Changing the subject gives v_{av} equal to the area divided by $(t_2 - t_1)$.

To average a varying voltage we have to find the area under the graph and divide by the length of the base. In **Fig. 4,** finding the area is a matter of geometry but, if the line is more complex, we can use integration. The curve in **Fig. 5**, from its shape, must represent a complicated function. Without saying precisely what the function is, we can say that v is a function of time, or $v = f(t)$. It is possible to draw a rectangle having the same area as the area under the graph between t_1 and t_2. It is easy to calculate $(t_2 - t_1)$, so the main problem in calculating v_{av} is to find the area. The area is the definite integral of $v = f(t)$ from t_1 to t_2:

$$\text{area} = \int_{t_1}^{t_2} v dt$$

Putting this into the equation above we arrive at an equation for v_{av}:

$$v_{av} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} v dt$$

For example, given the function $v = t^2 - 5$, calculate the mean value of v over the range $t_1 = 3$ to $t_2 = 5$. **Figure 6** shows the curve and the area beneath it. From the equation above:

$$v_{av} = \frac{1}{5-3}\int_3^5 (t^2 - 5)dt = \frac{1}{2}\left[\frac{t^3}{3} - 5t\right]_3^5$$

$$= \frac{1}{2}\left[\frac{125}{3} - 25\right] - \left[\frac{27}{3} - 15\right] = 11.33 \text{ (4sf)}$$

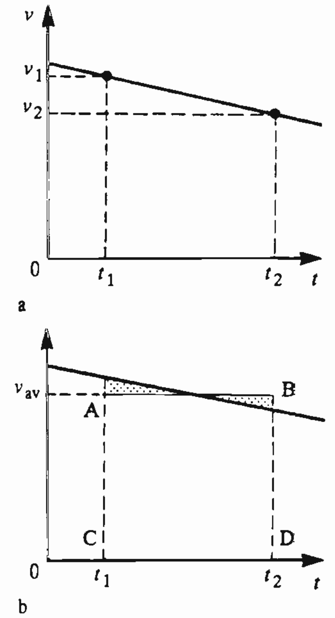


Fig. 4. Graphs showing voltage varying with time.

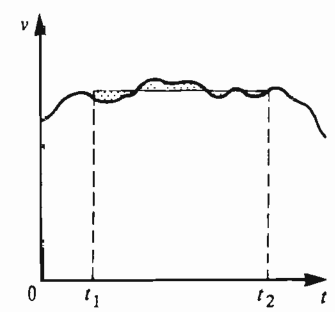


Fig. 5. Curve of a complicated function.

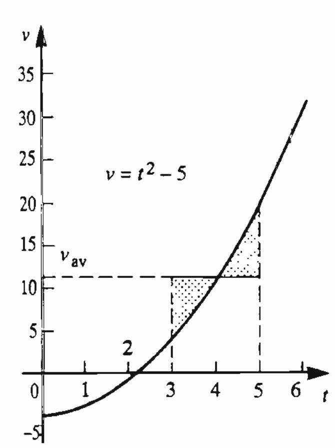


Fig. 6. Curve for $v = t^2 - 5$.

The mean can be taken over part of the curve where v is negative. For example, integrating from $t_1 = 0$ to $t_2 = 5$ gives v_{av} equal to (1/5)(50/3) = 3.33 (3 sf). Although the range of t is greater than before, v_{av} is less because it includes values of v which are negative. In terms of area, the area below the x axis is negative area.

Integrating sine waves

The equation for the average value of v can be applied when v is a trig function. The simplest case is $v = \sin t$. This is the equation for a sine wave in which amplitude $A = 1$ and angular velocity $\omega = 1$. The period of one cycle is $P = 2\pi/\omega = 2\pi$. This corresponds to a frequency of $1/2\pi = 0.16$Hz. We will find the average value of v during one cycle. Applying the equation:

$$v_{av} = \frac{1}{2\pi}\int_0^{2\pi}\sin t\,dt = \frac{1}{2\pi}[-\cos t]_0^{2\pi} = \frac{1}{2\pi}[-\cos 2\pi + \cos 0]$$
$$= \frac{1}{2\pi}[-1+1] = \frac{1}{2\pi}[0] = 0$$

The average value is zero because the positive values of v from 0 to π are exactly cancelled out by the negative values of v from π to 2π. This is the same situation as we mentioned in connection with the curve of **Fig. 6**.

