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DESIGN

Linsley Hood on pre-amplifiers

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ISIS: intelligent schematic capture?

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SAFETY IN NUMBERS?

06

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```
SECTOR 00-0000,1FFF
DATAMAN S3 HELP 2.4
>CONFIG
13 2764-FAST  21.0V
FILE: INTEL
>LOAD 2764-FAST
SECTOR 00-0000,1FFF
>SEEK 0000,1FFF
 45,53,43,XX,XX,XX
0E26,
>EDIT 0E20
0E20  4E 54 3D 4F 4E 20 45 53   NT=ON ES
0E28  43 3D 4F 46 C6 44 5E F3   C=OFFD^s
0E30  99 77 0D 08 18 05 EA 00   .w....j.
0E38  A1 20 EA 64 DA 20 F9 20   ! jdZ y(
0E40  DA 48 8E 28 96 38 EA 48   JH.(.8JH
>COMPARE 2764-FAST
SECTOR 00-0000,1FFF
SAME
>EMULATE 2764
_
```

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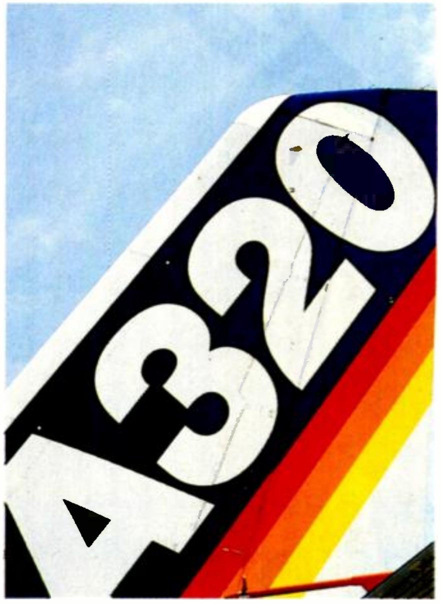

All new civil passenger aircraft will require electronics to stay in the air. Failure of these primary control systems will be life threatening. Have the plane makers developed a truly failsafe technology? David Learmount of *Flight International* reports.

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Offensive marketing

Mrs Thatcher doesn't seem to be getting many things right at present, although the central tenet of Thatcherism – that free enterprise is a solution, not a problem – holds good. It is a shame that she hasn't applied this principle to the electronics industry.

For years, our industry has been crippled by the imperative for military development and, until recent times, government spending power in telecomms. Concepts such as industry infrastructure, consumer electronics, marketing, robotics and electronics for a post-industrial society never really entered into the equation. Billions of pounds destined for the military have distorted the UK electronics industry grossly, and left it ill-equipped to meet the free market challenge of a European common market.

There is much moaning about Japanese trade aggression. Those who indulge are really saying, "Why can't we make things that ordinary people and businesses want to buy in the same way that Japanese industry does?" Success in the nineties will depend on our industry believing this and acting upon it just as the Japanese believed and acted in earlier times. The erection or maintenance of tariff barriers is no substitute for marketing awareness. To complain about the numbers of Japanese cars, video recorders, dynamic memories or whatever coming into the country is simply to say, "Why can't we design and build them in volume, and at a price which people are willing to pay?"

The opening up of Eastern Europe will result in a new, free market for the things which we currently hold so dear in the West: videos, personal computers, efficient factories and MacDonald's hamburgers. Notice the absence of military supplies from the shopping list.

Although nobody welcomes Bruxelles bureaucracy, a greater pan-european commitment might create a co-ordinated market for electronics products, replacing the partisan and useless defence interests of individual member countries. The marketing departments of the Japanese corporations are currently better placed to serve the new consumers of Eastern Europe than our industries, despite our geographical advantage.

We don't really have the option. We are now in the Common Market, for better, for worse, without alternative. It makes sense to embrace its opportunities and attenuate the penalties from within. Military technology is more political than practical and national politics doesn't have much say in Europe. The electronics industry must be led by marketing departments, not politicians working through the military establishment.

Frank Ogden

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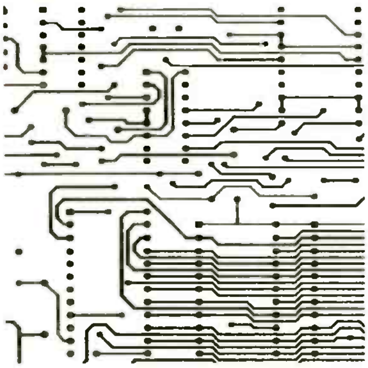

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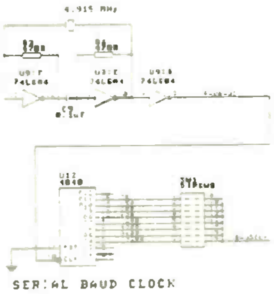

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Practical solid-state visible laser

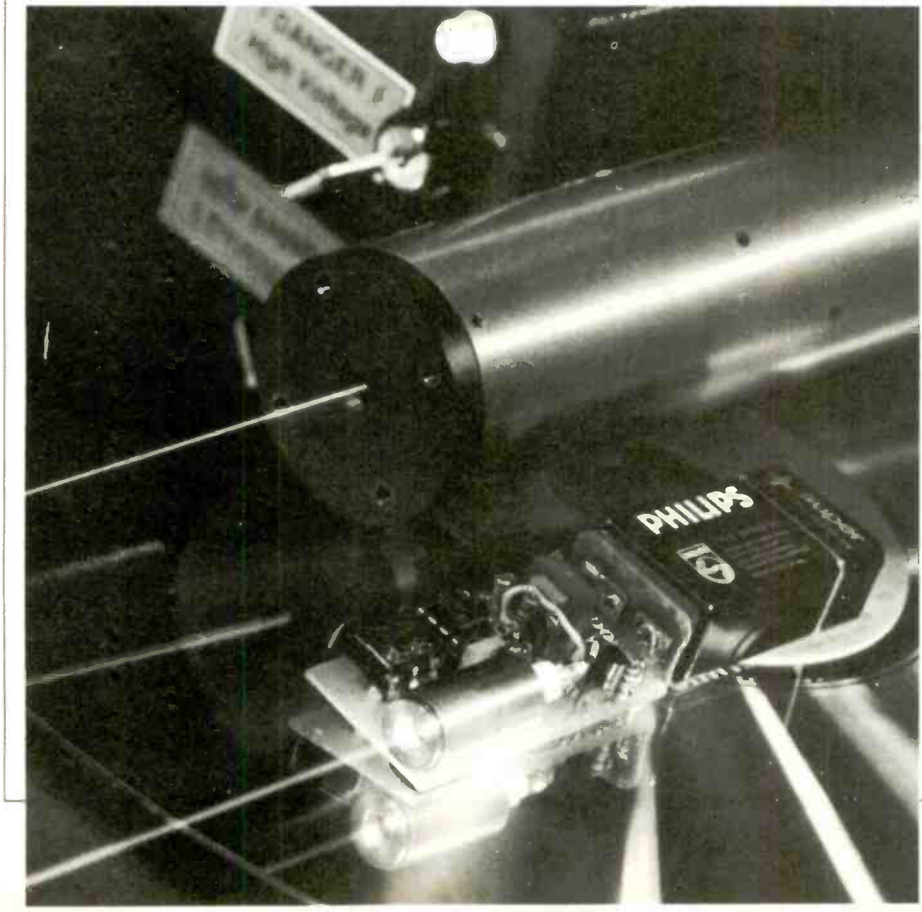
Staff at the Philips Research Laboratories in Eindhoven have, for the first time, succeeded in creating a semiconductor laser for practical use which emits radiation with the same light-red colour as the widely-used helium/neon gas laser (a wavelength of 633mm).

At present, applications for semiconductor lasers include glass-fibre communications and optical recording and playback, such as the reading of CDs. The semiconductor lasers produced so far emit light with a "colour" between infrared and barely-visible dark red (670 nm). The new laser is the first semiconductor laser to emit light which is clearly visible to the human eye. The wavelength is exactly the same as that of the gas laser, which is used widely in laser printers and barcode readers. Previously, this wavelength could not be achieved with semiconductor lasers for practical use, since it resulted in excessive losses in the material. Now, Philips has succeeded in reducing these losses.

Replacing the helium/neon laser with the new semiconductor laser is an attractive prospect, on account of the very small dimensions (the laser length has been reduced from 300mm to 0.3mm), the high operational safety, and high efficiency (which means that a low-voltage source is sufficient to power the laser).

The new laser is based on extremely thin layers of gallium indium phosphide, which are grown from the gaseous state on a gallium arsenide substrate, giving them a perfect structure. The new laser differs from dark-red-emitting semiconductor lasers in the thickness of these layers. Each layer is ten thousand times thinner than a human hair (the thickness equals a few nanometres, or a few tens of atoms). Philips claims to be the first to have succeeded in using such thin layers in a completely controlled manner and in understanding their behaviour, which has been of vital importance in achieving its results.

Philips's semiconductor laser, its control circuit and PSU in the foreground, compared with a helium-neon laser of the same wavelength and its ancillaries behind it.



Seeing smaller with squeezed light

Optical microscopes are limited to a magnification of around 2000 times, not because of defective lenses, but because objects smaller than the wavelength of light must, by definition, be transparent. So if you want to 'see' tinier things it's necessary to use a viewing medium of shorter wavelength – hence the development of the electron microscope. The only trouble is that specimens are frequently damaged by aggressive preparation techniques or by the high vacuum needed by the system.

Recent research is now suggesting, however, that ordinary light may not be subject to quite the limitations that were once thought. It's all based on the experimental observation that if light is forced through a hole smaller than its wavelength, then the photons appear to get smaller, at least for a short distance. It's as if they were made of rubber!

In practice, any object placed near the hole becomes visible in much finer detail because it's illuminated with what amount to smaller than normal photons. The only trouble is that such a system is hugely inefficient because photons strongly resist being squeezed.

A recent paper by Raoul Kopelman of the University of Michigan and a team at the Hebrew University in Jerusalem (*Science* vol. 247, p.59) has shown an alternative way of generating 'squeezed' light. Using a powerful argon ion laser, they illuminate tiny crystals of anthracene which in turn generate molecular disturbances known as excitons. These excitons collect at certain spots on the crystal surface, where they interact and decay into a sort of visible blue fluorescence. What's unusual, though, is that this visible light emerges from points that are smaller than its own wavelength.

Unlike normal light, this point-source emission will readily pass through a tiny hole – in this case a 100nm diameter pipette – and at the same time provide the researchers with a practical source of reasonably powerful 'squeezed' light.

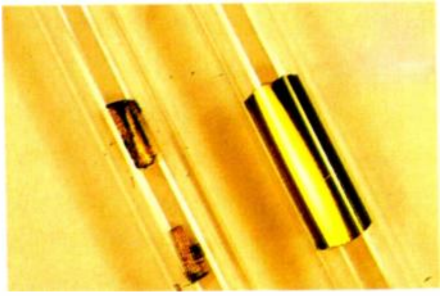
How to use this strange emission for microscopy is quite another matter, however.

The gold that no-one wants

Imagine a polymer that has a dull golden sheen, conducts electricity almost as well as metals and will superconduct at suitably low temperatures. You'd imagine industrialists would be falling over each other to find uses for it. Yet a provisional patent lodged by Arthur Banister of Durham University has lapsed and no British company is willing to exploit it further.

Poly(sulphur nitride) — the brackets having the same significance as in mathematics — is not a recent discovery, having been synthesised in British chemistry laboratories as long ago as 1910.

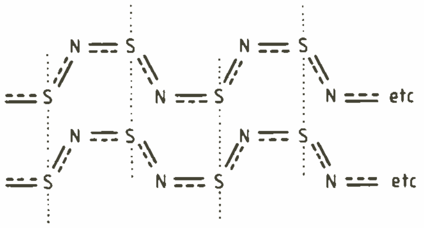
Later researchers, notably at IBM, worked out its electrical properties in some detail, soon realising that poly(sulphur nitride) had the highest intrinsic (undoped) conductivity of any known polymer. Crystals approach a conductivity of 1000 S/cm, which increases tenfold under pressure, reaching a level comparable to that of mercury. So, you might ask, what's the snag?



A coating of $(SN)_x$ on glass (left) and crystals of $(SN)_x$

The snag lies in what until now was the only known method of chemical synthesis, one that almost guaranteed regular loss of the laboratory windows!

Previously poly(sulphur nitride) was manufactured from tetrasulphur tetranitride (S_4N_4), a dangerously explosive substance. What Banister and his colleagues have now done is to tame the manufacturing process using a relatively benign electrolytic cell with a special silver electrode. In so doing they've also succeeded in depositing the conducting polymer on a range of substrates, including metal and glass.



Poly (sulphur nitride)

For those of a chemical turn of mind, the process proper starts with a ring-compound, $S_5N_5^+Cl^-$, which is made by heating sulphur chloride and ammonium chloride, which are then exposed to chlorine gas and iron filings. The $S_5N_5^+Cl^-$ is then dissolved in liquid sulphur dioxide and electrolysed, with the result that the chlorine is lost and the sulphur/nitrogen ring opens up to form long chains of $(SN)_x$.

These chains have a high intrinsic conductivity, partly because electrons can flow along the chain of atoms but also because sideways flow is possible between adjacent sulphur atoms. Other polymeric conductors are either markedly anisotropic or else (like poly acetylenes) require doping to bring conductivity up to the level that exists naturally in poly(sulphur nitride).

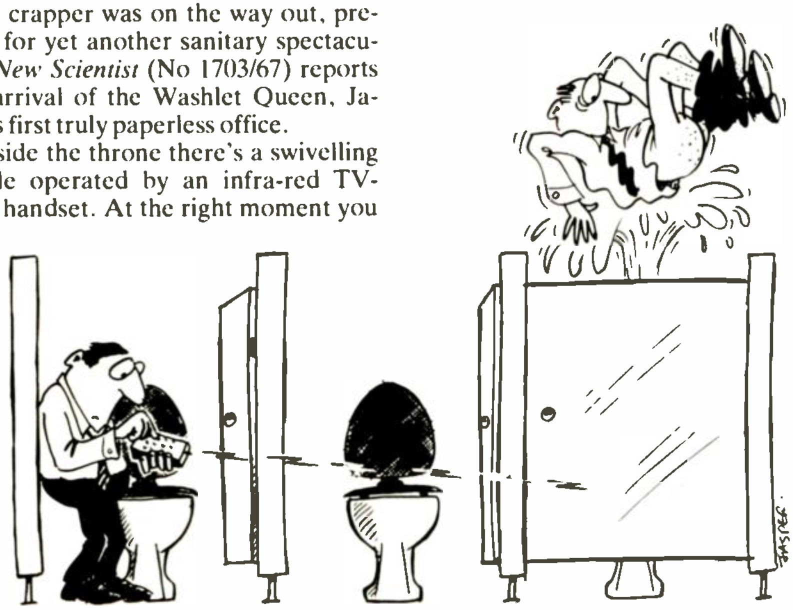
As for applications, the Japanese patents mention conductive resins, batteries and solar cells. In these areas the relatively low weight, compared to metals, would be of enormous benefit, especially in space. Arthur Banister adds that, because $(SN)_x$ has a high electronegativity (higher than gold) and a high work function, it has interesting possibilities in the world of semiconductors. When used as a substitute for gold in, for example, blue zinc sulphide-based leds, light output is increased approximately a hundred times. There is also a dramatic increase in the efficiency of Schottky barrier devices for the same reason.

Banister believes fervently that British discoveries could be exploited far more effectively if only our universities could improve their interface with industry.

Clean round the bend

If the latest lavatorial marvels from the Orient (Research notes, *EW+WW*, Feb 90) didn't convince you that the traditional crapper was on the way out, prepare for yet another sanitary spectacular. *New Scientist* (No 1703/67) reports the arrival of the Washlet Queen, Japan's first truly paperless office.

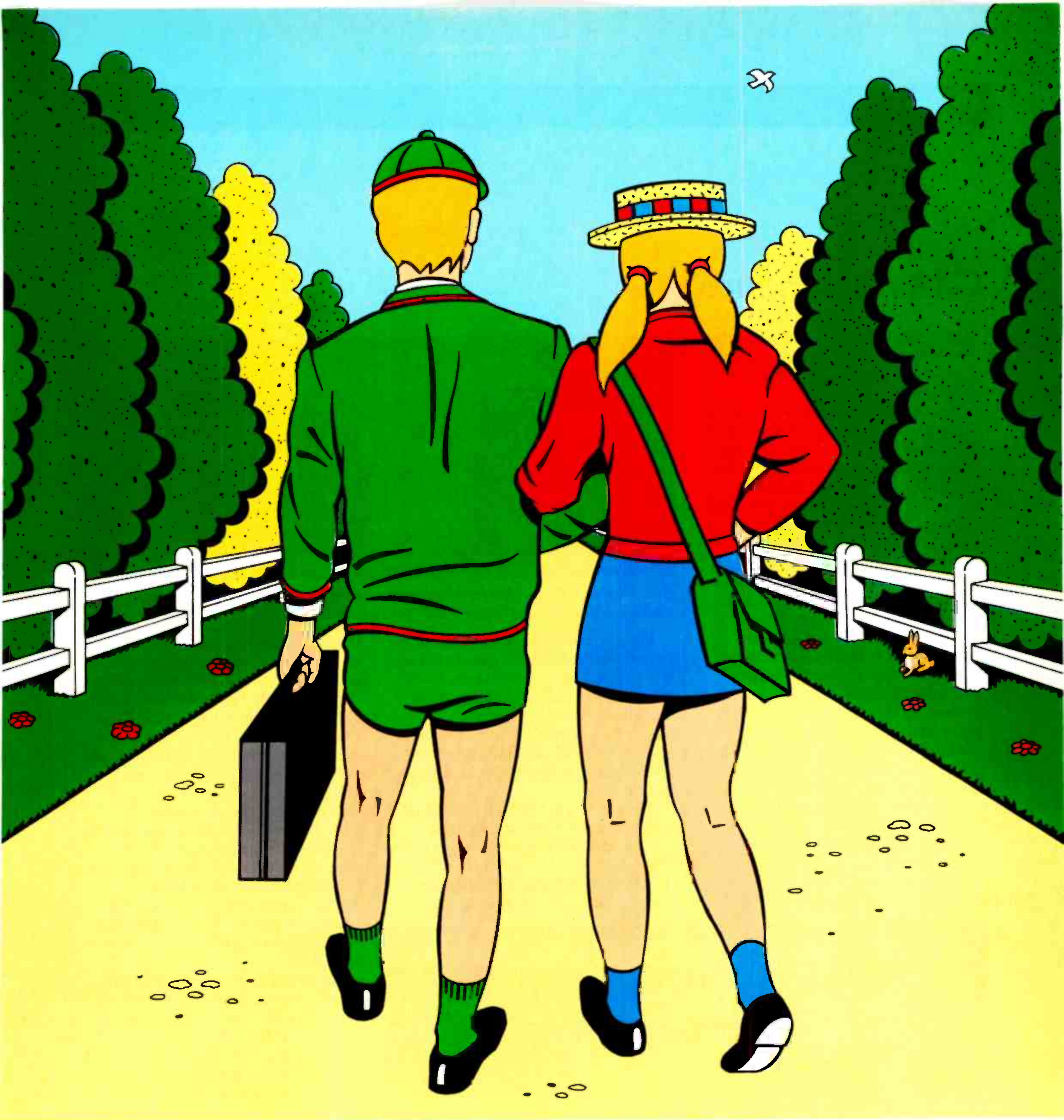
Inside the throne there's a swivelling nozzle operated by an infra-red TV-style handset. At the right moment you press the appropriate button and your nether regions are instantly sprayed with a jet of hot water. And should the trajectory be wrong, then a few degrees of course (coarse?) correction can be programmed into the nozzle.



The next stage of this sensational sanitational spectacular is the blast of hot air similarly discharged from motorised swivelling jets. Grasping the remote controller with all the enthusiasm of a flight director at Cape Canaveral, you call for full wind, praying that neither the O-rings or the U-bend will give trouble.

But there's nothing to fear. Japanese technology is so well tested that nothing will go wrong. There's even a body sensor that prevents the system blasting off in the absence of someone in the driving seat (which as a bonus happens to be heated). As *New Scientist* observes, this safety feature will prevent children having a whale of a time when their parents are out.

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



BACK TO BASICS ON ASICS

These days, even the most gifted among us are stretched to stay in touch with the practical applications of technology. Especially with ever-more-complex developments taking place in the world of advanced electronics.

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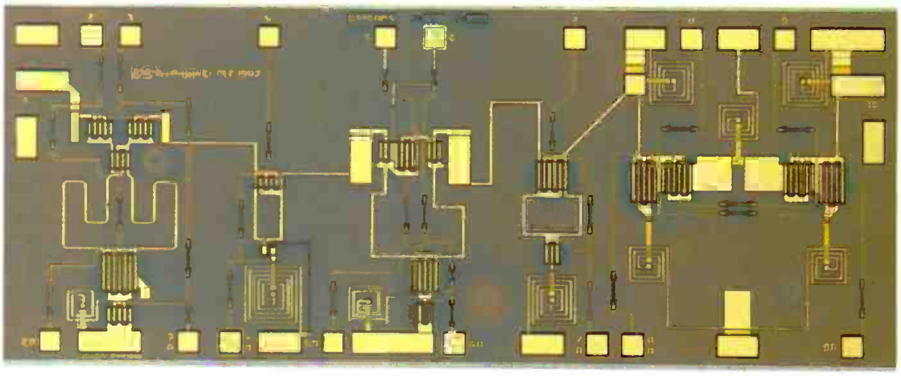
GaAs telephones

Mobile telephones look set to become the problem that the gallium arsenide solution has spent some 20 years looking for.

Since its early days there has been no shortage of forecasters predicting that the days of silicon were over and that GaAs would be the technology of the future. But silicon's success has continued and, given that its potential only lags three years behind GaAs, many have felt the investment not worth the risk.

What has changed is the rush to put mobile telephones into the hands of everybody across Europe. Here it would be some three to four years before silicon would be able to match today's GaAs performance. Add a year's development work and you have an unacceptable time-span for what looks set to be the industry's fastest-growing sector. Customers are queueing up for the phones today—they don't want to wait until 1995.

Despite GaAs' high speed, it is harder to work with than silicon and that puts up the price. So it has only really found favour in the military sector where money has up until recently seemed to be no obstacle.



Five-bit phase-shifter chip for Mesar phased-array radar (above). Transmit/receive module chipset in 17 x 17mm ceramic package (below left).

Plessey, one of the pioneers of GaAs in the 1960s and 1970s, only started with the material because of its potential in phased-array radars. And one of the world leaders today, Texas Instruments, openly admits that if it were not for military applications its GaAs facility in Dallas would probably not exist.

The military aspect today still plays a major role. One of Plessey's most advanced projects is a new GaAs-based phased-array radar, and some 80% of TI's GaAs business is in the military sector. But recent world events and the threat of a new recession looming will make military expenditure more difficult to justify in the coming decade.

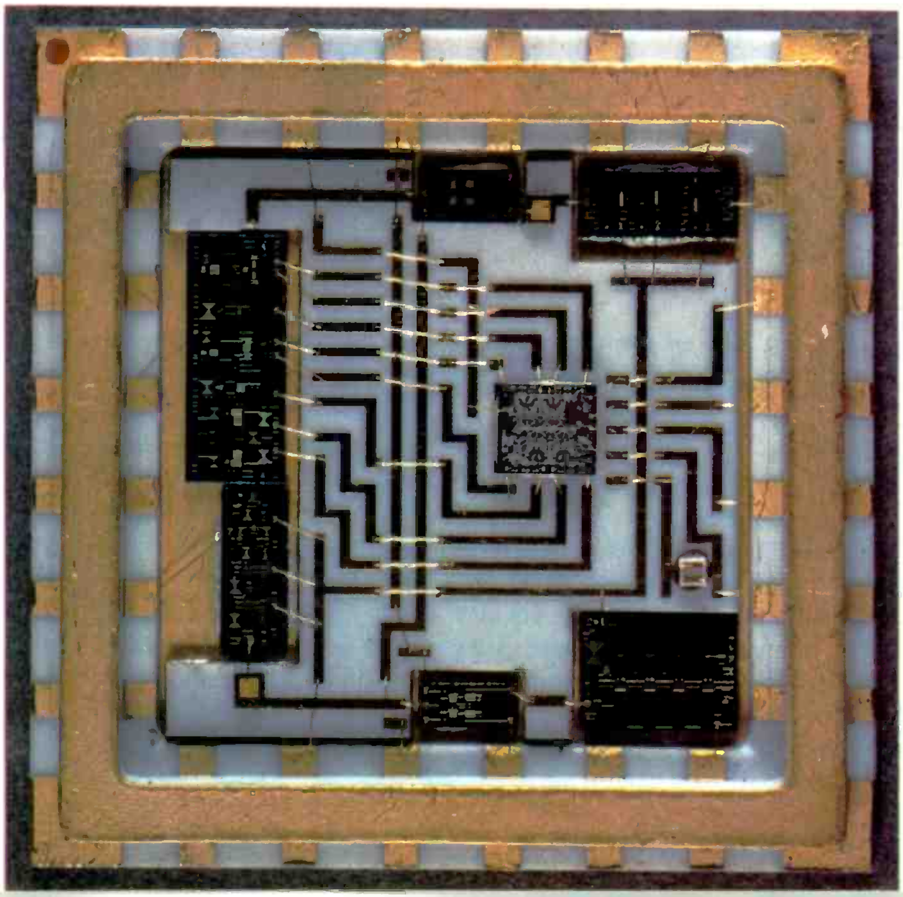
This is partly why John Hudson, a European products manager at TI in Bedford, predicts that, "There is a strong chance that the commercial side will be more than 50% by the mid 1990s."

Bedford is already showing clear signs of expansion in the design side of GaAs and strong rumours from the USA suggest that the Dallas plant is being expanded to increase the production of GaAs. Given normal timescales, one would expect the new facilities to be up and running within two years.

The target for these facilities is the increase in commercial applications. Mobile communications is the driving force behind the expansions, but GaAs is also finding uses in global positioning systems (GPS), automatic test equipment (ATE) and even home entertainment.

Hudson said: "It is true that military spending is likely to fall in the next few years. It is really too soon to judge the impact of all that has happened in Europe, but it does give us the impetus to try to apply our military technology commercially."

Plessey has already made a start in attacking the mobile phone market. It has produced a switch that is being tried out by major cell and cordless phone makers. David Smith, a production manager at Plessey Research in Caswell, admits that, "It is not a world beater in terms of performance, but it is good enough. The key is the price."



This shows the difference in approach between Plessey and TI. Plessey uses ultra-violet photolithography for manufacture, a very fast technology suitable for low price and high volume. TI, though, uses an e-beam method.

Hudson said: "We are not into millions of units in volume. People are looking for performance rather than cheap high volume. For high performance instead of volume, e-beam is cost effective."

But Smith sees things changing: "The fate of the MMIC [monolithic microwave IC] is to do things at a lower cost. As long as performance dominates the market then MMICs will be a problem."

Given some of the target markets that TI's Hudson is looking at, one has to say that Smith may have a point. Hudson admits that GPS will become a user of GaAs because it "will come down in price, hopefully, to cover even the low-end yacht market". And in home entertainment it will be the drive to reduce the price of satellite dishes that will increase the interest.

The Amstrad receiver, for example, uses three or four GaAs fets for the amplifier and down converter in the receiver. The next generation is likely to be cheaper and smaller and will probably use GaAs MMICs, assuming that the satellite business does start to take off.

Mobile communications again is a very price-conscious market and, though early generations of phones in all the new systems will be expensive, to get the volume sales that are being planned for, the cost has to come down.

Outside the military it is only really ATE that looks like being a high-performance and high-cost market. As components become faster then ATE will have to become faster as well. In some cases already only GaAs is good enough to handle the requirements.

In contrast, Plessey is spending a lot of its time and money on what is definitely a top-end application, and that is the Mesar phased-array radar. Mesar stands for multifunction electronically scanned adaptive radar, and the US Navy already has a primitive version in service.

On any one face of a Mesar there are about 1000 dipole radiators. Behind each radiator there is an active transmitter and an active receiver. If each unit is 2W it brings a face up to about 2kW.

But the phase of each has to be controlled. If they were all identical then the radar would have a pencil beam. By controlling the phase, the beam direction and shape can also be controlled. To do this using phase shifters gives a very powerful and controllable radar. When they reach production, each Mesar will have three or four of these faces.

In 1986 Plessey produced the prototype transmitter and receiver block containing an MMIC power transmit/receive switch, an MMIC 4 bit time-delay shifter, an MMIC low-noise amplifier and a discrete fet transmitter amplifier chain. Though impressive, it was never going to be cost-effective. The packaging and the chip had to be improved.

In 1988 the first improvement happened with a transmit/receive module taking up 23mm^2 in a ceramic package. This was done by using various elements to save space on the GaAs, including multifunction circuits. Since then all the same functions have been squeezed on to a 9.5mm^2 circuit.

For the future TI is looking to the hetero-bipolar transistor (HBT), the 1.5μ version of which won a technology award in 1989 from the US defence agency, Darpa. To give some idea of performance Hudson compared the results with a 5W, 900MHz power amplifier with a gain of 46dB. In silicon it uses five stages to get a 32.5% efficiency, compared with only three stages in GaAs and an efficiency of 60%.

Both TI and Plessey are also looking at high electron mobility transistors or HEMTs. TI has already demonstrated low-noise amplifiers and power amplifiers with this technology, and plans to have a 0.25μ HEMT out by the end of 1991. Plessey is trying to integrate HEMTs into its monolithic process.

It has to be said, though, that the future of Plessey's GaAs foundry and research department at Caswell is still in doubt, following the GEC/Siemens takeover last year. In fighting the bid, it closed down the Plessey III-V company and the GaAs business was put back under the control of Caswell.

For it to keep going the firm hopes that the GaAs business continues to grow.

New Electricity Bill may provide enquiry loophole

Government proposals in the recent Electricity Bill, which came into effect on March 31, could give the new electricity companies a loophole to erect new pylons without giving people a chance to object at a public enquiry.

A Statutory Instrument could be introduced in the House of Commons, perhaps in the form of an Early Day Motion, which if unopposed would result in such new proposals being incorporated within the new Bill without further discussion.

According to Councillor Scott of the Calderdale Council Development Control Sub-committee, which in February was among objectors to proposals to build super pylons from Elland to Blackstone Edge on the Yorkshire-Greater Manchester boundary, if the rules were changed then the pylons could be put up without the consent of Energy Secretary John Wakeham.

The proposals would exempt the new private power companies from having to get consent if, for example, proposed new pylons did not carry any more power than previously, were not more than 10% higher than the existing pylons, and were not more than 60 yards from the towers they replaced.

Councillor Scott asked the meeting whether the new proposals had been suggested as a way of getting around Calderdale Council's objections to the super pylons. Phil Raper, the senior planning officer, said that the council would be asking the Energy Department how the proposed changes were going to be interpreted.

Meanwhile the Council was putting in a holding objection to the proposed exemptions, through the Association of Metropolitan Authorities.

Optical processing

Optical computers are a bit like the Loch Ness Monster – everyone has heard about them but no-one has ever seen one. Everyone knows someone who thinks they might have looked at one at a show once, but they weren't really sure what it did or how it worked. Sightings of systems by the press are usually followed by a graceful sinking back into the murky depths.

Small wonder that most engineers are sceptical about light ever replacing electricity as the basis for data processing.

Researchers at British universities are becoming more realistic about the applications for their light-processing systems. AT&T told the world earlier this year that its optical array chips would build into microprocessors. UCL's Professor John Midwinter, who works on similar devices, pointed to more practical uses in high-speed switching systems like telephone exchanges.

Scientists at Heriot Watt have demonstrated two kinds of optical digital processors which could be combined to run simple computing tasks. The team intends to produce a system later this year using both techniques but does not pretend that this will lead to a light-driven VAX in the near future.

The first experiment showed repeated processing of a single channel of information, carried on a beam of light. Although the devices used can only switch at 10kHz, the team believes that parallel processing will provide a useful data rate. The second experiment demonstrated the possibilities in the field, by connecting two arrays of 225 digital optical processing elements.

Heriot Watt's logic devices consist of Non-Linear Interference Filters (NLIFs) which are grown onto sapphire substrates 25mm across and 1mm thick. As the power of the light shone on the filters passes a certain threshold, their reflectivity changes from one stable state to another. The amount of light passing through then increases significantly to a higher level. This gives them output characteristics similar to electronic transistors and enables logic devices to be built.

The first experiment involved using these devices to build an Optical Cellular Logic Image Processing (O-CLIP) circuit. The arrangement is based on electronic CLIP systems used in research computers and is powered by seven 30mW laser diodes operating at 833nm.

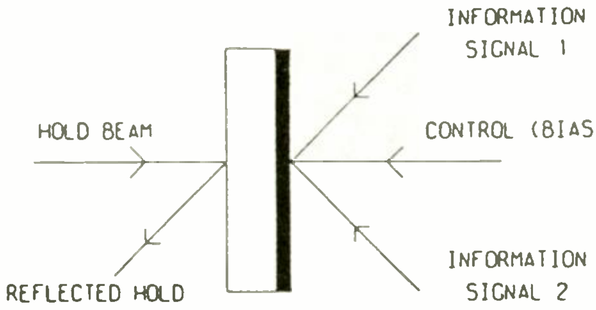
Heriot Watt's system had five main parts. The input image, produced by the lasers, fell on a programmable logic unit (PLU) made of NLIFs. The PLU also received an image fed back from the previous processing cycle. The output of the PLU was a logical combination of these two, determined by a programming signal which set the filters to their required state.

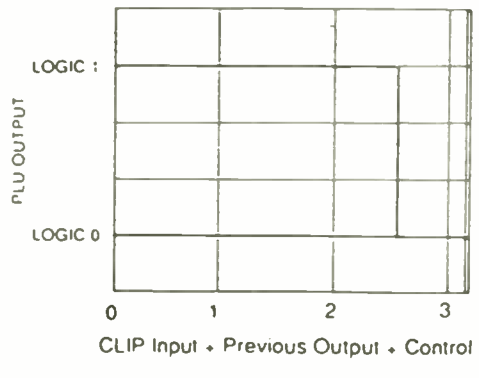
The optical interconnects used simply joined the PLU to storage devices which held the data, but the university is working on holographic connections to increase the scope of the system. A threshold device was used to convert the fanned-in combination of inputs into binary output levels, and a clocking unit stored the levels to synchronise the parts of the image.

A cache memory unit was also developed, made up of a series of NLIFs operating as a 2D shift register or volatile FIFO memory. The team tried different instruction sets and combinations of PLUs until they settled on the hardware shown in the accompanying diagram. The table shows the full set of logic functions obtained from the different input combinations and control systems.

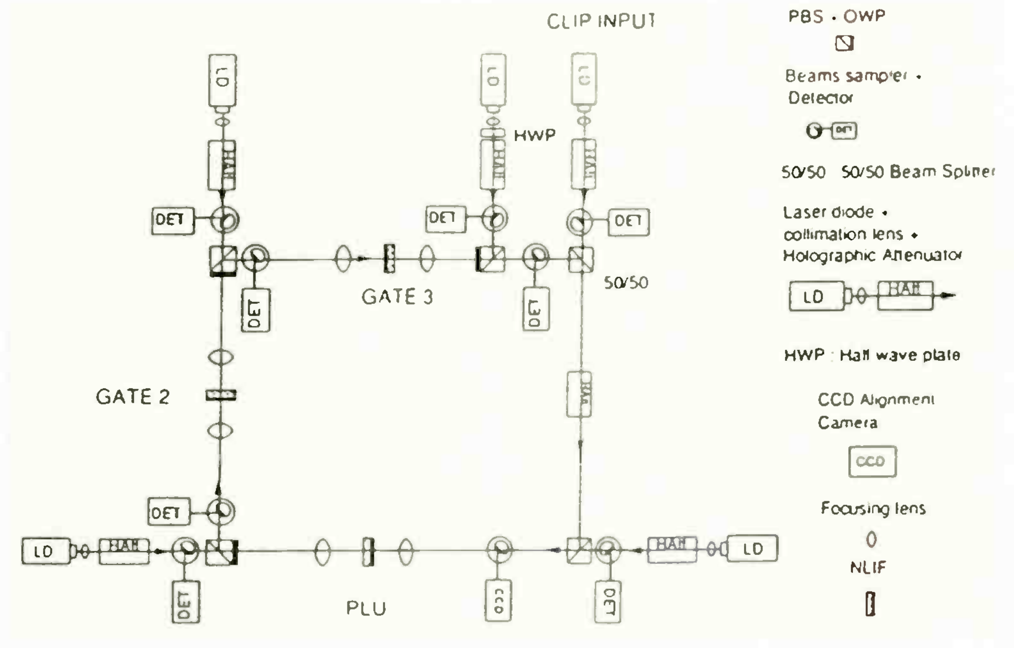
The second experiment demonstrated lock-and-clock transfer of data between two 15×15 arrays of images. This will allow the single PLUs used in the CLIP architecture to be replaced with optical gate arrays. To test the transfer of data, the first array was switched on and the second turned off. Interrupting the power to the first caused the second to switch on and stay on when its own power was removed.

The NLIFs used in the arrays were designed to operate at $1.06\mu m$ so that a continuous wave Nd:YAG laser could be used as the optical power source. A single input beam was split using a Damman grating to produce an array of spots with diameters of about $15\mu m$. Each gate on the NLIFs used about 8mW to switch, giving a total of 1.7W input power per array. The gates were spaced $136\mu m$ apart which reduced





Reflective mode bistable device optical address and output (above). Example optical response (hold reflection versus total signal) (left). Optical interconnects join the PLU to data storage devices, but holographic connections would increase the scope of the system.



Hardware implementation of the O-CLIP loop circuit.

crosstalk to a level where one gate would stay in the off state even if all the others were switched on.

Combining the two experiments will be the next stage of development. The system will then be able to perform logical combinations of digital images, and will be used to carry out optical processing controlled by an electronic computer. The parallel nature of this technique will increase the processing speed, which will then be limited by the time taken to get the control signals out of the electronic computer and into the NLIFs.

The current switching speed of Heriot Watt's optical PLU is slow compared to electronic devices. But applications which can make use of the array's parallel-processing abilities should be able to run much faster. A 15×15 array of elements each switching at 10kHz should provide a processing rate of 2.25 million bits per second.

Holographic interconnections will provide greater advantages over parallel electronic systems. Silicon elements sharing a computing task need physical links which take up a lot of space and can be difficult to route from one point to another without crossovers. Holography offers the chance to make connections as and when they are required.

The combination of parallel processing and easy interconnections makes the Heriot Watt system suitable for use in distributed computing systems and neural networks. Although these would still have a silicon core, optical subsystems would be able to add processing power as and when it is needed. It should be possible to build a system which can connect any two points without having to connect every point.

Digital image processing is another application in which the CLIP has advantages over electronic circuits. The arrays can already be used to transmit images in parallel, without having to pixelate them and send each portion in sequence. Adding the computing element would let the system process the image without breaking it down and reconstructing it.

By concentrating on practical applications of digital optical processing, academics should be able to overcome scepticism about light computing. It should also be easier to convince systems builders to use the technology in the real world.

AT&T's publicity department may believe that the the company will build a light-driven PC, but it is better known for its telecoms equipment than its computers. Opto-electronics will extend further into data processing systems, but it is moving from the outside inwards.

Fibres already link systems together, and the O-CLIP should eventually change the form of data sent round networks. But if the optical 486 is ever a possibility, at the moment it is still lying at the bottom of a dark Scottish loch.

Wavelength multiplexing

The capacities of fibre-optic networks will increase by thousands of times over the next few years. This conclusion is suggested by work done at British Telecom's Research Labs (BTRL) at Martlesham Heath near Ipswich, which has demonstrated the UK network's ability to carry simultaneous pulse transients at different wavelengths.

And in the USA, AT&T's Bell Labs has developed a laser chip with four independently tunable light sources on the same substrate, which should reduce the cost of the new equipment.

The secret to getting more signals down a single fibre is called coherent transmission. Although lasers are fairly coherent sources compared to light bulbs, they still produce a spectrum with energy at wavelengths away from the centre. Coherent transmission systems narrow the range of the spectrum produced by the lasers, reducing the possibility of crosstalk between signals sent at different wavelengths. If the centre frequencies are far enough apart, the number of signal channels can be increased dramatically.

BTRL's engineers set up a field demonstration earlier this year in which they transmitted two wavelengths through an optical repeater down 200km of fibre between Edinburgh and Newcastle. They tried two different systems, the first with a long external cavity semiconductor laser producing signals which were multiplexed using differential phase shift keying. A commercial distributed feedback laser generated pulses for a frequency-shift keying system.

The trials involved each system sending two wavelengths without repeaters between Galashiels and Newcastle, about 130km, with a loss of 45.2dB. An intermediate optical repeater at Galashiels was then used to send the two signals another 70km to Edinburgh with a loss of 21.5dB. Each wavelength channel carried 622Mbit/sec, equivalent to about 8,000 calls on each.

The lasers transmitted channels with guard bands as small as 7GHz. A single fibre has a bandwidth of 50,000GHz, so the coherent transmission technique has a theoretical capacity of 7,000 channels.

Bell Laboratories has been developing several integrated circuits which use light. The latest so-called photonic integrated circuits (PICs) are designed for use in coherent transmission systems.

The wavelength division multiplexing (WDM) PIC consists of four independently tunable quantum-well lasers and an onchip optical amplifier. Each laser can generate a signal to be passed down the line and separated by optical filters at the other end. In experiments the devices have each transmitted 2Gbit/sec, giving a total capacity of 8Gbit/sec.

A balanced heterodyne receiver chip converts optical frequency signals down to microwave levels which can then be processed using conventional microwave radio electronics. The receiver consists of an electronically tunable quantum-well semiconductor laser, two waveguide optical detectors and a directional coupler optical switch. It has demonstrated error-free reception of digital FM signals at up to 100bit/sec.

AT&T's PICs are both based on indium phosphide substrates. The devices are produced using metal-organic vapour-phase epitaxy, which allows the definition of layers down to 50 atoms thick. Both devices operate in the 1.5μm range.

There are practical limitations to the scope for wavelength division multiplexing apart from the width of the pulse train's spectrum. The total power output drawn from the laser and the noise floor built up by the signals will prevent BT extending the capacity of its long external cavity laser to its theoretical limit of 56 million calls on a single fibre.

But the technique has the great advantage of being able to increase a network's capacity without having to lay new fibre. On major trunk and international routes that will allow links to be used until they need to be replaced because they are worn out or damaged.

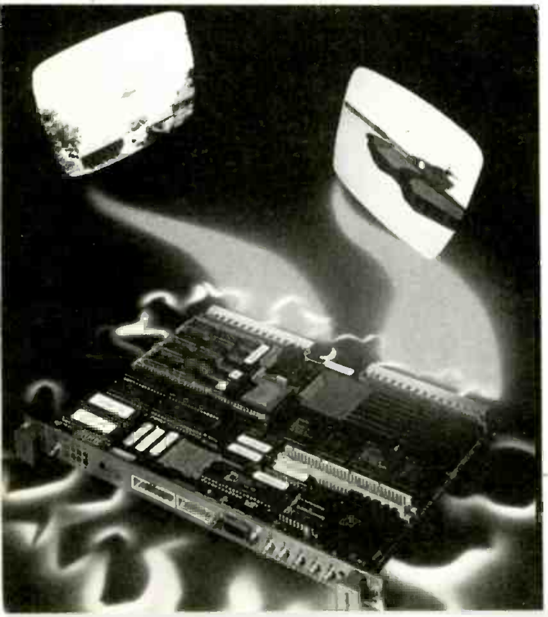
Rob Causey
Electronics Weekly

Real time simulation on VME

Specialist image processing company Akebia has come up with a set of VMEbus boards which, it hopes, will take it into the low-cost simulation and training market. Its AGE II system combines digitised photographic backgrounds with computer-generated moving images, using a transputer-based parallel processing system. According to the company's technical director, Geoff Thiel, this results in a compromise between costly full animation systems and CD-ROM type captured images.

The key to the system is a central board which combines a transputer module containing SRAM and a T800 processor, an AMD 95C60 graphics processor, and an Intel 80186 processor. A gate array provides the video data assembly functions, including the system's ability to pan across a scene, pixel by pixel.

AGE II combines digitised photographic backgrounds with computer-generated moving images.



AGE-XMEM is a memory card which can be added to the CPU board for more image storage. The board comes with an 80188 controller and up to 64Mbyte of memory, which then dumps data to the video RAM on the CPU card itself.

The third element in the AGE system is AGE-MIX, which provides digital mixing facilities, supplementary colour look-up tables, anti-aliasing filters, and synchronisation. This allows users to synchronise AGE-controlled visuals with, for instance, PAL TV signals.

Thiel explained that the use of VMEbus and transputers has produced a system which can be expanded and improved using off-the-shelf parts. Extra transputer modules can be added to increase the number of available colours to 256 and beyond, and overall image resolution runs from 500×500 to 1000×1000 pixels.

Much of the real-time processing power provided by the transputer goes into producing realistic visual effects. These include manipulating the resolution and colouring as moving images change their perceived distance from the viewer. Animated images can also pass 'behind' sections of the background. This is done by generating a duplicate of the relevant section of background, and laying it 'over' the actual background data. A moving image then passes 'between' the real and reproduced backgrounds.

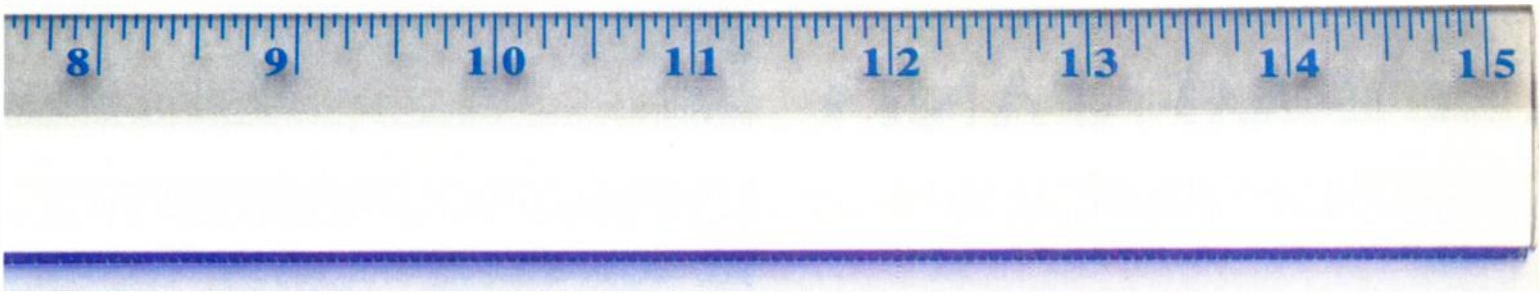
Animated objects can be provided with moving sections: helicopters have moving rotor blades, wheels can be seen to turn, and undercarriages can ascend and descend. Object generation is based on the Autocad CAD system.