For comparison, calculate the value of v for a half cycle, from $t_1 = 0$ to $t_2 = \pi$. Incidentally, all the examples we have looked at relate to varying voltage but they could equally well deal with varying current and its average i_{av}. For a sine wave voltage during a half cycle:

$$v_{av} = \frac{1}{\pi}[-\cos t]_0^{\pi} = \frac{1}{\pi}[-\cos\pi + \cos 0] = \frac{1}{\pi}[1+1] = \frac{2}{\pi}$$

The result applies when amplitude $A = 1$. If we include A in the equation, it becomes $v = A\sin t$. Integrating this from 0 to π gives $v_{av} = 2A/\pi$. We can adapt the equation further to cover other frequencies, when $\omega \neq 1$. The function then becomes $v = A\sin\omega t$. Integrating:

$$v_{av} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} A\sin\omega t\,dt$$
$$\Rightarrow v_{av} = \frac{A}{(t_2 - t_1)\omega}[-\cos\omega t]_{t_1}^{t_2}$$

Calculate the average voltage when $v = 24\sin 50\pi t$, for period $t_1 = 0$ to $t_2 = 0.01$s. Examining the function, we find that $A = 24$ and $\omega = 50\pi$. Applying the equation for v_{av}:

$$v_{av} = \frac{24}{0.01\times 50\pi}\{[-\cos(50\pi\times 0.01)] - [-\cos 0]\} = 15.28$$

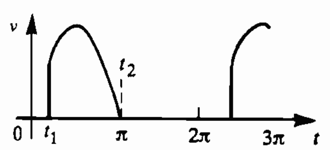


Fig. 7. Modified sine wave as may be found in the voltage output of a thyristor controlled power suppply.

The curve in **Fig. 7** might be the voltage output of a thyristor controlled power supply. To simplify the calculation, let $A = 1$ and $\omega = 1$. Now we have to integrate from $t_1 = \theta$ to $t_2 = \pi$:

$$v_{av} = \frac{1}{\pi}[-\cos t]_{\theta}^{\pi} = \frac{1}{\pi}[-\cos\pi + \cos\theta] = \frac{1}{\pi}(1+\cos\theta)$$

The result shows, if the voltage is switched on when $\theta = 0$, the average is 2π, as found previously. If θ is increased gradually from 0 to π, the average value gradually falls to zero.

Root mean square (rms) values

The root mean square of an alternating voltage or current is the square root of the mean of the squares of the instantaneous value of the voltage or current. Because it is equal to the steady DC voltage or current that dissipates the same power in a resistance, it is an important quantity in electronics. The definition sounds involved but the calculation is similar to the calculation of the average value given above, except that we square the function before we integrate it, then take the square root of the result. In symbols:

$$v_{rms} = \sqrt{\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} v^2\,dt}$$

Compare this with the equation given earlier for v_{av}. In this expression, v is any function of t, but most practical calculations are concerned with sine waves. For a sine wave of amplitude A and angular frequency ω, $v = A\sin\omega t$. To obtain an rms value we have to integrate v^2, but $v^2 = A^2\sin^2\omega t$. This means we have to integrate $\sin^2\omega t$ using the trig identity $2\sin^2\omega t \equiv 1 - \cos 2\omega t$. Without going into details, the integration yields this result:

$$v_{rms} = \sqrt{\frac{A^2}{2(t_2 - t_1)}\left[t - \frac{\sin 2\omega t}{2\omega}\right]_{t_1}^{t_2}} \qquad (5)$$

Over a whole cycle, from $t_1 = 0$ to $t_2 = 2\pi$, we find:

$$v_{rms} = \sqrt{\frac{A^2}{4\pi}\{[2\pi - 0] - [0 - 0]\}} = \sqrt{\frac{A^2}{2}} = \frac{A}{\sqrt{2}}$$

This is often expressed to 3sf in the equivalent form $v_{rms} = 0.707A$. By integrating over part of the cycle, equation (5) is used for finding v_{rms} for waveforms such as those of **Fig. 7**. ■