Background generation and manipulation can be done on a PC or compatible. Photographs taken by 360° revolving cameras can be flat-bed scanned into the PC. These are then split into vertical sections for manipulation. Software facilities allow the removal of unwanted images, duplication of sections of the photograph, and mirror imaging of user-defined areas. Tools for recolouring and blending objects are also provided.

The next stage in the process sees background sections spliced back together. The required moving images are then added.

Andy Gothard
Electronics Weekly

The best way to appreciate our new thermal array?



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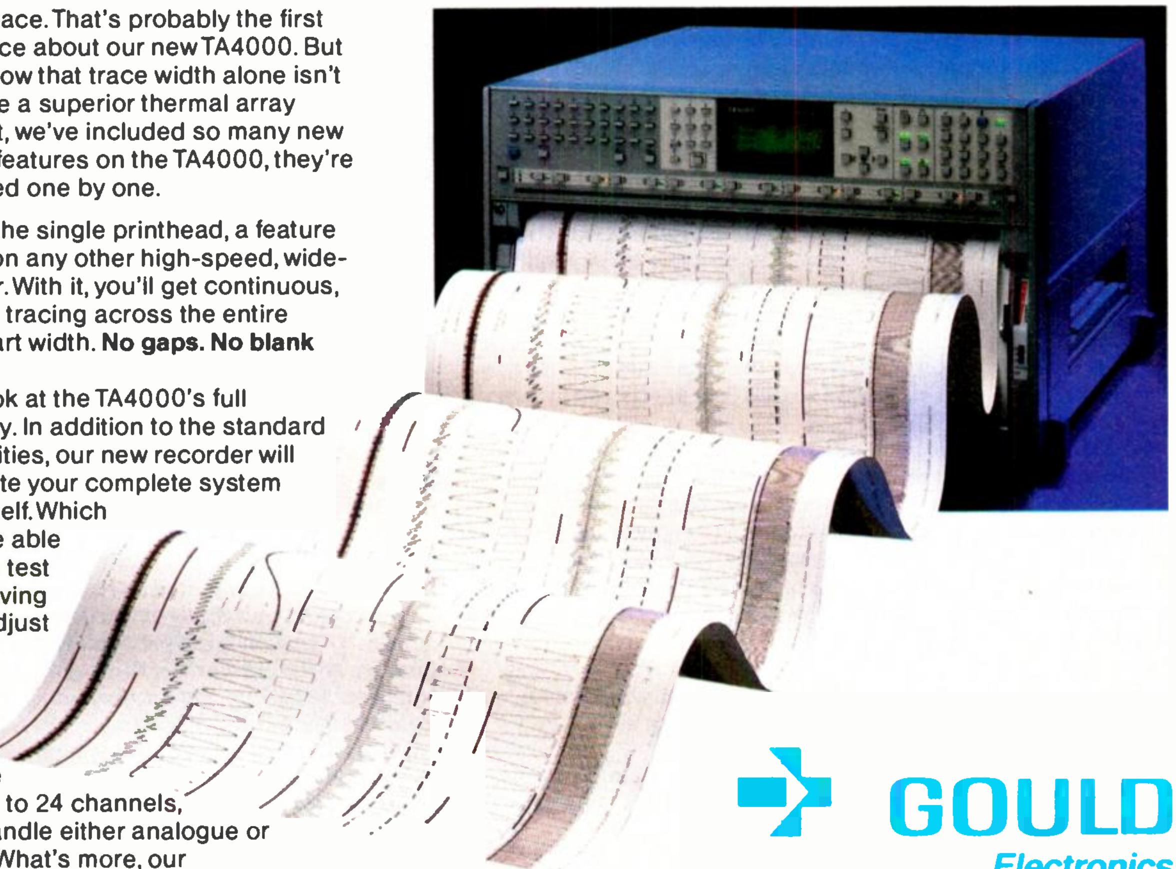

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OF MEN AND MACHINES

Would you trust your life to a computer? The plane makers think that we should. All the big jets coming into service over the next few years will incorporate computers into their primary control systems. The manufacturers argue that multiple computer redundancy minimises the effect of failure: if one, two or three computers go down, there will always be a fourth or a fifth to prevent calamity.

Much the same situation exists in aircraft with traditional control systems. Multiple sets of hydraulics back up one another in the event of individual systems failure. However, accidents can and do happen when catastrophic events occur, such as the bulkhead blow-out on a Japanese 747 several years ago which cut through all tail end controls.

Electronic hardware on its own is certainly as reliable as the mechanics which it replaces or, more usually, augments. The real problem presents itself when the electronics have to rely on men to write the software so that they may perform their intended function.

Most people will be familiar with computers operating outside aviation, and the dull mechanical stupidity which occasionally results: million-pound gas bills, mistaken identities and general systems failure. Computer operators will know the frustration of a machine which 'locks up' without apparent cause. The error can be traced to human factors in nearly every case, mostly due to software bugs or corrupted data. Aeroplanes don't have Ctrl + Alt + Del keys.

The currently limited association between safety critical systems on aircraft and computers has already gathered a (growing) number of well documented horror stories.

> A three-engined, wide-bodied airliner habitually lost the middle engine whenever the on-board HF transmitter was operated on a particular frequency;
>
> The auto-stabilising system on a Sea King helicopter, which functioned so well in peacetime, became a liability when operated under battle conditions during the Falklands war. Designed to stabilise flight during the landing phase onto a pitching flight deck, the hyperactive ship's radar caused the system to turn the aircraft into a bucking bronco;
>
> Two Phantoms crashed during low level flight in West Germany, resulting in much publicity. The cause was later found to be high-intensity transmissions from a nearby broadcasting station adversely affecting the aircrafts' fly-by-wire control systems;
>
> Advanced munitions of all sorts popped off unexpectedly during the Falklands campaign due to the effects of battlefield and seaborne radar.

Concorde uses an analogue fly-by-wire system which has operated creditably and without mishap since it came into service some 15 years ago. However, it seems questionable to use this performance as a yardstick for judging digital fly-by-wire fitted to the latest generations of civil aircraft.

A lightning-induced transient, or perhaps the inductive surge from a motor switching on, may produce a random string of data which can enter the control system to react unpredictably with the system software. The system may ignore it or react safely by rebooting to a safe state. It may also produce an unforeseen overflow error which causes the computer to lock up. By contrast, even the most powerful transient causes little more than a minor blip in the response of an electronic analogue control system.

The plane makers go to extraordinary lengths to protect electronic circuits from transients. Wiring throughout the aircraft is carefully screened and earth bonded at all entry and exit points. Complete aircraft, fitted with strategically placed current and voltage monitoring probes, are subjected to low-level RF pulse tests. Induced voltage levels at all wiring ports are recorded. Individual items of equipment are analysed for RF sensitivity in the laboratory by scaling up the measured pulse values to levels which might be encountered in extremes of service. If, after all this, equipment remains functional, it is declared fit for service.

Software for each of the computers operating in a majority decision system is written by independent teams working with chinese walls between them.

It could be that the civil aircraft industry has found a way of taming computer control to the point where it can be absolutely guaranteed. This would be an outstanding achievement; no other area of industry can claim to produce totally reliable and predictable software. Only time and accident records will prove its claims. **Frank Ogden.**

SAFETY IN NUMBERS?

The new generation of airliners will all be controlled by electronics, the pilots demanding the trajectory and the aircraft deciding how best to comply. David Learmount of *Flight International* describes the systems, the only trouble with which has been in the air-conditioning and lavatories.

In the heat of a US midwestern summer day the huge airliner careered across the airfield, breaking up as it did so. Film crews were calmly recording the tumbling impacts, the rising dust and fire enveloping the 296 passengers and crew.

The scene, Sioux City, USA, sounds celluloid. Unfortunately the place and the event were both real. It was July last year, and 111 people died. There would have been far more deaths except that the entire emergency services of a county were waiting alongside the cameramen.

Nearly an hour had passed since the Douglas DC-10 captain had declared the emergency: the pilots' flight controls – control columns and rudder pedals – had been disconnected completely from the elevators, ailerons, spoilers and rudder. The only influence over the aircraft's behaviour left to the pilots was through control of thrust from the two remaining engines.

The tail engine had failed catastrophically, severing the three separate hydraulic flight control systems. Any one system would have left the pilots with control, but all had been cut. A similar event four years earlier in a Japan Air Lines Boeing 747 killed 520 people (only four surviving), although Boeing control connections are by cables and bell cranks, not hydraulic lines.

Fly-by-wire

What has this to do with fly-by-wire? The intention is to establish the "base" with which fly-by-wire is being compared, and to make it clear that digital control is not competing with failure-proof systems. Also, the only two fly-by-wire airliners – Concorde and the Airbus Industrie A320 – both have "conventional" control systems to back up the digital system.

In addition to total failure, conventional controls can suffer partial failure from leakage or actuator malfunction (hydraulic), jamming and cable severance (mechanical), or a combination of the two (hydro-mechanical).

From now on any completely new airliner will be equipped with digital fly-by-wire controls; the industry does not question it. The A320 is already there, and the A310 and A300-600 have been in commercial service with fly-by-wire-controlled slats, flaps, and spoilers since 1983. (Neither type has ailerons: spoilers provide their roll control.)

Apart from the already-launched fly-by-wire Airbus A330 and A340 which will be flying commercially in 1993, there is only one new airliner design proposed: it is the Boeing 777, the USA's answer to the very-big-twin A330. Boeing, well advanced in its market research to define the 777's precise characteristics, is not giving customers a choice over fly-by-wire. It is clear that the US manufacturer believes that, in five years when the 777 is ready, there will be no realistic alternative. The only questions are over the signal delivery medium: will it be electric cables or fly-by-light (fibre optics)?

Fly-by-wire's attractions to the air

Fig. 1. A320 flight deck, showing the two sidesticks. Cockpit is for two crew, all "lateral" system controls being accessible to pilots

transport industry are many. The installation's light weight means easier installation and easy maintenance (fewer mechanical moving parts). It is also more naturally compatible with modern avionics and flight management/navigation systems and will deliver more reliably the precision-programmed, four-dimensional (three dimensions plus real-time) flight paths which future air traffic control systems will demand.

The equipment will use modern technical skills for operation and maintenance. Its self-monitoring and diagnostic ability, which allows presentation of exact faults to pilots during flight, and to ground engineers for maintenance, far exceeds that of any digital-mechanical system: this keeps the pilots better-informed, and saves the engineers huge amounts of time, thus cutting costs.

Finally, the computers through which pilots' instructions are routed can prevent the crew asking more of the aircraft than it is designed to give: that means preventing high speeds or 'g' forces which could break the structure, and preventing low speeds which would cause the wings to stall, losing lift.

These safety limits are known as "flight envelope protection", which means keeping the aircraft within its designed performance envelope. It also means that if, in an emergency, the pilots want the maximum performance the aircraft can give without stalling or breaking up, they do not have to operate cautiously for fear of exceeding the limits: they simply demand the limits.

Windshear

Perhaps the most emphatic example of this automatic delivery of maximum performance is known as "alpha-floor"; its primary purpose is to save an aircraft from a fierce meteorological phenomenon known as a microburst or windshear, which has caused a number of fatal airliner crashes just after take-off and on final approach to land, (**Fig. 2**).

A microburst, often associated with a thunderstorm, is a powerful downflow of air close to the ground which, when it approaches the ground, spreads laterally, creating a strong radial outflow of wind. Entering this wind pattern, the aircraft suddenly gains airspeed from the headwind: the pilot typically reacts by reducing speed. Then the aircraft enters the central area of the microburst, loses more airspeed and is hit by the downflow. If the aircraft manages to clear that phase without being thrown to the ground, the next phase is the loss of still more airspeed as the outflow becomes a gusting tailwind.

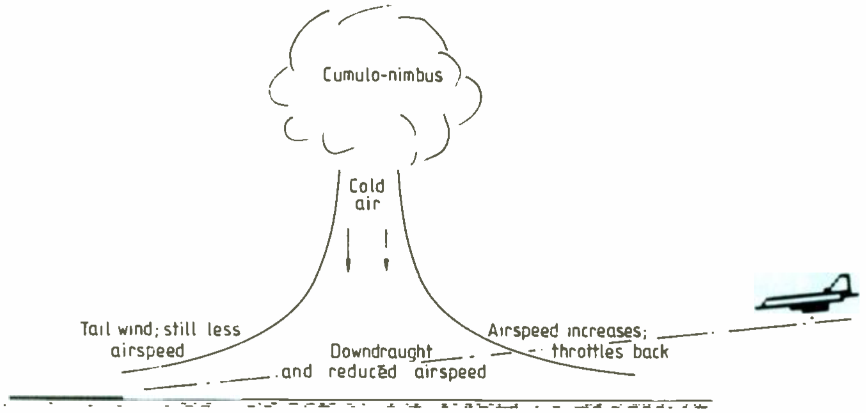
Alpha-floor is simple: the pilot's only required reaction is to pull the sidestick fully back and hold it there until the aircraft is clear of danger. The computerised controls provide instant maximum angle-of-attack (known as "alpha"), which is maximum nose-up angle without stalling to give maximum available lift, and full engine power is selected automatically without the need to touch the throttles. While the pilot continues to hold the stick back "on the stops" the aircraft rides out the storm, providing maximum available aerodynamic and engine performance. A pilot without alpha-floor would constantly be holding back from maximum "alpha" for fear of exceeding it, then stalling and losing height.

Control philosophy

When, in the early 1980s, Airbus was carrying out its airborne research into a fly-by-wire system, it used one of its A300s: its control linkages were conventionally mechanical, but Airbus fitted its now-famous "sidestick" at the left-hand (captain's) seat, routed the sidestick's signals to the new control computers installed in the cabin of the test aircraft and their output to the old-fashioned autopilot, which flew the aeroplane as if it were receiving instructions from its normal pilot-selected inputs. At the right-hand seat was the A300's normal control column, and the autopilot was directly available through its standard control panel on the coaming above the instrument panel.

This experimental aircraft was ideal

Fig. 2. Microburst, which can give rise to three-stage, disastrous reduction in airspeed



for testing theories: for developing sensors for flight envelope protection and working out the flight profiles which would deliver the associated performance limitation; for developing the pilot's work position, and determining what feedback or "feel" he might need when operating a system which totally divorced him from physical contact with the control surfaces; for determining what degree of sensitivity the sidestick should have – what rate of bank should be delivered per degree of sidestick deflection.

There was also an opportunity here to revise flight philosophy completely. Software had to be written, but why write it according to the way a pilot thinks and acts in a conventional aeroplane?

For example, when a pilot pulls back a conventional control column, he selects a column deflection which gives him a desired rate of nose-up pitch which, he knows, has a direct relationship to the aircraft's *indicated* airspeed; the 'g' which results is proportional to the deflection and to the *true* airspeed. All these factors become instinctive to an experienced pilot, who varies control-column input according to speed and altitude.

Why not have a stick which (in pitch) specifically selects a 'g' force which is exactly proportional to the degree of stick deflection, and does not vary with aircraft speed?

That is what the A320 has. In pitch, deflection demands 'g' (except at very low speeds, because 'g' would be too insensitive, so it reverts to pitch demand). Laterally, deflection demands roll rate. It is a spring-loaded stick with no artificial feel and, when the pilot releases it to the central position, he has selected not a particular attitude, not level flight, but 'zero g' flight; the aircraft will alter its own attitude, if necessary, to maintain 'zero g', so stick-central flight has some of the attributes of flight in autopilot mode.

There are four "laws", however: ground, take-off, in-flight normal, and landing. This means that the software laws differ slightly according to the flight phase, automatically "washing" out of one into the next according to a height above the ground. The changes take place just after take-off and just before landing.

Obviously, the functioning of the whole electrical flight control system (EFCS) is based as much upon the reliability of sensors as on the reliability of system hardware and software. The sensors are the fundamental databases: radio altimeters are essential, as are the inertial data and air data systems. Radio altimeters measure height above the ground by reflected radio signals; the inertial system supplies acceleration, groundspeed, and directional information; air data systems supply indicated and true airspeeds, barometric altitude, air temperature and magnetic heading.

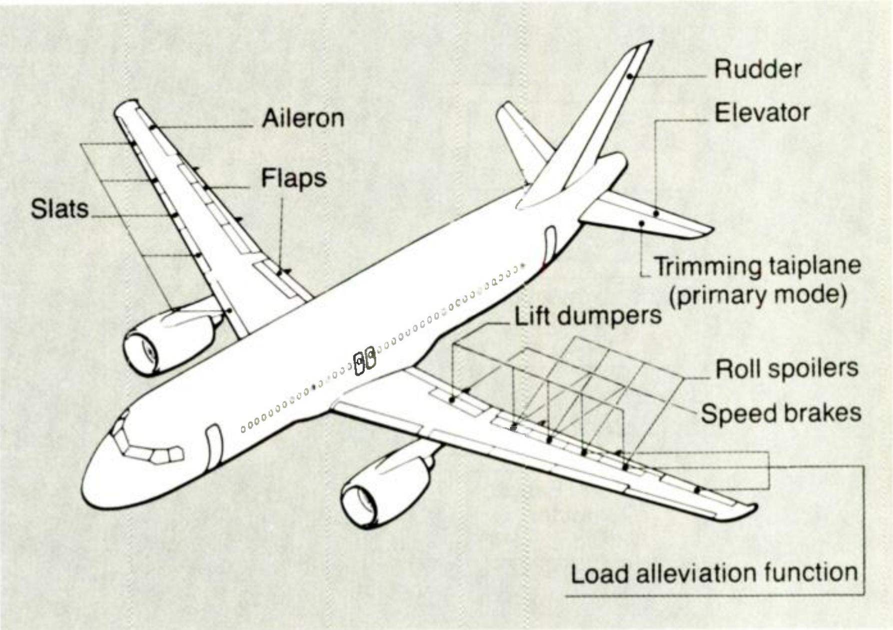


Fig.3. A320 flying controls. All are electrically actuated except rudder and (in extremis) elevator trim

System failure

There are three inertial data computers, three air data computers, and three radio altimeters. However, if sensors, data systems, computers, software, or flight controls fail, or if loss of control law is detected by the system monitors, the flight control system automatically leaves in-flight "normal" law and goes into in-flight "alternate" or "direct" control mode. This means the sidestick works much like a control column in an ordinary airliner: in the alternate mode, flight envelope protection is limited, and in direct mode there is no flight envelope protection – only the conventional aural and overspeed warnings. The system is using different software, and traditional tasks are handed back to the pilot: his judgement and flying skills, instead of the computers', are now required to keep the aircraft inside the flight envelope.

If there is a total electrical failure on the aircraft, the pilots have limited mechanically signalled controls as the ultimate fall-back. The rudder, mechanically connected to the rudder pedals as in a conventional aircraft, provides directional control – sluggish on its own, but it works. The elevator trim wheel, a device also on all conventional aircraft, has mechanical connections to the elevator trim tabs, and will provide pitch control. That is all. A safe approach would be established far out to settle the pilot for a long, straight run to the runway; it would be difficult in rough weather because the control responses would be slow. All A320 pilots have to practice it.

A total electrical failure however, is unlikely. Each engine has a generator, as does the auxiliary power unit (an independent gas turbine). If all three of those fails, the ram air turbine (RAT) drops automatically out of the lower fuselage into the airflow and produces both hydraulic and electrical power. If that fails, there is more than half an hour on the batteries.

So there are plenty of alternatives to operating with the complete fly-by-wire system. But how likely is the system to go wrong or to give misleading information in the first place?

There are five fly-by-wire system computers, and any one of them can provide the pilot with basic control of the aircraft. Each computer is divided into two physically separated units: a control unit and a monitoring unit, each with different software as in **Fig. 4**.

Two of the computers are known as ELACs (elevator and aileron control), each of which provides normal pitch and roll control. The remaining three are called SECs (spoiler and elevator control): they provide roll (spoilers), and stand-by pitch control. The rudder is mechanically signalled, independently of the EFCS. **Fig. 5** shows the system.

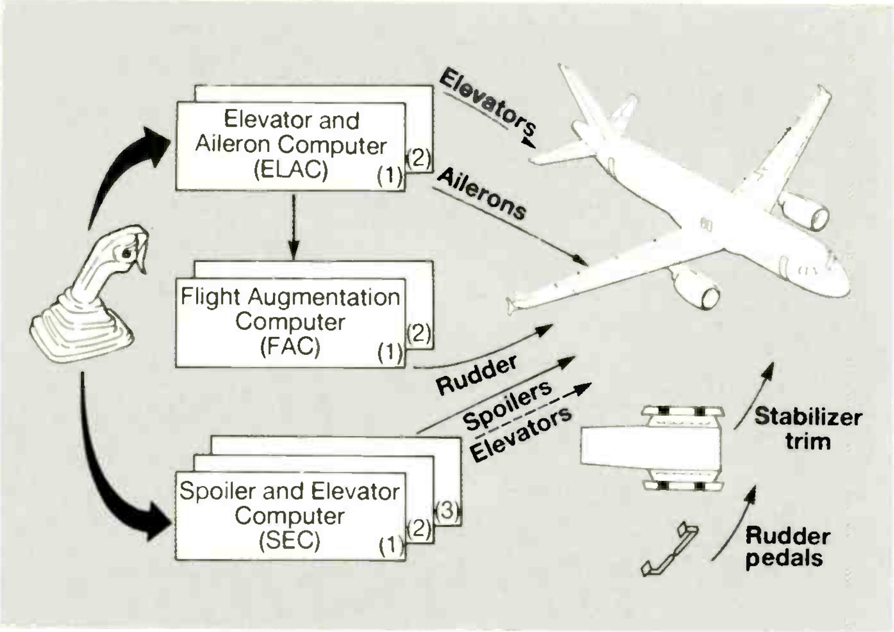


Fig. 4. Electrical flight control system (EFCS) of A320. There are five fly-by-wire system computers, each of different types with different software

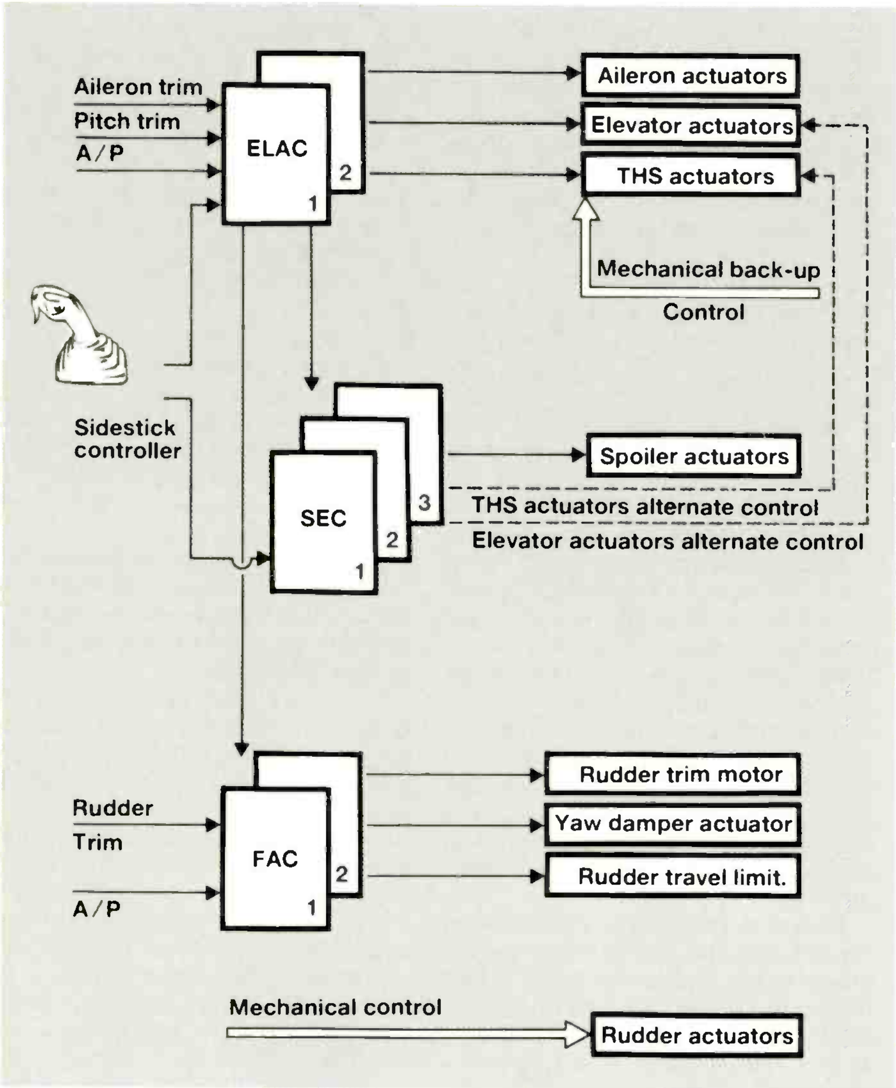


Fig.5. System architecture of A320 EFCS. Rudder is mechanically operated at all times

To reduce the probability of system-wide bugs, the hardware for the ELACs and SECs is supplied by different manufacturers: the ELACs by Thomson CSF, and the SECs by SFENA. Software is supplied by the respective hardware manufacturer in each case. The microprocessors are also made by different companies: Motorola 68000s in the ELACs, and Intel 80186s in the SECs.

The engines are also purely electrically signalled, via individual computers known generically as Full Authority Digital Engine Controls (FADEC). However the A320 is not unique here. All Boeing's 737s are now fitted with FADECs, as are its 757s, 767s, and 747-400s. There is no mechanical backup. Each FADEC has two redundant channels, with built-in monitoring and automatic switching to the optimum channel.

Why FADEC? Throttles on the A320 have a number of detents which represent phases of flight. The pilots can either use the throttles normally or select the detent appropriate to the flight phase, in which case the FADEC then delivers the most efficient engine power setting for that flight phase, given all the parameters affecting the aircraft.

FADECs on the A320 are fully integrated with the EFCS (so it can play its part in "alpha floor" and other flight-envelope protection services) and with the automatic flight system (AFS). The AFS is what used to be called the autopilot, into which the pilots enter their instructions when "flying on autopilot". Another way of putting it is to say that the pilots can give their instructions to the EFCS either through the sidestick or the AFS, and to the FADECs either through the throttles or the AFS.

Electromagnetic compatibility

Airbus will tell you that it has put its hardware and software through fiendishly imaginative testing, involving extremes of temperature and abnormal power supplies, blasted it with extremely powerful electromagnetic interference sources from a range of 10m or less, and subjected the aircraft to real lightning strikes in flight (which struck holes in the aircraft skin) and simulated ones on the ground. All this has been monitored by civil aviation authority representatives from the USA, France, Britain, Germany, Holland, Australia, and other countries. All of them have certificated the aircraft without reservations. The USA had required the electromagnetic compatibility tests to be re-run to its own specification before it signed the form.

The relevant electromagnetic interference (EMI) sources are classified by the US Federal Aviation Administration as follows: transients, in the form of lightning or electrostatic discharge; 400Hz power from the aircraft generators; and RF discharge from ground radar, FM radio, aircraft HF radio, and VHF TV stations. See **Fig. 6.**

Airbus set about protection in three basic ways: by taking installation precautions; by equipment-hardening; and by system design precautions.

Installation precautions consist of electrically bonding composite structures by covering non-conducting composites with aluminium foil, or covering external surfaces with anti-static coatings; electrically bonding movable parts; bonding and shielding to limit the coupling between EMI and aircraft installations; shielding wiring exposed to EM fields in metallic braided conduits, raceways, foil, and mesh; and segregating wire routes.

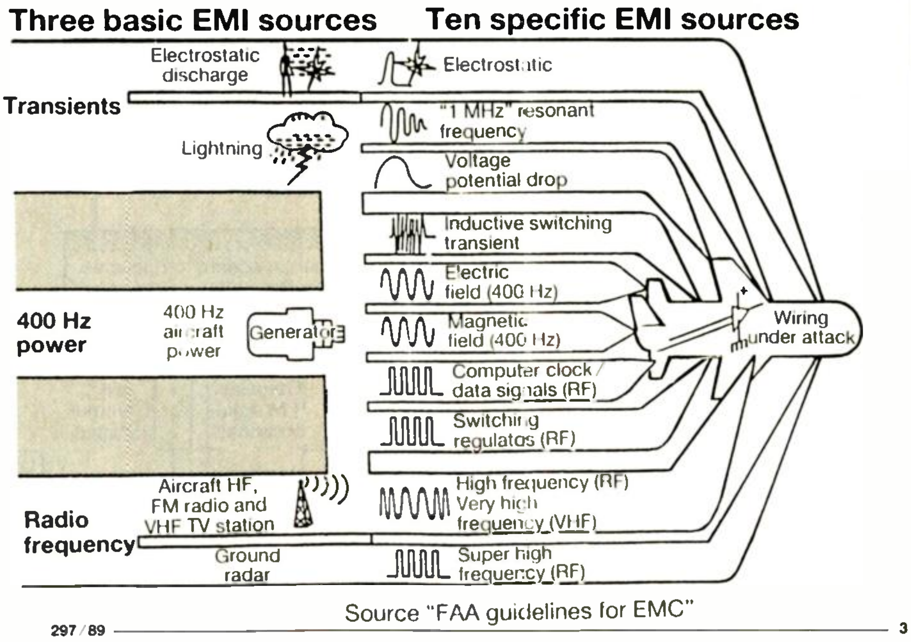
Hardening means that essential equipment can stand voltage levels of 2000V fast wave, 600V (inputs) or 1500V (power supply) slow wave, or 1000V oscillatory wave.

Circuit design and equipment choice precautions taken are intended to minimise electrical transients. Active signals required in aircraft operation are defined taking into account the potential disturbance. Analogue and digital inputs are filtered and monitored and computations of active and monitoring systems are performed asynchronously. Redundancy dissimilarities are introduced in hardware and software, and sometimes a particular computer has components physically separated. Finally, checks of overall processor activity are operated cyclically.

How safe?

But does it all work? In Spring 1988 the first airlines to take A320s into service – Air France, British Airways, and Air Inter – were standing by for even more trouble than a new airliner usually gives. The attitude had not been brought about by test programme troubles, but because the A320 was new in all respects; it was not a direct derivative of anything. Trouble arrived, but it was mostly to do with the air conditioning.

British Airways' fleet engineering manager for the A320 and DC-10, Ernie Bracken, says: "The flying controls are working extremely well. When there have been problems, the redundancy systems have dealt with them exactly as predicted, and most of the snags have been cleared up at line level."



Source "FAA guidelines for EMC"

Fig. 6. Electromagnetic interference sources, as classified by the FAA

In the early months of operation a number of computers needed software modification. Among these were the flight management and guidance computer (FMGC), fuel quantity indications computer, cargo compartment ventilation computer, avionics equipment ventilation computer, window heat computer and bleed monitoring computer. These are all important items, but not instantly fundamental to safe flight. The problem, Bracken explains, is a power supply spike or transient, "usually a switching transient." Each "box" vets its own power supply, and a spike can trip it. Resetting, then, is easy, but immensely irritating to have to do.

"These are computer problems of a type experienced on all new digital aircraft," says Airbus. The way they manifested themselves in the A320 was, first, that 95% of them occurred on the ground before engine start – British Airways confirms that figure. Then, when a "box" has tripped, the fact is immediately notified to the pilots on their instrument panel ECAM CRT screen (electronic centralised aircraft monitor). The most common tripping spike occurs at switchover from ground power to the APU generator before engine start. "You'll never cure spikes," says Bracken, "so it's best to make them acceptable." That has been the basis for the software modifications. The number of reported transient-related pre-flight equipment "trips" has now reduced to rarity, but not to elimination. The cure is to reach around to the circuit-breaker panels behind the pilots' seats and reset the switches.

Airbus says that spikes have never tripped the ELACs or SECs, and attributes their reliability simply to the particular effort that went into their hardware and software design. FADEC software has been modified only to update performance parameters, since there have been no problems. Their reliability from the start has been such as to make them "completely forgettable", according to pilots from several operating airlines.

One of the most embarrassing things that ever happened to the A320 occurred as it was flying low over the Champs Elysées on a service-entry celebration flight with the French President on board. A number of computers began progressively to "drop off", including the flight management guidance computers by which the aircraft is navigated. The ECAM screens, most worryingly, were telling the pilots nothing about what was going on. The only clue was that the working systems were all alternating current-powered, the drop-offs all DC.

What was happening was that one of the two transformer/rectifier units was failing. It was allowing voltage to drop enough to cause systems to cut out, but not enough to generate warnings, or to cause automatic transfer to the standby TRU or the DC busbar. There was no TRU failure warning, because when TRUs fail there is normally a sharp voltage drop; no sensors had been set to warn of a slight voltage drop. Airbus

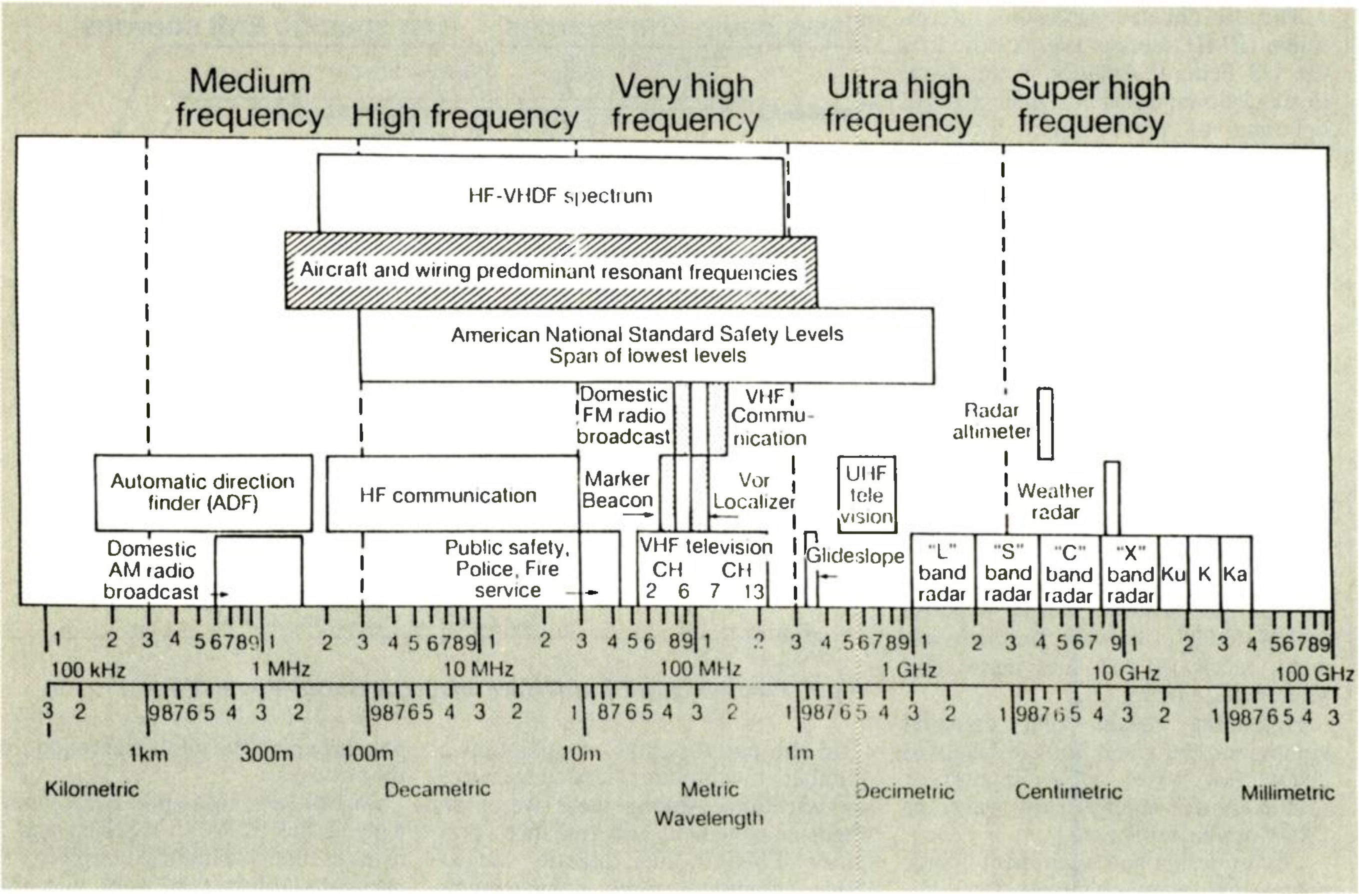


Fig. 7. RF sources, showing aircraft resonant frequencies spanning 1 to 400MHz

called it "a subtle failure".

Investigation proved the fault to be a progressive failure of diodes in the TRU because of the high current used to start the APU. Now the TRUs are higher quality, and the APU problem has been eliminated. The aircraft survived the incident with no trouble, but at the time it was carrying a number of baffled, embarrassed Airbus officials.

More embarrassing have been two fatal crashes in the aircraft's short life, especially since it is supposed to be safer than ordinary airliners.

The first, at Mulhouse-Habsheim Aerodrome in France, was caused by serious pilot misjudgement in electing to carry out a particular exercise at all, and then by basic pilot error while performing the exercise. Even if, in the judicial review of the accident which is currently in progress, facts emerge which were not available when the technical accident report was completed, the pilot error is still there and still fundamental.

The pilot elected to carry out, with 130 passengers on board, the kind of exercise which would normally be carried out only with an empty aeroplane. It was a low, slow flypast at an air show, purposely taking the aircraft to its performance limits, intending to demonstrate the A320's stall-protection. But then he seemed to forget that the aircraft's systems still assume some pilot inputs, and failed to deliver them on time.

The first error was in the briefing to conduct the flypast at 100ft above ground level (AGL) at an airfield strange to both pilots: that is inadvisably low. Then the pilots saw the airfield late, and descended with engines at idle. Instead of flying past at 100ft, the flight data recorder (FDR) records 32ft AGL, with throttles still closed and undercarriage down. In that flight phase, the aircraft still provides alpha (stall) protection, but not alpha-floor (if it provided the latter, full power would come on automatically just as pilots settle their A320s onto the runway. Alpha-floor cuts out below 100ft AGL). So the pilots had to select throttles manually to clear the trees at the end of the runway and climb away. These engines, characteristically of jet engines, take 8s to wind up from idle to full power. The digital flight data recorder (DFDR) shows that the pilots pushed the throttles forward 5s before impact with the trees, although there is dispute on this point.

The alpha-protection system did work, and may have saved lives. The A320 was fully under control as video film shows it sinking eerily smoothly into the forest. Three people died in the fire which resulted from the impact.

An accident at Bangalore is a puzzle as yet, but although it is known that the Indian investigators have huge amounts of data from the FDR and the cockpit voice recorder, they have not contacted anyone with evidence of technical faults. It is normal practice, for obvious reasons, immediately to share with the rest of the industry – particularly the manufacturer and other operators of the same type – any lessons learned from an accident. Either the Indians are departing unwisely from normal practice, or the crash was caused by a non-technical problem like sabotage or pilot error.

If it was pilot error , the big question hanging over the A320 seems not to be "are the computers safe?", but "are pilots safe with computers?". Do pilots expect too much from them, and thus take their aeroplanes closer to performance limits than they would ever dream of going in conventional airliners? ■

Illustrations by courtesy of Airbus Industrie

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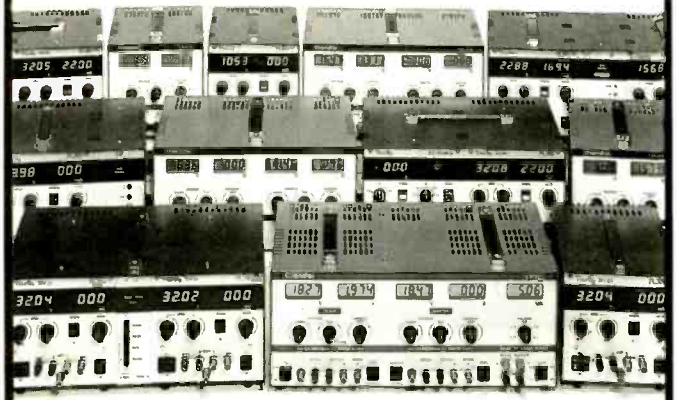

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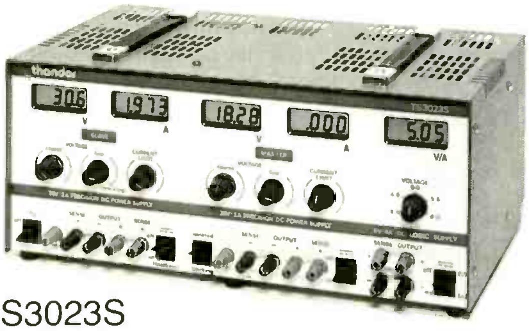

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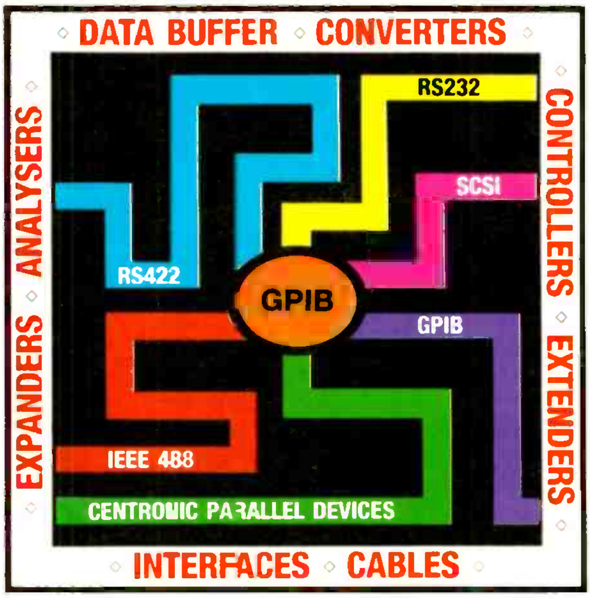

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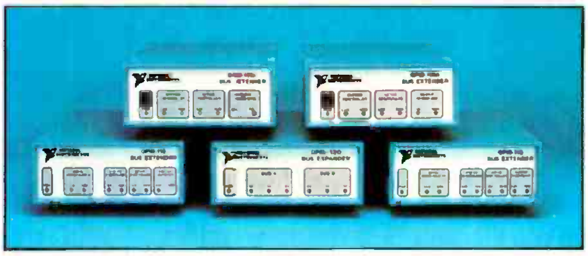

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ISIS: INTELLIGENT SCHEMATIC CAPTURE?

John Anderson investigates the claims to intelligence of Labcenter's software package. Is it brighter than the average, or simply rather fast?

ISIS is a new British schematic capture product from Labcenter Electronics based in Bradford. The package, which may be used for stand-alone schematic capture, can also operate as the input section for Labcenter's autorouteing PCB package PC-B PRO/AR. It comprises two floppy disks and a desk-top published manual in a low-budget A5 ring binder.

Installation

Two different methods of installation are offered, depending on whether you are using twin floppy or hard-disk drives. The hard-disk installation is achieved by placing the ISIS system disk in drive A and typing HDINST. This is an executable file which goes away and fiddles with your hard disk, creating its own directory and copying files across. Once the library data has been transferred, the user is given some rather strange printer and plotter selection prompts, with no guidance from the manual. I selected at random only to be told that the selection may be changed later.

In common with many schematic capture programs it is not dongled, the program being stamped with the license holder's name.

Documentation

Although rather cheaply produced, the manual is well laid out and well written. It is effectively in three parts: installation, a discussion of concepts with comments as to how the program works, and a reference manual. It would have been helpful if a tutorial section had been included — particularly important for a program which has no on-line help and yet has facilities which are not wholly obvious.

Operation

The whole program works in a graphical WIMP (windows, icons, mouse, pull-downs) environment, which means that the user would normally work through the mouse. A number of operational areas compose the screen: the top line menu, from which conventional pull-down window menus are available; three small boxes on the right hand side of the screen termed the overview win-

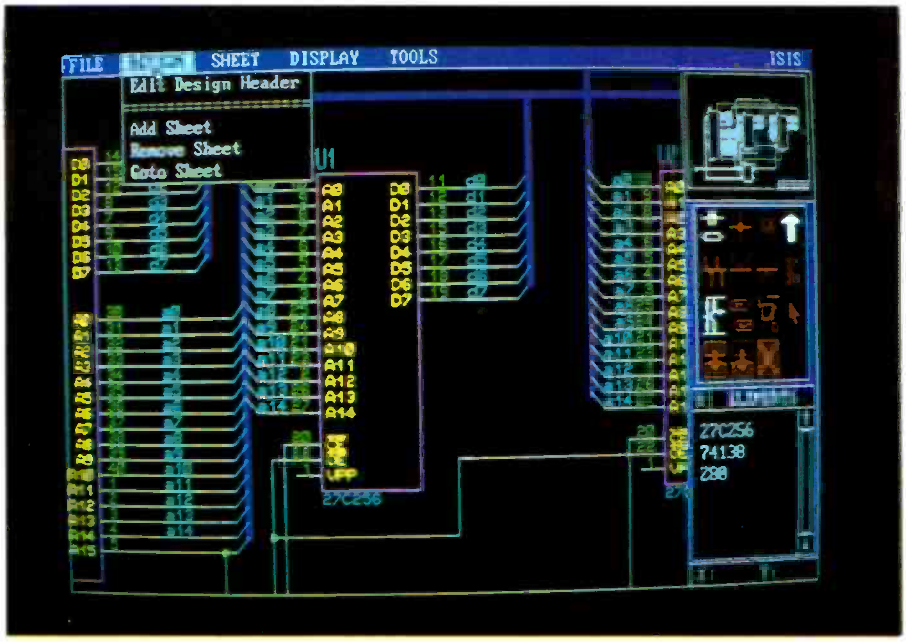

Fig. 1. ISIS working screen, showing the overview window, toolbox and element list on the right

System requirements
PC, PCAT, or PCAT 386 compatible
minimum 512K of RAM
MS-DOS 3.0 or later
Hard disk or two floppy disk drives
Graphics card EGA or VGA
Colour monitor
Mouse (Microsoft compatible)
Pen and ink plotter
Printer

dow, the toolbox and the element list; and the remainder of the screen which is available for editing.

The overview window shows the whole sheet, with the current rectangular view imposed upon it. By clicking the mouse on a particular part of the overview window, the main view is switched to show that area — a facility which effectively replaces the pan command of other cad packages.

One thing that sets ISIS apart is the use of an icon-based toolbox menu. The way in which this works is that the user points the mouse at the required icon, presses the left-hand mouse button and that mode is selected.

It is worth saying that, although a picture can save a thousand words, a poorly drawn picture (in this case an icon) can generate several dozen swear words. The basis for the Xerox icon-based environment (adopted later by Apple) is that the icons must be more expressive of the object or command action than the corresponding words. ISIS offers both its rather confusing icons and a conventional character-driven pull-down window system. It would have been better to have named the icons on screen, or have adopted a separate pull-action menu consistent with the other menus.

Connections are made intelligently — at least, they are supposed to be. The way in which this works is that, the components having been placed, they are connected by selecting the wireup icons, and clicking with the mouse on the end of the first component. This generates an elastic band response, with one end tied to the component end just clicked and the other at the end of the mouse cursor. Clicking at the second component node converts the elastic band to a permanent route, which is evaluated as horizontal and vertical lines only.