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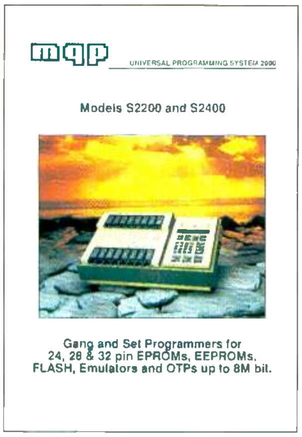

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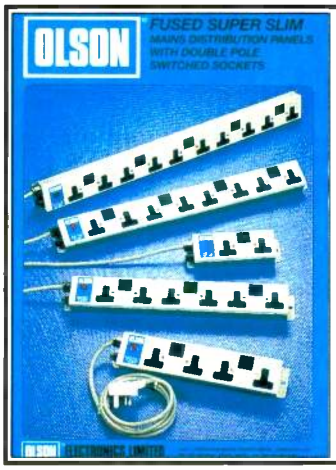

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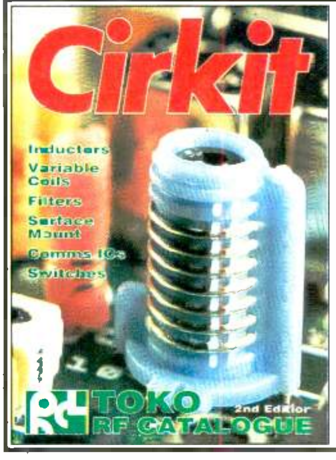

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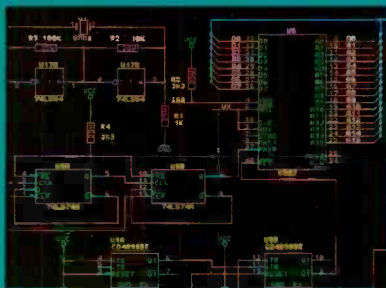

Your design ideas are quickly captured using the ULTIcap schematic design Tool. ULTIcap uses REAL-TIME checks to prevent logic errors. Schematic editing is painless; simply click your start and end points and ULTIcap automatically wires them for you. ULTIcap's auto snap to pin and auto junction features ensure your netlist is complete, thereby relieving you of tedious netlist checking.

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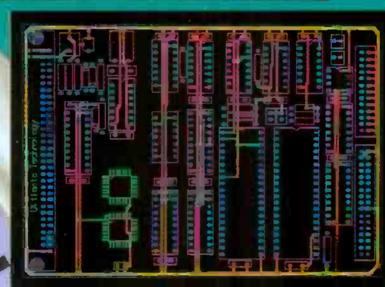

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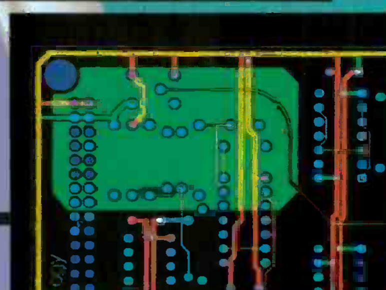

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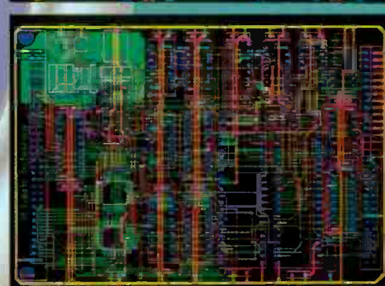

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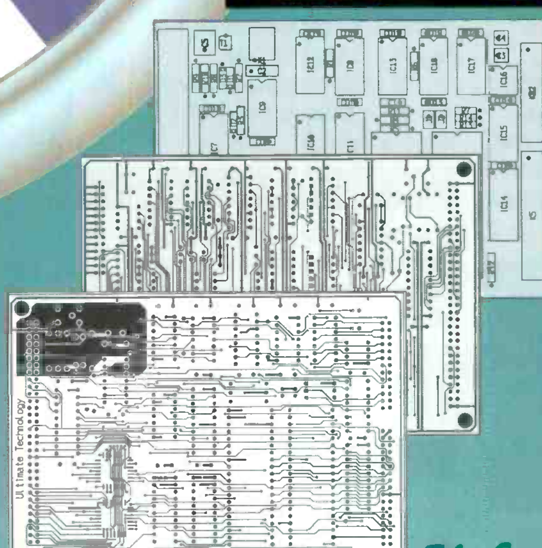

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