In many cases, this conversion is reasonable, giving a highly presentable finish. However, it seems to take only a local view of the routeing requirement; for example, if a component is in the way of a direct horizontal or vertical route, it is avoided by introducing a notch in the route. Although this seems reasonable, it can lead to a somewhat unpolished drawing. The automatic routeing may be turned off, either at the toolbox or by clicking the mouse at some intermediate point between nodes.

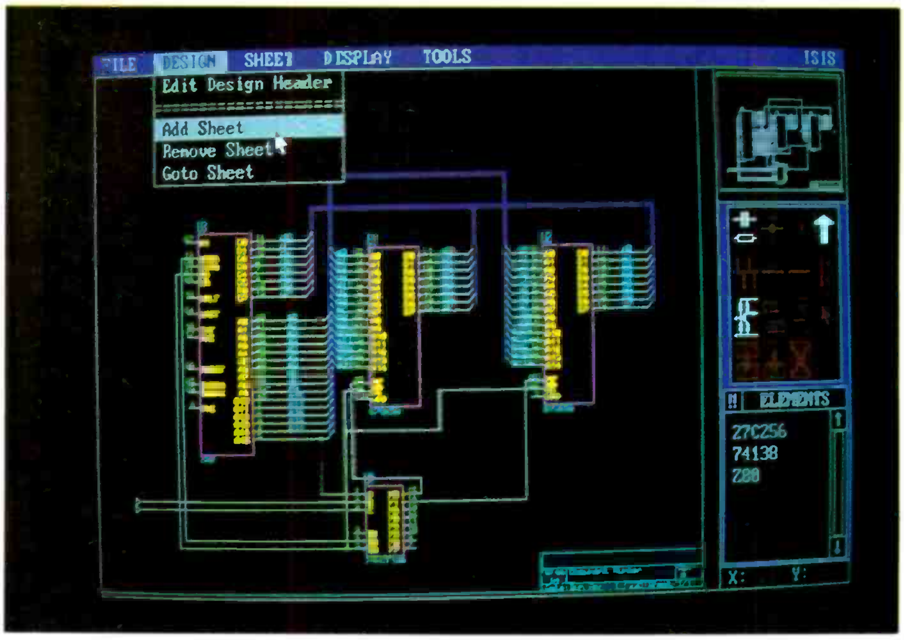

Fig. 2. Buses are shown as lines with named wires terminating on component pins

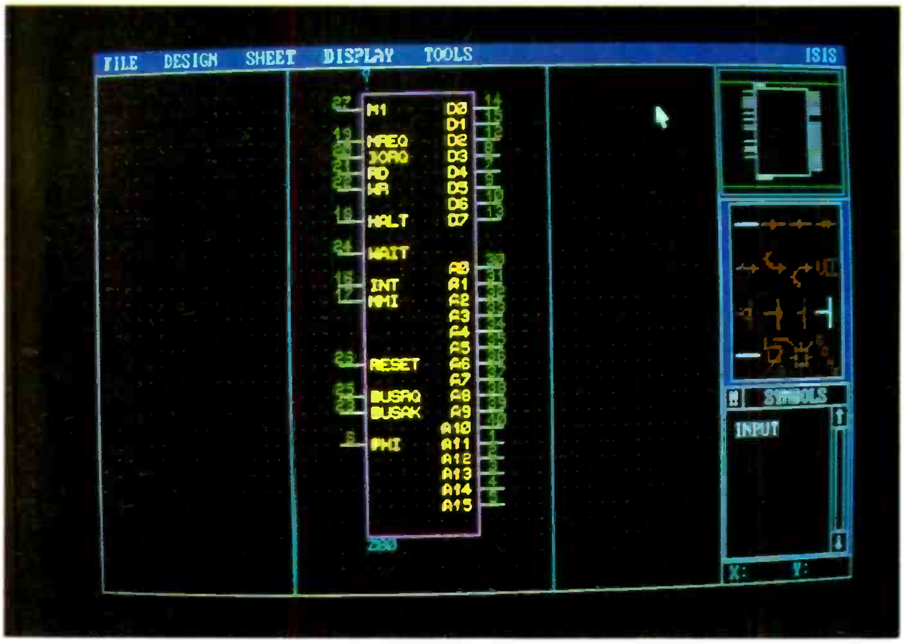

Fig. 3. Edit Component mode for creating "new" devices – in this case a microprocessor

One minor criticism was that the overview window was not updated as a matter of course (a repaint screen command is required), so there were times when there wasn't a direct correspondence with the edit area.

Editing

Most of the editing features of other schematic capture programs are available with ISIS. However, one point worthy of mention is the novel tagging system. Tagged objects can be treated as a single entity which in turn can be moved, copied or deleted.

Speed

Speed of window draw and remove is excellent, comparable with that of the highly optimised GEM environment, and makes the screen redraw speed look rather slow, though in fact it is very fast.

Components and library

This works by preselecting a group of components from the libraries into a selection list, components then being

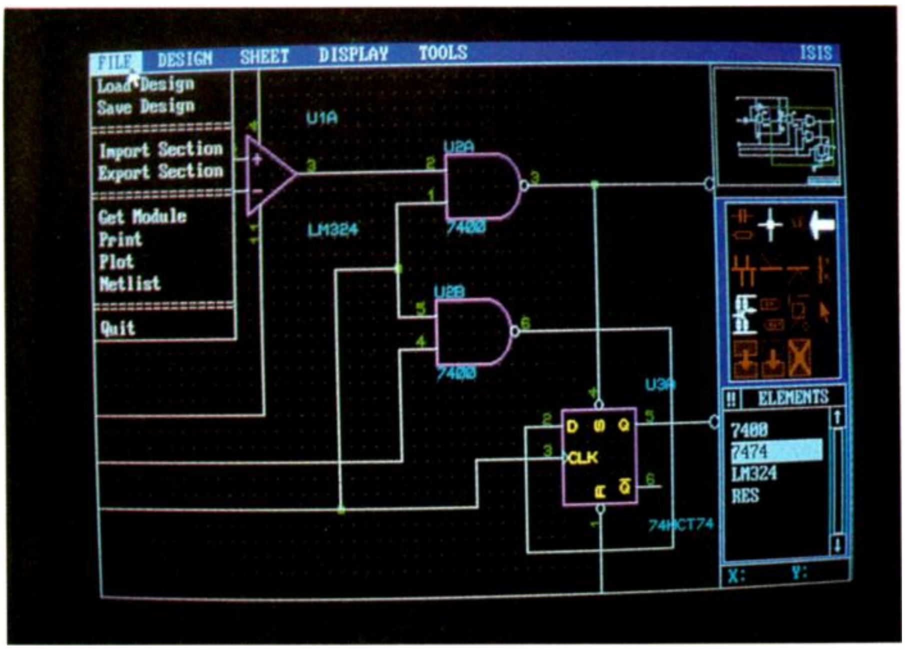

Fig. 4. Large designs can be built up from a number of smaller sheets, such as this one

selected from the list for placement on the schematic. The system works well, and makes for very fast access to the chosen components.

The libraries themselves can be described as barely adequate. In the absence of any demonstration programs, I considered drawing up a simple microprocessor system, but was initially dissuaded because there were no microprocessor or connector components.

This forced an to attempt to create a new component. On selection of the Edit Component mode, the toolbox icons switch to a new set, in some ways equally enigmatic. However, once the rudiments of component generation had been mastered, the process turned out to be quick and straightforward, with smart repeat facilities for pin naming and numbering.

Multi-sheet designs

Larger systems must be represented by a number of sub-systems, which in turn may be documented by a number of sub-modules. This is the basis of the ISIS hierarchical tree structured scheme, in direct contrast to other packages which provide linear sheets in which a design is built up with a number of sheets, conceptually at the same level. This method is preferable for documentation of a large system, in that it should assist in providing a positive structure to the design documentation process.

Demonstration files

No demonstration files were available in the package. This is a silly omission because the user interface is somewhat quirky, and the new user needs as much help as possible.

Lines and buses

ISIS can handle buses in the same way as most other schematic-capture programs, with a bus-style line and named wires emanating from the bus to the individual pins of the components. This again prompts a comment about the slightly quirky nature of this program. It has a simple-to-use repeat facility invoked by double-clicking of the mouse button, rather than the more usual repeat-count controlled repeat.

One fiddly aspect of this is that the entry to a bus is through a specific 45° route section.

Supplier
Labcenter Electronics
14 Mariners Drive
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Price: ISIS £399 plus vat
ISIS SUPERSKETCH £69 plus vat or £99 plus vat with extended library

Netlists and auxiliary files

Schematics can be translated to a netlist form termed by Labcenter as Schematic Description Format or SDF. The file format thus generated is ASCII, which can be conveniently converted to other formats if necessary; a conversion facility to convert to some of the better known formats (including SPICE) is supplied.

Two other programs are supplied which process the SDF files: a bill of materials facility; and, more interestingly, an electrical rules check which provides automatic checking that the schematic makes sense — that outputs are not connected together, for example. Very nice.

Conclusion

Initially I did not find the software either easy to use or convenient even when I had mastered the commands. However, during the course of preparing this review, the slightly idiosyncratic methodology of ISIS was learnt and, as a result, I believe that productivity of schematic capture with ISIS may ultimately be as good as with any competitive product.

In a short discussion with Labcenter, I discovered that the company is addressing many of the criticisms made in this review. It is continually extending the ISIS libraries — the demonstration file is currently only supplied on its free demonstration disk and a tutorial is being considered for the manual.

Perhaps of more interest is that a new low-cost version of this product called "Supersketch" is now available, in effect ISIS without the netlist and post-processing facilities. As an introduction to schematic capture, this may be particularly useful in education.

So, is ISIS the Intelligent Schematic Input System? Well, the answer is, "Yes and no." It is certainly an adequate schematic-capture package, with capabilities comparable to those provided by very much more expensive foreign (mostly US) competitors. The software, however, possesses no special attributes to warrant its name, although it is a workmanlike product and, at £399, it undercuts its peers as well as outperforming them in terms of its speed of response.

This enthusiasm must be dampened because, inevitably, productivity will initially be curtailed while the user builds up the libraries from the currently rather restricted base. ■

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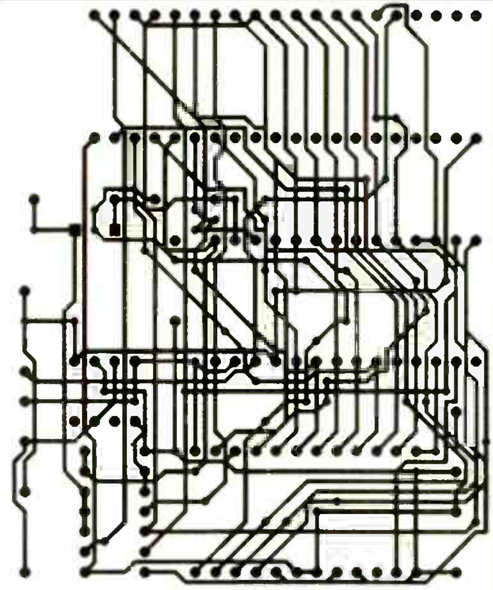

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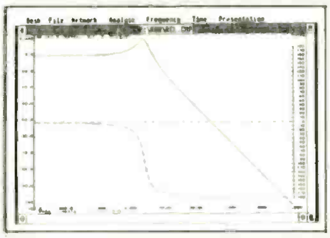

Frequency response of a low pass filter circuit

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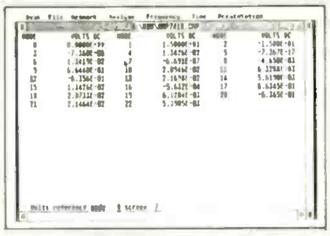

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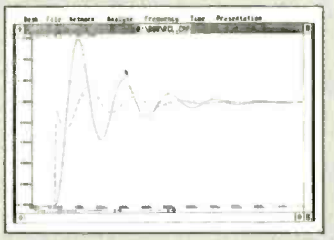

Impulse response of low pass filter (transient analysis)

3 Transient analysis

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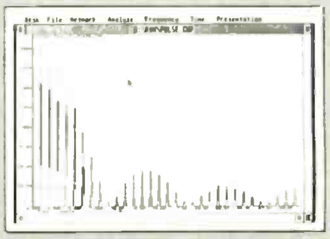

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MAINS SIGNALLING

Industrial and domestic wiring is a wasted resource. You may be ignoring an effective datacomms network. Kevin Kirk explains how to make use of it.

The use of the mains electrical wiring for the conveying of information, either in digital form for control and computer applications or as an analogue signal for intercommunication or music transmission, seems at first glance a very sensible use of an existing resource. In this way information will be conveyed between remote corners of a home, factory or office without the cost of extra cabling and without reverting to licensed transmission methods such as radio.

Indeed, with the cooperation of the relevant generating utility it may be used to return information from the customer's premises for remote meter reading, faults, service information and alarm conditions.

There are, however, of course, snags, one set of which is physical and may be overcome with the judicious application of some electronics. The other, however, is political and needs the cooperation of a wide range of interests from national governments through the various manufacturers to the consumer, all of whom can normally be expected to protect their own interests. This latter problem is, as usual, the most intractable.

Problems of mains communication

The reactance of the mains wiring depends very much on the environment, but at 100kHz it is usually reckoned to have resistance of 2 to 5Ω in an industrial environment and 5 to 30Ω in a domestic one. The inductance is usually between 10 and 30 μH. The final reactances are not precisely known, since they vary from installation to installation and each time an appliance is plugged in (for example, equipment line cords on their own show about 0.7μH and 30pF per metre). In addition, there is an attenuation of about 7dB on a 50m run with a 10Ω termination; the impedance of the line at 125kHz, yielding a quarter wavelength of 600m, is 100Ω.

BSI recommend an artificial mains network with a resistance of 50Ω and an inductance of 50μH. Apart from being of low impedance and reactive, the mains suffers from a series of other problems.

Noise. This is mainly impulse noise which appears in the baseband and has a frequency interval of (carrier ±2.data.). Its frequency spectrum is continuous (as impulse is defined to be of infinite amplitude and zero time duration) which translates into a carrier of short duration at the receiver, mainly due to receiver saturation, if inadequately clamped. It may also ring with the natural frequency of the line.

CW interference, which can be caused by various sources, the worst culprit being low-pressure mercury-vapour (fluorescent) lights. Its spectral components tend to be multiples of 60kHz, amplitude modulated at 100Hz.

Line impedance modulation. The impedance of the line changes according to the number and power comsumption of the various pieces of equipment loading the mains at any one time. 100Hz impedance modulation occurs as a result of rectification at 50Hz.

Power factor correction capacitors used on fluorescent lighting can cause serious attenuation and distortion.

System crosstalk from two adjacent control systems (for instance in two adjacent houses) or two non-compatible systems. Added to this list is the requirement for mains isolation, which must comply with at least BS415.

Fluorescent lights are not entirely compatible with mains communication. In the USA, power factor correction is not usually used, since the customer is not penalised if a poor power factor is generated on an industrial site.

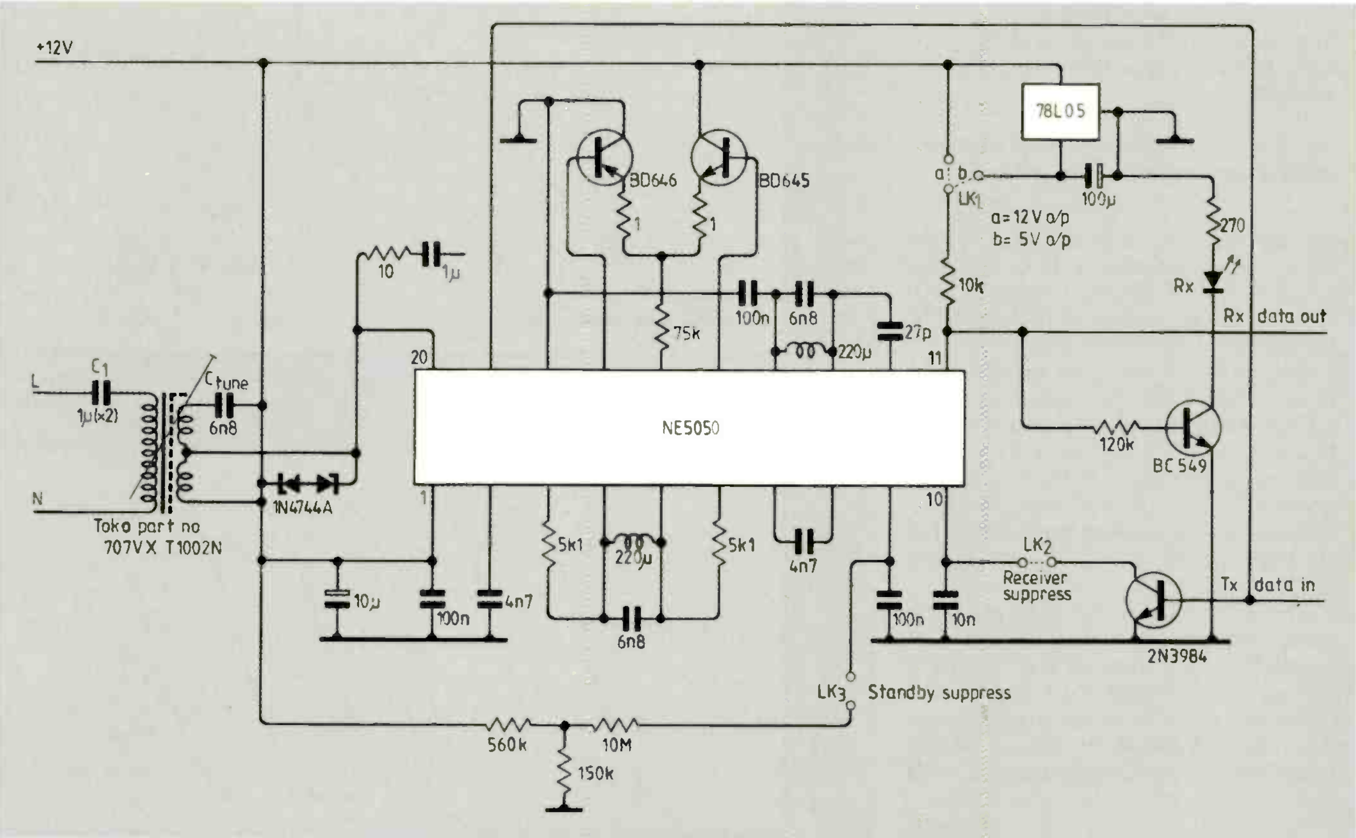
There are two products of power factor correction, the first being that with power factor capacitors fitted the impedance of the line is reduced and communication becomes more difficult. The second effect is beneficial in that the capacitors do help to filter out the CW interference to a certain extent. So any system must be able to cope with either or both situations.

One way of reducing the effect of many of the above problems is by carefully designing the mains interface stage. This should consist of some form of isolating transformer/tuned circuit arrangement, which must provide mains isolation at least to BS415; a stable resonant frequency that is not affected by the changes in line impedance of the mains network; and tight coupling for the transmitted carrier with loose coupling for transients.

Where cost is no object, the best solution would be two separate transformers for transmitter and receiver with the Tx circuit having a low Q and the Rx circuit having a very high Q, the receiver working at line voltage with more than 110dB of dynamic range. Apart from difficulties of designing a receiver with these specifications, the system poses problems of safety as well as tremendous cost.

So a compromise must be reached, which usually involves the use of a single specially wound transformer with series and parallel capacitors to provide a tuned input, the transformer used depending very much on which modem IC is used.

At present, there are two main chips: one from National Semiconductor and the other from Signetics. The NS unit uses FSK and the Signetics device uses amplitude shift keying (ASK) which is analogous to CW, since it consists of switching on and off a carrier. FSK has a better bit error rate than ASK (with PSK better still)



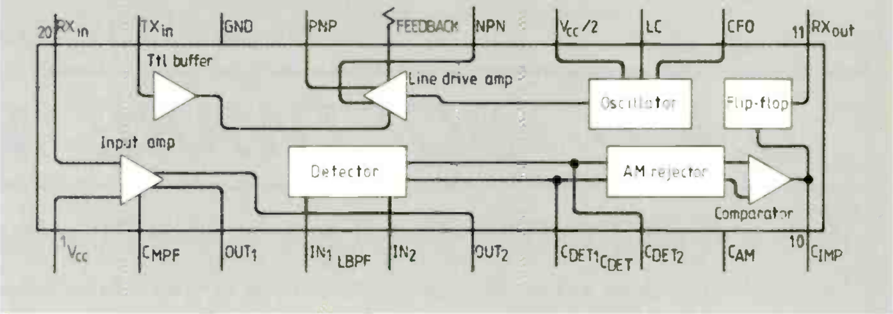


Fig. 1. Circuit diagram of mains signalling transreceiver. Block diagram of the NE5050 is shown below.

with a white gaussian noise input. However, as most mains noise is impulsive, there is some doubt about which is best.

Experimental circuit

Probably of more importance is the transmission speed and protocol, which means that either system could be used. For this design the Signetics device has been chosen, primarily because it is readily available; it is also very popular in the USA, being used on the General Electric *Homenet* system.

Figure 1 shows the circuit diagram of the complete unit. It is fairly straightforward, but there are two components whose selection is important.

The first is the transformer, which is the most critical part of the unit because it isolates the circuit from the mains; it couples the signal to the mains; and it provides a tuned input (first-order filter) for the incoming signal. It can be wound by hand, but it is easier (and safer) to use the transformer recommended by Signetics, which is a TOKO 707VX-T1002N.

This is coupled to the mains via a capacitor whose value is chosen to provide a high-pass filter in conjunction with the transformer to provide rejection of about 100dB at 50Hz. At the same time the capacitor must provide a lower-impedance path to the carrier than the nominal 15Ω power line impedance. Once the value is chosen, it should be checked to ensure that the line current is small enough to keep the transformer out of saturation (around 10A/turn).

The line current varies linearly from about 5mA for a 100nF capacitor to 500mA for 10µF. It is necessary to ensure that the capacitor is not series resonant with the transformer and reflected tank impedance or the low resistance will decrease the transmitted range. The capacitor type should be a 600V AC rated capacitor (X2). The tuning capacitor C_{tune} is around 6.8nF for a carrier frequency of 100kHz, a polypropylene capacitor's −150ppm/°C temperature coefficient exactly compensating for that of the transformer.

The circuit itself consists of a transmitter and a receiver, the majority of both functions being contained in the NE5050.

Transmitter. This consists of an oscillator formed around the components on pins 12, 13 and 14 which, in turn, feeds a differential line driver amplifier whose output can either drive booster transistors as in our circuit, or can drive the line direct at a reduced level. The output is amplitude modulated (the manufacturer insists on that, although as far as I can see it is just turned on and off as in CW!) by an incoming data input from pin 19 via a TTL buffer.

Receiver. A much more complex circuit is needed to resolve the incoming signal. The first stage is a differential amplifier which can accept signals up to ±35V and will give a differential output of 1.2V. These outputs on pins 3 and 6 are usually fed into a bandpass filter but this can be left out if desired or, in noisy environments, may be replaced by a quartz filter. Note, however, that the bias requirement of the next stage is such that the output needs to be biassed to the middle of the supply range.

Pins 4 and 5 form an input to the detector stage, which is a four-quadrant Gilbert multiplier giving full-wave rectification, which provides a hyperbolic tangent squared output (not a rectified sinusoid!). So it acts like a phase detector with an output proportional to the bias current, carrier amplitude and load resistance.

The next stage is the AM rejection circuit, which gives a rejection of 40dB at 100kHz, the output of this being fed through a comparator to C_{IMP} which filters out impulse noise. It also feeds the output flip-flop on whose output (pin 11) the received signal appears. ■

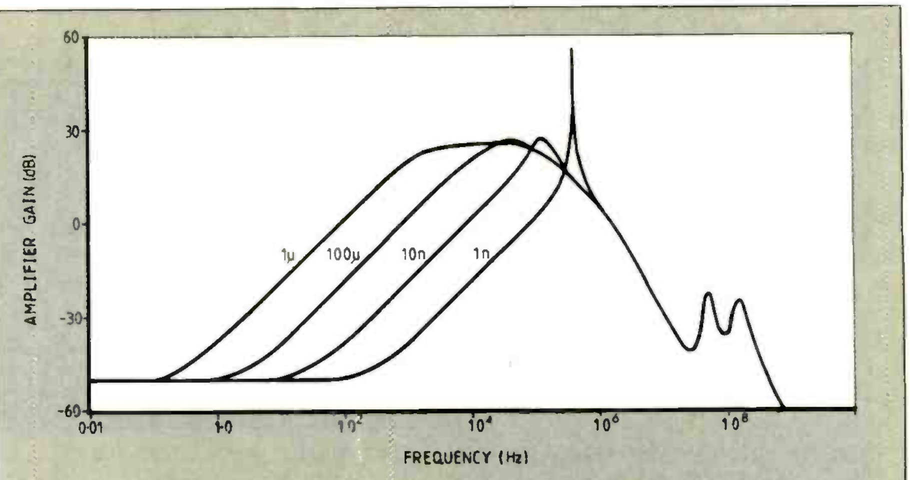


Fig. 2. Receiver amplifier gain vs frequency for different values of the high-pass filter capacitor on pin 2 of the NE5050.

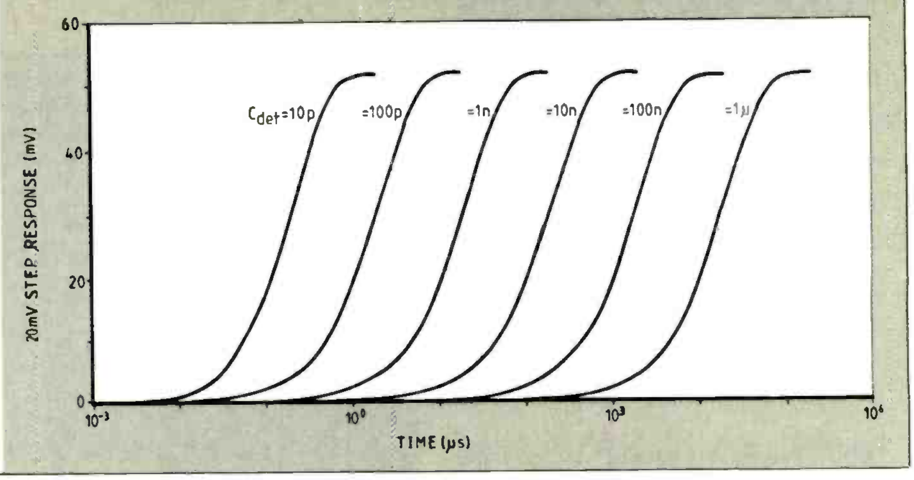


Fig. 3. Delay of AM detector for values of output capacitor between pins 7 and 8.

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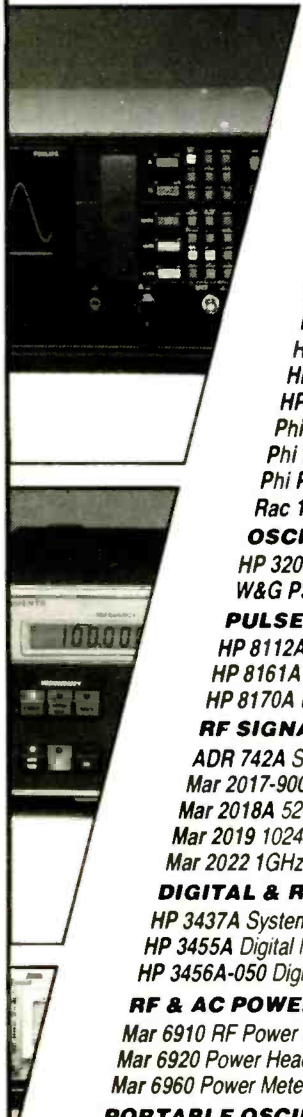

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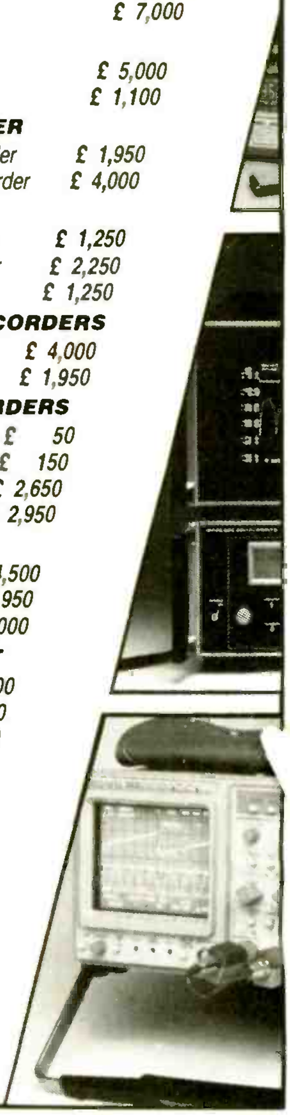

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MIL-TECH DATACOMMS

Several establishments of the MoD conduct research into the theory and techniques of radio communication. Some of their developments have civilian applications and Simon Atkinson describes three examples of modems for radio data communication

HF communication still provides unbeatable price/performance characteristics, as well as flexibility. Considerable effort is being expended by the military in improving HF techniques and the first two inventions originate from this interest, although the techniques have possibly their most commercial attraction in other bands.

The HF band is not a reliable medium, partly due to atmospheric effects on the ionosphere and partly due to the lack of strict international control on its use. In any event, such control is likely to break down in wartime.

Atmospheric effects are such that, at different times of day, different frequencies are better or worse for communication, the main problems being noise, interference, and fading; **Fig.1** shows some typical HF interference spectra. These problems are usually dealt with by careful frequency/time planning, but the result is that effective communication may take some time and information transfer will not be up to date.

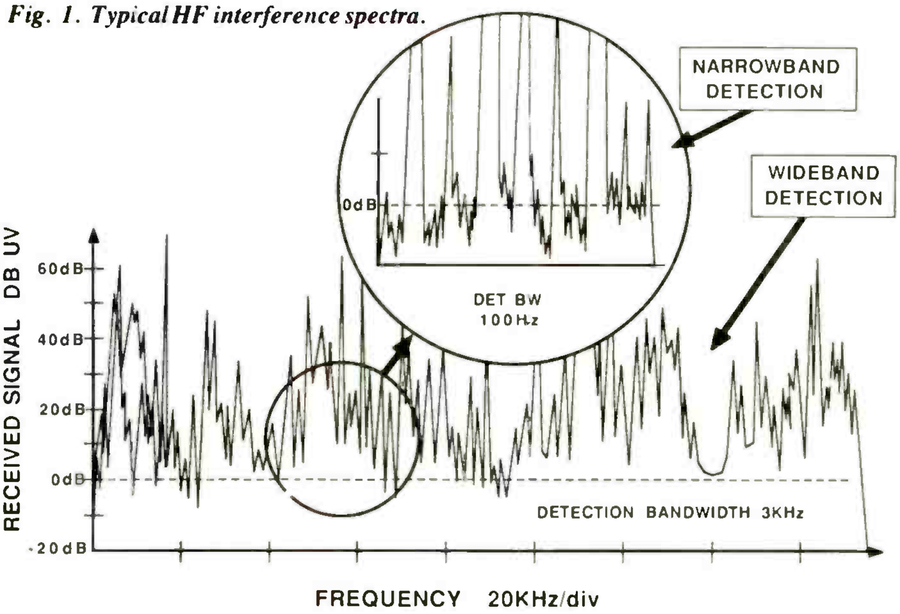
There is, therefore, a need to improve the reliability of HF communications. Another way of looking at this is that maintaining existing reliability levels would require less power, which is where commercial benefits would lie. Since voice communication needs a lot of power for reliable hearing, this is ruled out. Morse is subject to interference, requires trained operators, and is not amenable to modern computer processing. Thus, the solution lies in digital data communication.

High-reliability modem

The first solution to be described originates from the Admiralty Research Establishment and is a highly reliable communication system using both frequency and time diversity; that is, the signal is sent at different frequencies at different times, so maximising the possibility of successful reception. The obvious penalty is one of speed, but this does not necessarily imply loss of throughput, since a slow, successful transmission may be better than a fast one that must be repeated.

The audio-frequency band is divided, for example, into ten frequencies, five alternate ones allocated to represent a digital 1, the other five representing a digital 0. To transmit a 1, each of the 1 frequencies is sent consecutively for a fixed length of time (currently 20ms),

Fig. 1. Typical HF interference spectra.



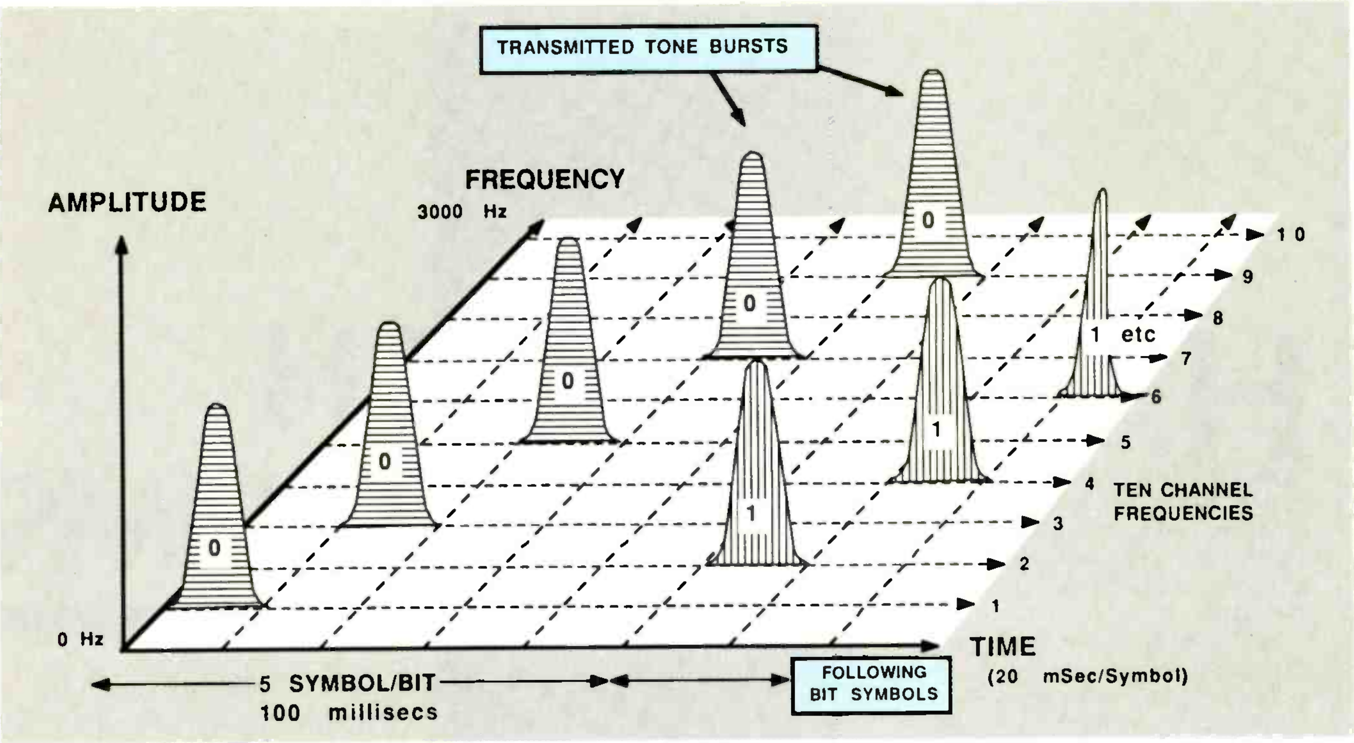


Fig. 2. Highly reliable modem system, in which information is effectively sent ten times by presence or absence of one or other set of frequencies.

the total bit time being five times the individual frequency time. At the end of the bit time, the information has effectively been sent ten times, five times by the presence of the 1 frequencies, and five times by the absence of the 0 frequencies. Transmitting a 0 is clearly the opposite of this, and both situations are shown diagrammatically in a 3-D manner in **Fig.2.**

The receiver has ten filters corresponding to the ten frequencies, accumulating information about all frequencies at all times. Noise and interference information is therefore also embedded in this data and, by suitable algorithms, the original message can be processed out of significant adverse conditions. These algorithms are the key to the whole system and, once proved, can be adapted to other choices of bit-rate/number of frequencies.

ARE has successfully proved these algorithms, using ten frequencies, five per bit, which at 20ms per frequency results in an effective bit rate of 10b/s. When the signal was 10dB *below* 3kHz wide-band noise, the received character error rate was less than 2%. Repeating the message significantly reduces the error rate without using parity checking or any other coding scheme; a message was received at a level of 40dB below an in-band standard frequency exchange keying (FEK) signal, and then resent at 30dB below, resulting in *no* errors in 330 characters.

On trials in Norway, a 3W manpack transceiver fitted with a small HF loop antenna transmitted a message with repeat, resulting in a character error rate of less than 6%. One apparently curious effect is that multipath propagation improves the transmission and reduces the error rate.

Having proved the concept successfully, ARE now intends to apply it in two ways: first, for the ultimate in low transmitter power working, a version operating at 1b/s has been specified; and second, for higher speed working, a version operating at 40b/s is envisaged.

While originally invented to solve the problems of HF communication, this technique has potential in other bands where low power is a constraining factor and low data rates are acceptable; for example, in battery-powered VHF/UHF radio telemetry, which is being increasingly used by public utilities such as water authorities.

Adaptive chirp modem

This is a similar, but alternative solution to the HF propagation problem. Rather

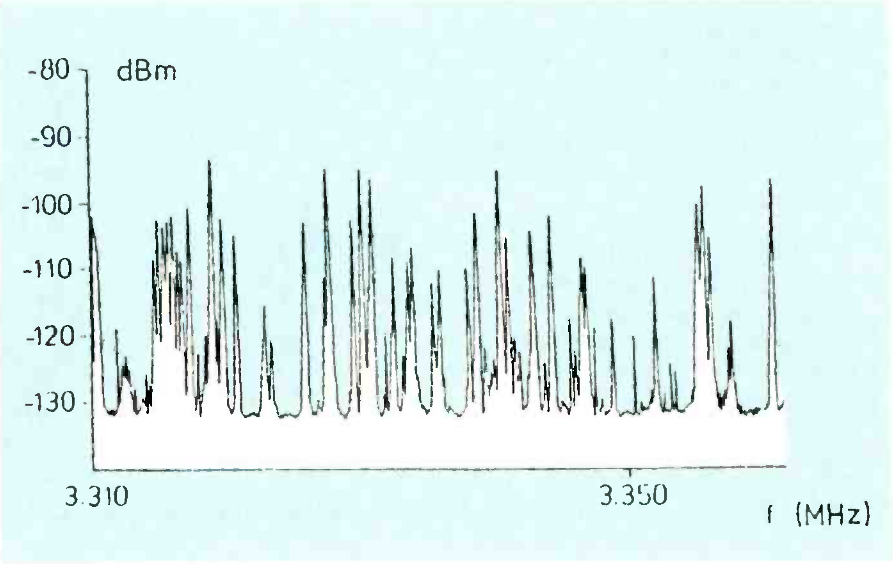


Fig. 3. Interference in the band used by the chirp modem is narrow-band relative to the sweep and is excised by adaptive filtering.

than sending a set of different frequencies, a "chirp" signal is used. (A chirp signal is one whose frequency is swept, and therefore contains all frequencies between the upper and lower limits).

A robust system was proposed and implemented at UMIST, which included automatic excision of the in-band interference. The main part of this work was supported by RSRE, and developments of the system continue to be undertaken at UMIST and RSRE.

UMIST has a research group under Dr G. F. Gott which has researched the HF area for many years. One of the subjects of research has been spectrum occupancy: the content of the band is continuously monitored and the signal and interference characteristics recorded.

An example of this is shown in **Fig.3.** This shows that much of the interference is narrow-band, relative to the chirp frequency sweep, so that excision is generally effective in rejecting it. However, without excision, the total power of interference within the sweep was often excessive for reliable communication.

Statistically, the probability of finding a narrow bandwidth which is interference-free is greater than that of finding a relatively uncluttered wider bandwidth. Hence, without excision, narrow-band systems may outperform wide-band systems, but with excision, the converse is true.

Excision is achieved by including in the detector an interference assessor, which measures interference levels across the chirp signal bandwidth. Those parts of the spectrum containing severe interference are then rejected by adaptive filtering before the data decisions are made, suppressing the interference and the corresponding parts of the chirp spectrum. However, the signal-to-interference ratio is enhanced and the rejection reduces the error rate when the power spectral density of interference within the chirp signal bandwidth is non-uniform.

UMIST and RSRE have now developed several systems which successfully prove this postulate. Initially, the chirp modem inserted time gaps into the transmission, in which the detector analysed the interference within the swept bandwidth and set up the adaptive excision filter for the subsequent data burst. Current versions continuously perform spectral analysis of the received chirp signals plus interference and conti-

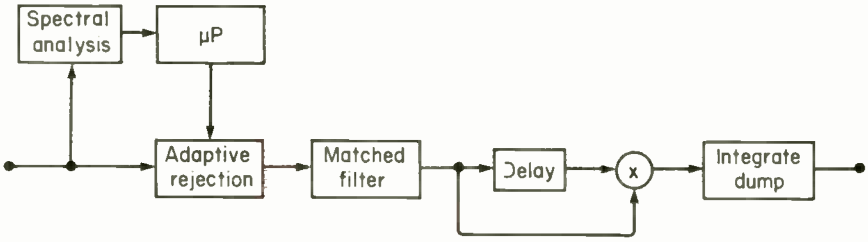


Fig. 4. Digital chirp modem, which carries out spectral analysis, interference estimation and adaptive filtering on one DSP chip.

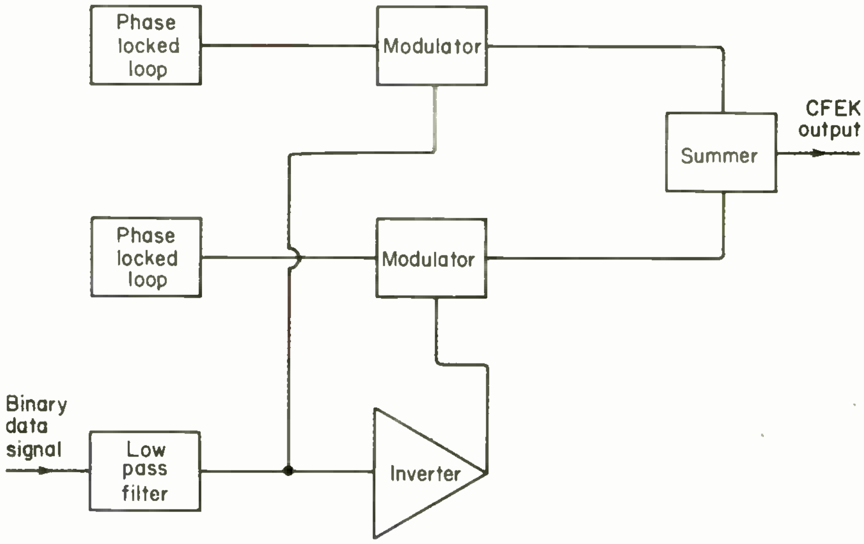


Fig. 5. Block diagram of coherent frequency exchange keyed modem, which provides reduced side-lobes to avoid adjacent-channel interference.

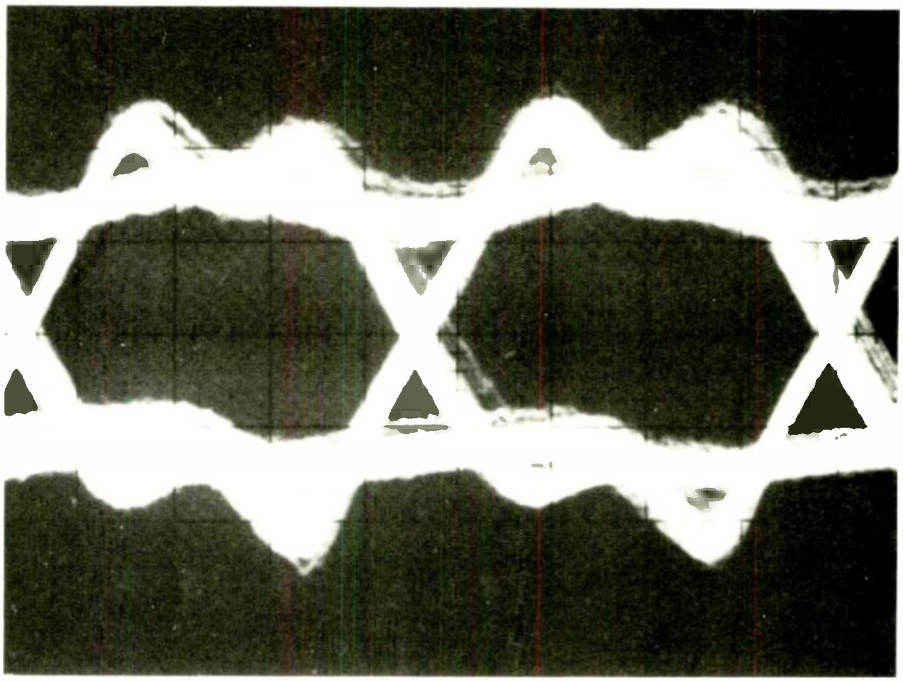


Fig. 6. Eye pattern of CFEK waveform at a high signal-to-noise ratio.

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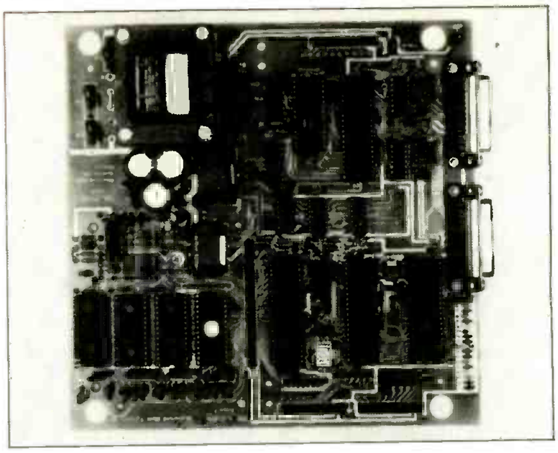

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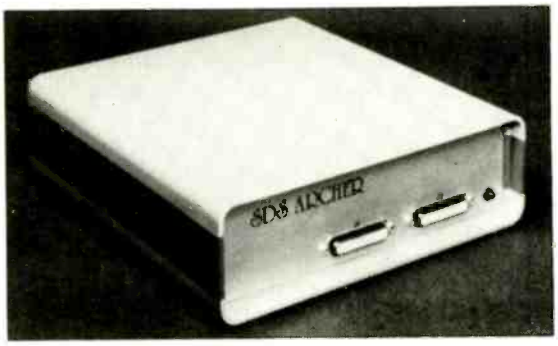

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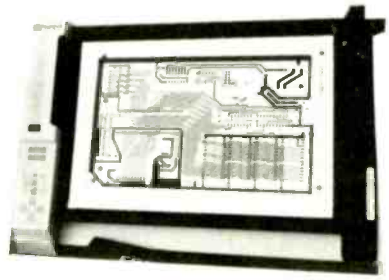

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nuously update the adaptive excision filter.

The information is sent in the differential phase of adjacent chirp signals and is therefore present at all points in the signal. Since it is a continuously varying signal, the number of frequencies is theoretically infinite, presenting a challenging processing problem. Originally, this was achieved on an analogue version running at 75b/s, but this has been converted to a digital version which performs spectral analysis, interference estimation, adaptive excision, and subsequent matched filter data detection, using a digital signal processor chip.

A block diagram of this implementation is shown in **Fig.4.** In addition, an analogue version of a higher-speed version has been developed and work on this is continuing, with the aim of producing a digital implementation running at 600b/s with Doppler rejection.

The potential commercial applications for this invention would be in the field of long-distance radio communications, particularly in the HF band. It has not yet been characterised in other bands.

CFEK modem

This is the invention of a group at RAE Farnborough and is being used to provide high-speed UHF air-to-ground telementry links.

The problems addressed by this development are the large bandwidth required for high-speed data and the poor envelope characteristics. The former gives rise to spectrum pollution and the latter to inefficient power usage.

CFEK stands for coherent frequency exchange keying, one of the distinguishing features of the technique being that there is no phase discontinuity of the modulated signal at the transition points of the binary data signal. The frequencies of the two carrier waves are related, in that the difference between them is an integral multiple of the bit rate. The result is a signal with greatly decreased side-lobes, and hence reduced adjacent-channel interference; it also has minimal envelope ripple, making for easy power amplification.

The technique has been implemented and tested at a number of different bit rates, mainly 16kb/s, but its main commercial use would be as a 4800b/s modem in the unlicensed 12.5kHz VHF/UHF low-power telemetry band (DTI specification MPT 1329 – 458MHz).

The present implementation uses two carrier waves which are amplitude modulated and summed to produce a frequency-keyed waveform, the binary data signal being filtered to produce a baseband signal and then split into two data streams. One stream is amplitude modulated onto one of the carrier waves, while the second is inverted and then amplitude modulated onto the second carrier wave. A block diagram of this implementation is shown in **Fig. 5.**

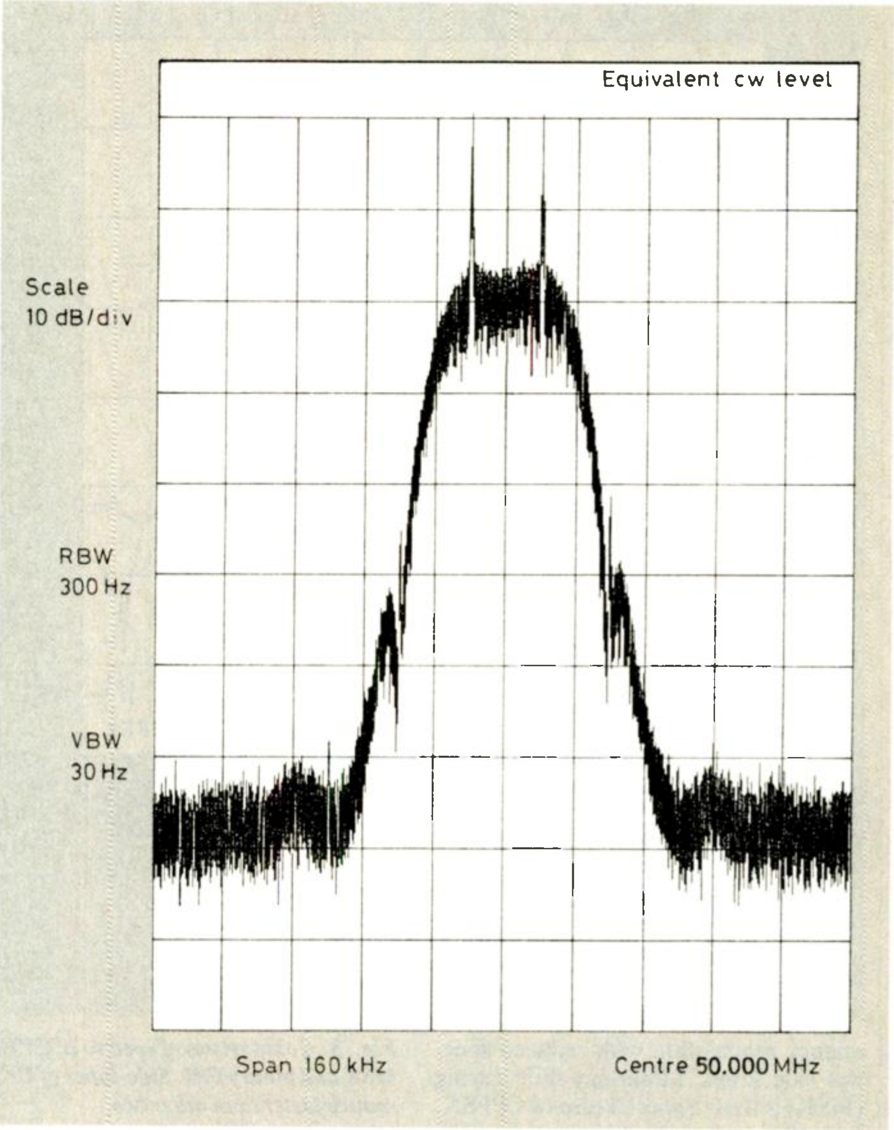

Fig. 7. Spectrum of CFEK at 16kbaud. Compare with Fig. 8.

Theoretical analysis and practical testing of this technique have shown it to have the expected superior side-lobe suppression compared to other forms of modulation. It closely approximates the envelope constancy of FM, and the signal is easily demodulated using standard FM techniques. A major advantage over FM is the lack of RF filtering required for FM spectral containment; the spectral shaping is performed at baseband.

Tests were made to compare the signal-to-noise performance of CFEK to that of binary FM. A 50MHz CFEK waveform with a 16Kbaud pseudo-random binary modulation was attenuated and delivered to the input of a measurement receiver. The demodulated FM output was displayed on an oscilloscope to make an "eye pattern", which closed as the signal-to-noise ratio was reduced. A similar procedure was adopted for a binary FM signal with the same modulation at a peak deviation of ±8kHz and the same receiver bandwidth; the CFEK signal could be followed 3dB further into the noise than the FM. **Figure 6** is a photograph of the CFEK eye pattern at a high signal-to-noise ratio.

Figure 7 shows the bandwidth of CFEK operating at 16kb/s. The bandwidth improvement is complex, and needs to be compared with other modulation types to recognise its true advantage. Continuous-phase frequency shift keying (CPFSK) is a form of binary fre-

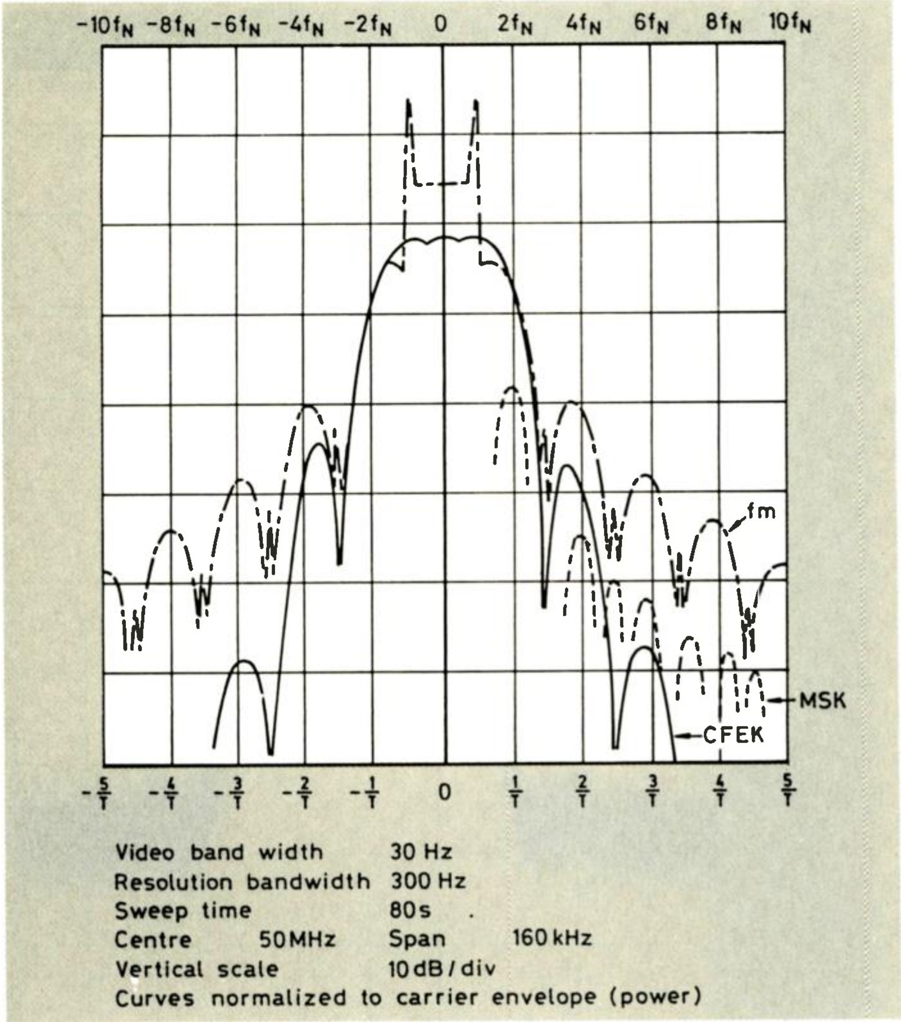

Fig. 8. Comparison of spectra of CFEK, MSK and binary FM. Side-lobes of CFEK reduce faster than other two.

quency modulation with reduced spectral side lobes. Minimum shift keying (MSK) is itself a special case of CPFSK, and offers an optimal compromise between occupied bandwidth and signalling efficiency. In terms of spectral occupancy, CFEK has twice the bandwidth of MSK at the first lobe. Successive side lobes, however, fall faster with CFEK than MSK, as can be seen in **Fig. 8**.

Often, importance is attached to the bandwidth at the −3dB or −6dB points, but with increasing congestion in the radio spectrum, more attention is now being paid to electromagnetic compatibility, viz. the reduction of spectral side lobes in adjacent radio channels. DTI specification MPT 1329 uses adjacent-channel power as one of its main parameters, setting the absolute limit on this at 200nW. This specification applies to systems whose effective radiated power is limited to 0.5W.

An analysis of the use of CFEK at 4800b/s in this regulatory environment shows that adjacent-channel interference would be of the order of 0.5nW, which implies that speeds up to 6000b/s could be achieved easily. Higher speeds could be achieved by modifying the modulation index, if the requirement of envelope constancy were to be relaxed.

In the commercial UHF telemetry bands, 1200b/s (occasionally 2400b/s) is the highest speed commonly achieved. A system that operates reliably at 4800b/s and possibly higher has significant advantages.

It is clear that research and development of great importance and interest is being done by these research establishments in the field of radio data communications. It is also an area where the results would have substantial commercial value and we are continuing to search out new applications for them.

The author wishes to thank the staff of the relevant MoD research establishments and Dr Geoff Gott of UMIST for their help with this article.

The author is an associate consultant with Defence Technology Enterprises of Milton Keynes. ■

Analog Electronics, by Ian Hickman. At a time when digital techniques are able to provide a solution to almost any electronic problem, it occasionally escapes the notice of engineers that analogue design can still sometimes offer a more effective, simpler and cheaper solution. It is greatly to be deplored that universities and technical colleges are so fascinated by digital processes that the teaching of analogue design methods is often neglected.

It is therefore heartening to see a new book on analogue design (even though the title is missing a couple of letters) from a well known author who writes in a relaxed mannner without any attempt to demonstrate his knowledge at the expense of clarity — a fault that is only too common.

This is for students, but the use of mathematics is not at such a high level that the book becomes inaccessible. The author points out that ". . . basic algebra and trigonometry . . ." alone are needed and compares his work with that of "Cathode Ray", with whom readers of this journal of a few years' standing will be familiar.

In eleven chapters, the book covers techniques in virtually the whole field of analogue design, beginning with passive components and going on to deal with audio design, passive and active signal processing inthe frequency and time domains, radio-frequency circuitry and power supplies in an entertaining, yet informative style. A final section contains some "tricks of the trade" — tips on design which the author has found helpful in saving time or in allowing a clearer view of the working of circuits. Heinemann Professional Publishing, hard cover, 330 pages, £30.00.

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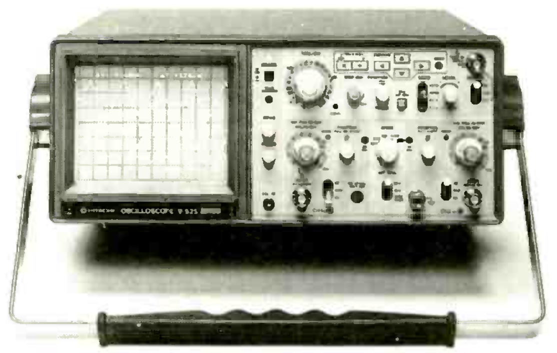

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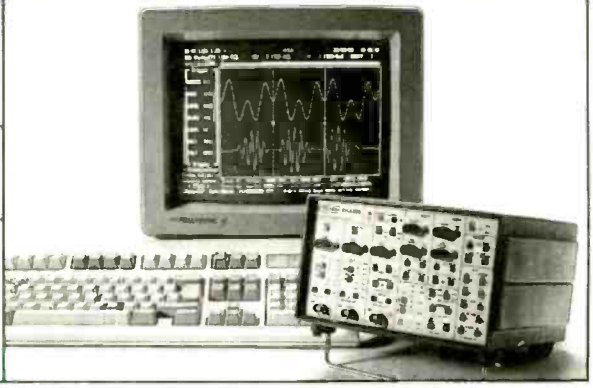

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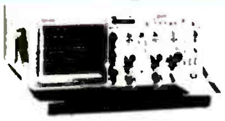

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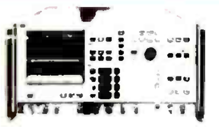

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TDR for component measurement

Time domain reflectometry is not solely the province of the RF engineer. Simon Harpham describes its use for extracting the parameters of active and passive components

Time domain reflectometry is a simple technique for measuring components, though often regarded simply as a tool for microstrip impedance measurement and for testing cables and connectors. It readily adapts to component measurement, allowing intrinsic networks to be assessed with a few simple formulae. All that is required is a good-quality oscilloscope, an easily fabricated pulse generator and a few lengths of cheap coaxial cable.

TDR is analogous to echo sounding; it exploits the propagation delay of a step function through a transmission line to "echo" a voltage facsimile of any impeding object on that line. This reflection is then displayed on an oscilloscope at the line's source for visual interpretation[1]. Any signal leakage past this discontinuity is regarded as the Time Domain Transmission or TDT.

TDR and TDT measurements are invaluable to the practicing engineer; the at-a-glance display of the relative impedance and reactance levels can be a powerful tool. The pulsed nature of the step-function encourages the use of large mark-to-space ratio pulses for very large-signal testing of components without causing excessive dissipation in them. This complements, rather than replaces, the small-signal parameters as measured on a network analyser in the form of scattered parameters. The TDR equipment's simplicity far outweighs the effort involved in using the maths needed, which is an ideal situation for even the tightest of development budgets!

Basic reflectometry

If we connect a step-function to an attenuator consisting of two 51Ω resistors, then monitor the attenuator's input and output, we would expect to see two synchronised traces, the first being twice the voltage of the second. By inserting ten metres of RG 58 cable between the resistors, as in **Fig. 1**, with the oscilloscope now monitoring the cable's input and output, we see a time displacement of the second trace's rising edge. No change in level occurs on the first trace after two propagation times, since the cable behaves as the second resistor during this propagation time; showing that the cable's impedance is equal to that of the second resistor, or 51Ω.

Any energy launched into this cable will travel down it at a rate determined by the permeability and permittivity of the media between the conductors. **Figure 2** shows the effect of an open-circuit terminating resistor; at the instant the energy reaches the end of the cable it "sees" the open circuit and commutates due to the distributed inductance's magnetic field collapsing. As this inductive flyback is attempting to maintain the original current flow, it can only do so by stepping up to twice the outgoing voltage and flowing back along the cable's impedance. When it reaches the source, the current flow ceases, all the energy now being stored in the cable distributed capacitance's electric field.

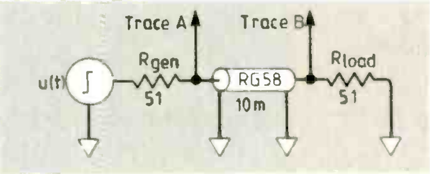


Fig. 1. Basic TDR test rig. Cable impedance is equal to that of second resistor, so no reflections are observed

By a similar argument, the steady-state energy storage for an output short circuit is completely in the magnetic field. For all conditions, the overall effect is for the load impedance to appear at the source after two cable delays. When the energy contained in both the electric and magnetic field of the cable are equal, ($E = 0.5CV^2 = 0.5LI^2$), the cable "sees" an impedance equal to its own characteristic impedance Z_o. This is usually defined as $Z_o=(L/C)^{1/2}$, neglecting loss terms[2]. It can be seen that the output load must equal the cable impedance when there is no reflection of energy from the output to input.

If the input padding resistor is removed, then only the generator output impedance appears at the cable input, causing secondary reflections since the cable and generator are no longer behaving as an infinite transmission line. However, useful information can be derived from the traces of **Fig. 3**; the termination is 26.3Ω, the mismatched load obviously causing the line voltage to decrease when less than Z_o; similarly the voltage increases when the load is larger than Z_o.

Now, from the voltage and impedance ratios present, we can derive the

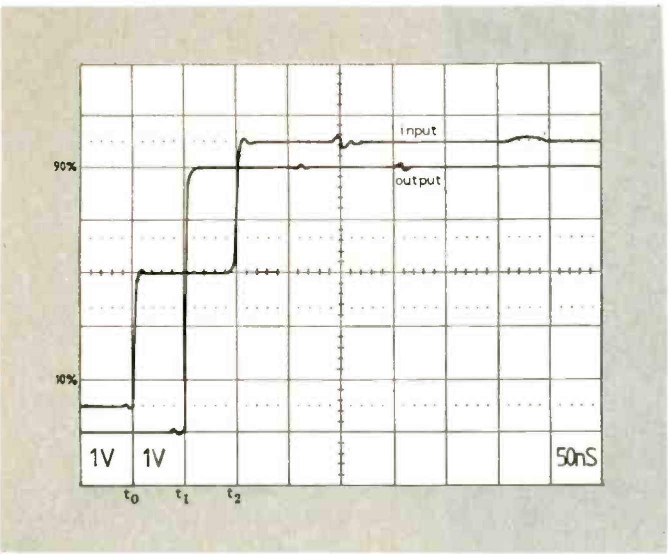


Fig. 2. Effect of an open-circuit terminating resistor. After twice the propagation time, load impedance appears at source

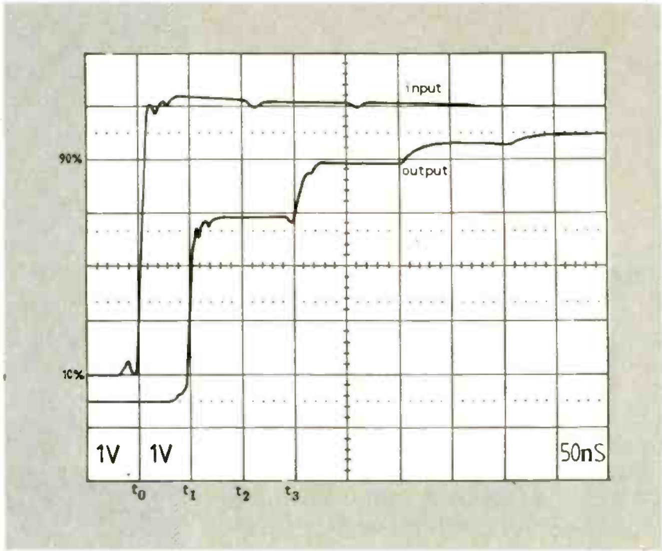
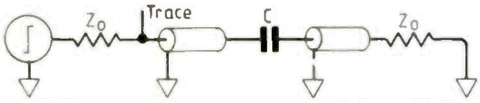
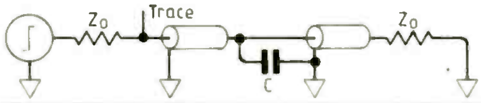
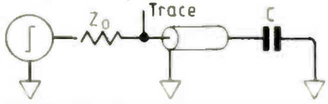
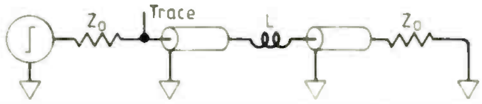
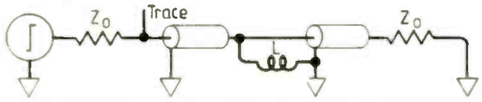
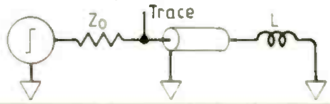


Fig. 3. Mismatched load of 26.3Ω. At time t_2, load impedance can be calculated from ratio of trace voltages

voltage reflection coefficient or Γ_V irrespective of the source impedance if the line is long enough. Γ_V is defined as the voltage of the reflected wave V_r divided by the voltage of the incident wave V_i on the cable. For passive loads this will vary between +1 for an open circuit and −1 for a short circuit. With an active load, Γ_V can be larger than one, since the load can be a source of energy. It can be shown[2b] that the voltage reflection coefficient can be expressed as $\Gamma_v=(Z_l-Z_0)/(Z_l+Z_0)$, where Z_l is the load impedance and Z_0 is the cable's characteristic impedance.

If we rearrange this to $Z_l=Z_0(1+\Gamma_v)/(1-\Gamma_v)$ we can calculate the load impedance from the ratio of the waves as they are displayed on the oscilloscope screen. Even though Fig. 3 displays a series of upward steps after the first cable propagation time at t_1, these steps will deliver information about the terminations at each end of the cable (the calculation of the secondary Γ_v is quite complex[3]). If we use the voltage level at t_2, we get a value of Γ_v for the output load of −0.32, which will give a value of 26.3Ω when plugged into the previous formula.

Table 1. TDR measurement configurations, with response shapes.

CONFIGURATION	TRACE RESPONSE	FORMULA
Series capacitance, terminated line  		$C=\frac{T}{2Z_0}$
Parallel capacitance, terminated line  		$C=\frac{2T}{Z_0}$
Capacitively terminated line  		$C=\frac{T}{Z_0}$
Series inductance, terminated line  		$L=2T.Z_0$
Parallel inductance, terminated line  		$L=\frac{T.Z_0}{2}$
Inductively terminated line  		$L=T.Z_0$

Refining the TDR rig

The multiple reflections of Fig. 3 are undesirable and should be damped by making the input generator output impedance match the line characteristic impedance. Similarly the "glitches" due to the oscilloscope input loading should be removed, as they "bounce up and down" the cable, blurring the detail originating from the load. This can be done by isolating the oscilloscope inputs by the use of line samplers, but other parasitic effects can still be seen: the gentle downward tilt of the traces (due to the distributed resistance in the cable) and the gentle rising tilt on the output trace (due to both the distributed resistance and susceptance of the cable). Similarly it will be found that the trace will never display the full input step, due to the filtering of the line impedance with the system stray capacitance.

By assuming a Gaussian response (which the oscilloscope should possess), we can "guesstimate" the system's limit by the displayed rise time t_r and can therefore assume the trace to have settled to within 2% of the correct value within $4t_r$. For events of less than $4t_d$, correction factors can be applied[3]:

$$V_{real}=V_{displayed}(1-e^{t_d/t_r})$$

where t_d is the displayed time constant.

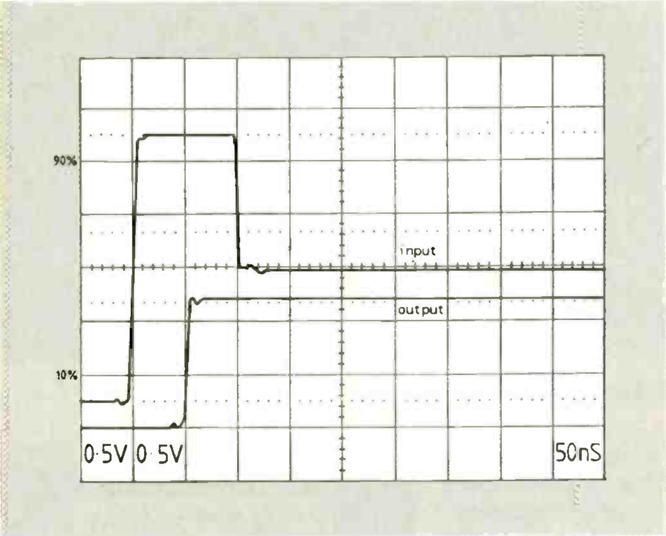


Fig. 4. A 16.5Ω load, giving $\Gamma_v = -0.52$. Use of a line sampler improves the display by isolating oscilloscope input circuitry and removing glitches

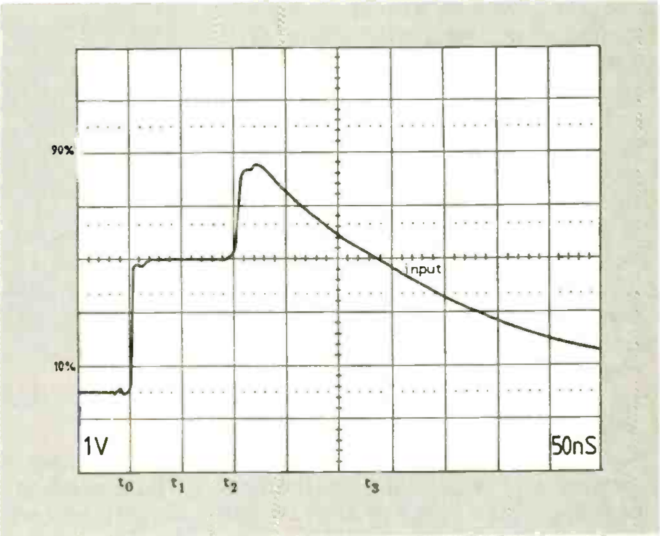


Fig. 5. Measurement of a 10.7μH inductor. Time measurement is from t_2 to t_3

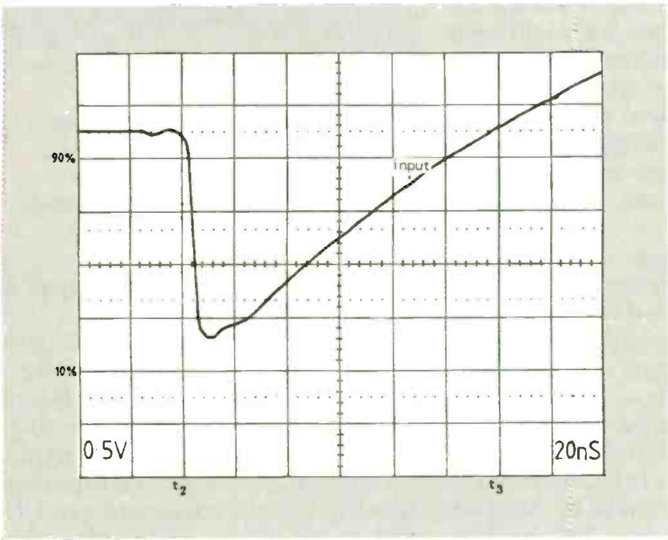
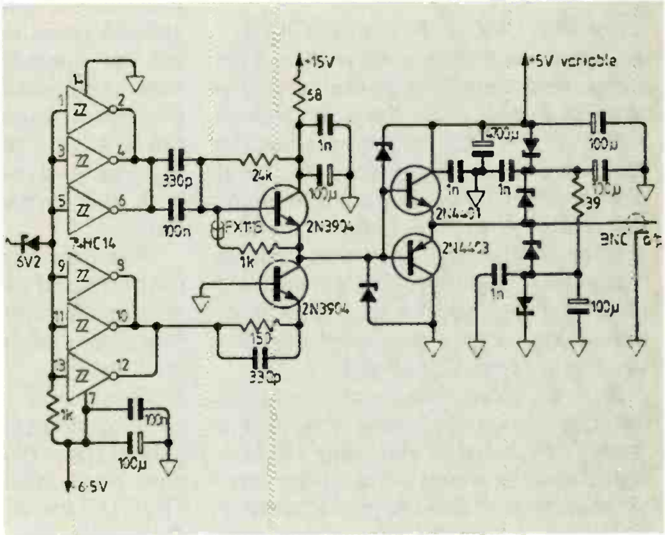


Fig. 6. Time from t_2 to t_3 gives capacitance of 3.3nF



5V reference pulse generator, giving t_r of 1.8ns. It should be built on a bare PCB ground plane. Diodes are BAT41. Keep leads less than 3mm long. Mount the BNC sockets near the decoupling capacitors through the ground plane. All 1nF capacitors are surface-mounting ceramic types. Input is active low for less than 1μs at "HC" levels. Pulse repetition rate is 10kHz.

This is usable down to about half of the system risetime for less than 6% error.

Results from the "improved" version using line samplers, are shown from **Fig. 4** onwards. The URM 62 cable used has a lower loss characteristic than RG 58, since its Z_0 of 53Ω represents the minimum loss structure for PTFE dielectric cable[4]. An input padding resistor of 51Ω is added to the generator output impedance of 2Ω, giving much cleaner displays, since the source is now behaving as an infinite line. Here the Γ_v in Fig. 4 is -0.52, which gives a calculated load of 16.7Ω and is in error by 1.2% from the 16.5Ω value measured at DC. Changing the load to 100Ω resulted in a Γ_v of 0.31 which is a calculated load of 100.6Ω.

Discrete-component reactive measurements

So far, I have only considered resistive measurements, which are identified by a level trace with time. If the trace displays an exponential decay, one may conclude that the terminating impedance is altering with time due to a reactive element. By changing the termination resistor on the rig to a (perfect) reactance, the resulting curves will (ideally) start with a Γ_v of +1 for an inductance and -1 for a capacitance; these will decay away to -1 and +1 respectively. Since we have already proved Z_0 to be purely resistive, we can assume these curves to be directly related to the single-pole L/R and CR time constant (using Z_0 as the resistor).

To ease the reading of the 1/e level for the "time constant", I find it much easier to use the 50% point, as we have a convenient on-screen marker – the point at which the termination impedance is exactly equal to Z_0. Given that τ is the reactive time-constant and that t is the time from the start of the step-function to the 50% "cross over" point; then:

$$\tau = t(\ln e^{-1})/(\ln 0.5)$$

or 1.4427. So if R is replaced by Z_0 in the time-constant formulae, they then become: $C = 1.4427 \times (t/Z_0)$ and $L = 1.4427 \times (t \times Z_0)$. The 10μH inductor measured in **Fig. 5** is: $L = 1.4427 \times Z_0(t_3 - t_2)$ or 10.7μH, with the 3.3nF capacitor in **Fig. 6** being: $C = 1.4427 \times (t_3 - t_2)/Z_0$ or

3.27nF. Table 1 shows some of the more common configurations used in TDR, with their response shapes and formulae.

The voltage reflection coefficient, Γ_v, is similar to the s_{11} measurement made for the scattering parameters of a one-port, forward and reverse power waves a_1 and b_1 being represented by the incident and reflected voltage respectively. The measurement system is not restricted to 50Ω; non-standard lines can be hand fabricated using two concentric copper tubes supported by Teflon spacers. A couple of commonly available sizes, 10mm OD and 25mm OD (23mm ID), give very nearly 50Ω. The limitations of coaxial lines is to the range of 6Ω to 150Ω [4], making them suitable for RF BJT input stages. Open-line cables give a haiger range of 150Ω to 600Ω, so they are more suitable to RF BJT output stages.

Active device measurement

Scattering parameters are usually used to measure the reflection and transmission coefficients of a device's intrinsic network, since the lines used allow the parasitics associated with test leads and connectors to be minimised. The major drawbacks to the s-parameter method are the continuous excitation causing excessive dissipation during high level measurements; and the need to use multiple frequency measurements to synthesise the "best fit" network.

Both of these can be overcome by exciting the device under test with a "unit" step function and using Laplace transforms to convert the resulting time-domain trace to the complex frequency s-plane. A transfer function is then synthesised from this data, since it allows all the network poles and zeros to be identified, from which the relevant phase and frequency responses can be plotted. The derivation and use of these transforms is beyond the scope of this article, but attention is directed towards reference 6 as an introduction, with reference 7 providing greater depth.

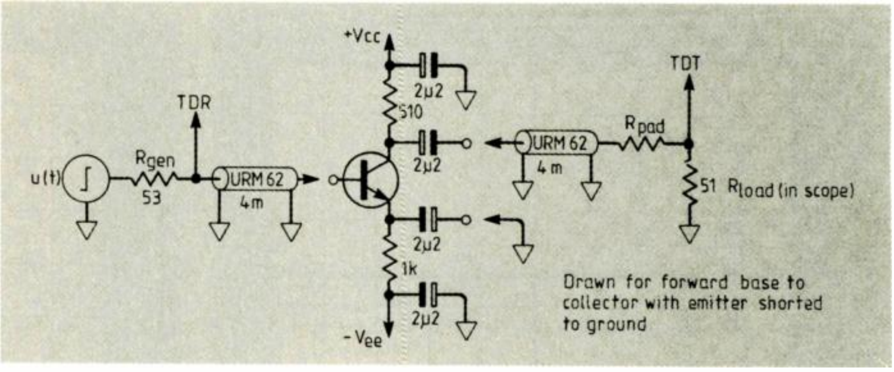
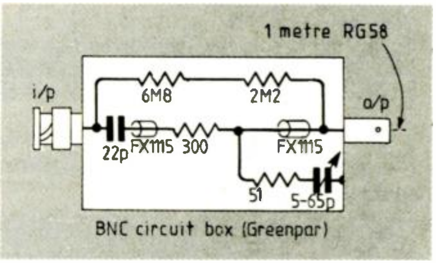


Fig. 7. Test rig for bipolar transistor measurement

If we consider a transistor as a two-port device **(Fig.7)** and measure the reflection and transmission coefficients for the common-emitter, collector or base configurations we can take 12 possible measurements by considering the switch-on and switch-off characteristics for each of the configurations, in both the forward and reverse directions.

These measurement techniques are not restricted to transistors; they work very well for integrated circuits, making short work of things like power-supply feedthrough, output loading and feedback-loop analysis. To establish some common ground with small-signal parameters I have derived some of the more basic ones here for a 2N3904 BJT. The TDT traces are scaled by 20.65 for **Fig.8** (due to a series 1kΩ resistor needed to isolate the 53Ω load) and by 1.039 in **Fig. 9** (to allow for the insertion loss of the 2Ω resistor used to pad the 53Ω cable from the oscilloscope's internal 51Ω termination).



Line sampler circuit. Adjust to give best response into 1m of RG58 cable connected directly to the oscilloscope input. Sampler behaves as a × 10 probe, but without the usual stray inductance. C_{in} is 15pF in parallel with 10MΩ.

Base-to-collector switch-off curves are shown in Fig. 8 and the emitter-to-base switch-off curves in Fig. 9. Figure 8 displays a distinct "bump" due to the unipolar nature of $r_{b'}$[8], which is reduced for the switch-on trace. This resistance is related to the charge-storage effect and momentarily isolates the source from the base/emitter capacitance while the device switches off.

From Fig. 8 we have at time t

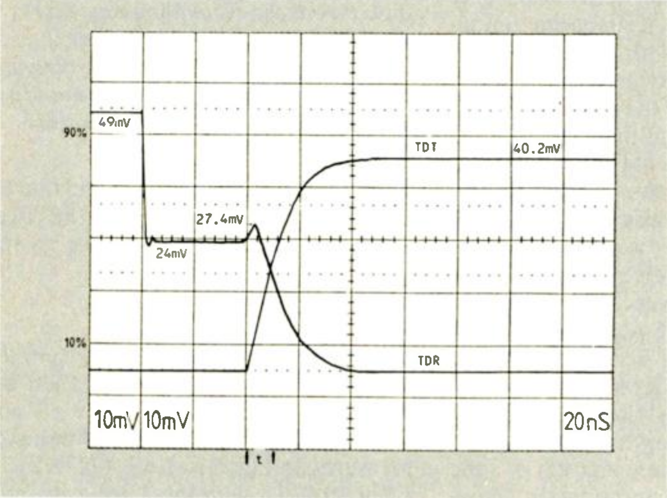


Fig. 8. Base-to-collector switch-off curves for a transistor — t=8.7ns

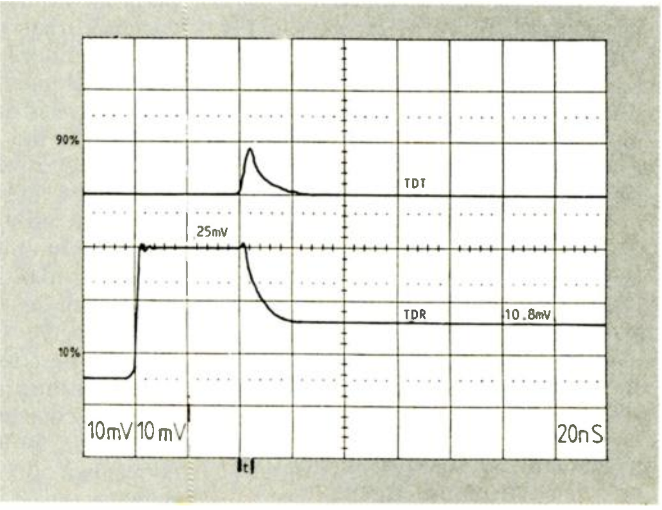


Fig. 9. Emitter-to-base switch-off curves — t=7ns

$\Gamma_s = V_r/V_i = 3.4mV/-25mV = -0.136$
$r_{b'} = Z_0(1-\Gamma_s)/(1+\Gamma_s) = 53\Omega(1-0.136)/(1+0.136) = 40.31\Omega$
also at the first negative edge
$\Gamma_s = 24mV/25mV = 0.96$
$R_{b'e} = 53\Omega(1.96/0.04) = 2.597k\Omega$
Now the combined resistance at the collector is $510\Omega \| 1.053k\Omega = 343.6\Omega$, so the collector current is
$i_c = V_c/R_c = 831mV/344\Omega = 2.41mA$
$g_m = i_c/v_{be} = 2.41mA/50mV = 48.4mS$
From the time constant of the TDR trace
$\tau = 1.4427 \times 8.7ns = 12.55ns$
$C = \tau/R_c = 36.5pF$
This allows us to estimate the delay time of the device
$t_d = 2.2 \times C \times r_{b'} = 3.24ns$
Now, $A_v = g_m \cdot R_c = 16.6V/V$, so $C_{cb} = C/A_v = 2.2pF$
Also $f_T = A_v/\omega\tau = 210MHz$.
From the TDT trace of Fig. 9, $\tau = 1.4427 \times 7ns = 10.1ns$, therefore $C_{eb} = \tau/(2 \times Z_0 + r_{b'}) = 69pF$

These values were for a V_{ce} of 3.6V. The values of R_{ce} and C_{ce} require an emitter-to-collector measurement to be made. The intrinsic high frequency model is shown in **Fig. 10.**

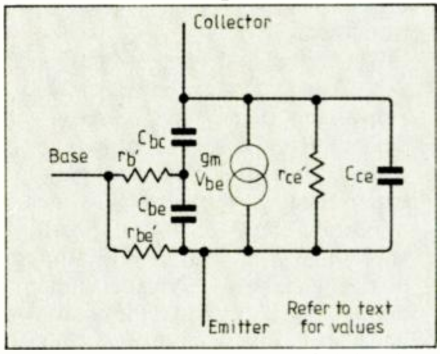


Fig. 10. Intrinsic HF model of 2N3904 transistor

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ALL IN THE MIND

"A tool to guide the user to a state of deep relaxation, to enhance creative visualisation, self-development, spiritual explorations or any of the other consciousnesses associated with deep relaxation or meditation." These are the claims being made in the sales literature of the MC2, a new machine being imported from the USA – and the MC2 is just one of a whole range of devices about to visit these shores.

Mind machines are set to become big money.

By offering a chance to change one's mental state at will, the machines promise to give one a chance to "switch on" increased concentration at work, to end the day in a state of meditative relaxation and to increase creativity and learning ability for brainstorming and the acquisition of new skills.

The machines also promote receptive states of mind, enabling users to "reprogram" their minds with self-hypnosis tapes to make them more confident, happier, or more successful at work.

The machines are being sold via mail order through specialist shops like MegaBrain in San Francisco and also appear in "mind gyms" where subjects can undergo supervised training programmes.

To see the reality behind the hype, and to understand their real potential, it's necessary to put the machines into context.

Biofeedback

An interest in deliberately controlling brain function has been developing since the 1930s, but first reached the public in the early 1970s in the form of biofeedback. A typical biofeedback machine would use physiological monitoring to determine, for instance, the subject's stress level. These findings would be relayed in the form of a tone or meter reading. Guided by the machinery, the subject could then learn to reduce his or her stress, controlling aspects of his or her physical state of which he or she would not normally be aware.

Biofeedback was intended to facilitate learning of meditation or relaxation techniques. In practice, however, the level of dedication necessary to learn to work successfully with the machines was offputting to the casual user. Although some mind machine pundits are veterans of the biofeedback movement, the technology and the way it is applied owes more to a different, quasi-medical school of research.

In the late 1960s, Margaret Patterson began using a device she called the Black Box in the treatment of drug addiction. She would give her patients a set of electrodes, which they were directed to place on their mastoids – the large muscles which close the jaw, prominent just ahead of the ear. A set of wires led from the electrodes to a small control unit which Patterson would manipulate throughout the treatment session.

Biofeedback has been a commercial reality since the early 1970s, offering a means of inducing tranquillity and reducing stress. Modern machines promise more, but the medical profession is sceptical

In the short term, very high cure rates were announced, with the patients reporting that their craving for drugs had been reduced or eliminated completely. Indeed, rock star Pete Townshend of "The Who" credits her with his rehabilitation. Patterson was coy about the workings of the device, but it was obvious that the machine was in some way influencing brain function.

Patterson's device paved the way for machines which could alter the user's state of mind without his or her conscious involvement. Researching this article, I encountered more than 20 different models of mind machine. Many of these, including the MC2, Oceanide's Dreamer, NeuroPep Mind Theater, Endomax, and the Theta-One, are already available on the UK market, with more models coming soon and a couple of home-grown versions on the way.

Two main developments separate the current generation of mind machines from Patterson's original. The first is in the preferred mode of stimulation. Only a few home-use devices now use the electrode approach, known as CES (cranial electrical stimulation). Most opt for a combination of headphones and specialised goggles with internal LEDs, both connected to a control unit. The headphones are standard personal stereo models, while the goggles carry anywhere from one to six LEDs in each lens. The combination of rhythmic sound and LEDs flashing onto the closed eyelid in a synchronised pattern induces effects like those of CES.

The second development is the increased sophistication of the control circuitry. A typical sound and light machine like the Dreamer or MC2 will be programmed with a number of patterns, each associated with a different brain state.

Brain states were first described by brain researchers working with electroencephalograph machines in the 1950s. They divided brain activity into four distinct conditions, each associated with electrical emissions around a given frequency. The beta state, the state with the highest frequency at around 13Hz, is prevalent during "wide-awake" activities like work and conversation. The delta state, the lowest at 1 to 3Hz, appears during sleep.

The two intermediate frequency bands have less obvious associations, but various experiments performed since the 1960s have shown that 8 to 11Hz alpha brain states appear during meditation. More recently, the theta state at 4 to 7Hz has been associated with creativity and learning.

Patterson's Black Box was simply an alpha stimulator, intended to induce a sense of meditative calm and detachment in her patients, and so dull their cravings. It worked by transmitting at the alpha frequency, inducing the brain to work in sympathy. A sophisticated modern machine will ext[illegible]'s pattern of operation to offer sti[illegible]n in all four states – for inst[illegible]elta frequencies to induce slee[illegible]eta frequencies to boost creativity or aid deep learning – but it will also go further.

IC-based circuitry has made possible sophisticated programming intended to guide the user through a sequence of mental events. Such programming is found in machines like the MC2 and Oceanide's Dreamer. A series of program options are accessible via numbered keys on the control unit. For instance, a typical "creativity" program might offer 20 minutes of theta stimulation, sandwiched between two five-minute alpha periods to allow the subject to relax before and after the session, with a concluding three-minute blast of beta frequencies to aid the return to the hurly-burly of the real world.

The idea of being able to arrange a mental experience in this way is obviously very attractive. A program offering a quick trip into alpha or theta land would seem to be just the job for people in pressurised careers needing a quick and effective means of relaxation, or people in industries like advertising where creativity is constantly in demand. However, not everyone accepts that this pick'n'mix model of mental function is adequate for the uses to which it is being put.

Professional scepticism

Dr Bernard Rosen of Guy's Hospital commented that the simplistic links drawn by the manufacturers between physiological brain states and mental experience makes him sceptical about the machines. "These notions of the brain states were derived from electroencephalograph scans. An ECG (electrocardiogram) can provide a useful record of heart function, because the electrical events taking place are essentially simple, but what happens in the brain is extremely complex. An EEG simply gives you an understanding of the overall level of activity. It doesn't tell you the precise events which are giving rise to the meditative or creative states of mind."

In other words, trying to understand the way that the brain is working by using an EEG is like listening to the hubbub in a large hall from a distance. You can pick out the overall level of activity but you won't be able to make sense of the individual conversations which give the meeting its meaning. A mind machine may be able to put the bain into a "meditative" alpha state, but it won't necessarily duplicate the mental conditions which made the meditative experience valuable in the first place.

As the industry has moved towards commercial maturity, doubts about the value of the blueprints for enlightenment provided by the manufacturers have become apparent within the mind-machine community. Last year saw the foundation of the Neurotechnologies Research Institute in California. Lynne Hendricks, a founder member, told me, "There's a lot of hype out there. We set up the institute because we felt that the machines needed to be seriously and professionally looked at."

Hendricks feels that we still have some way to go before we can fully understand the operation of the machines we have already. She and her colleagues are concentrating on simple applications for the machines in stress and tension reduction, leaving the work on meditation and enlightenment for another day.

She also has a highly practical concern to develop links and share skills with medical practitioners, psychotherapists and hypnotherapists. She hopes that the experiences of these people will be a valuable source of support to the NRI's subjects, giving them a context in which to examine their experiences and hence learn more from them.

The theme of the necessity of support was taken up by Caroline Röell of Euroneuro, one of the UK-based dealers. Röell, herself a trained counsellor, said: "No two people's experiences are the same. It's very important for people to feel that they are looked after, that it's OK if they go on the machine and they feel vulnerable afterwards, it's alright if they come out and want to cry, or if they feel elated."

At least one Stateside manufacturer is aware of the way that recognition of a need for guidance is changing the market. Synchro-Tech, which markets its Synchro-Energiser and Relaxman as devices for home use, has also opened a chain of 50 "mind gyms" across 12 states.

Besides the considerable advantage of not having to buy expensive equipment, presumably soon to be obsolete, visitors to the gym can develop a personalised course. Christine Zerrer, the trainer at the New York Synchro-Energize centre, told me that a course with her would entail an initial 45-minute session during which I would be introduced to the equipment and have my needs evaluated.

This would be followed by a series of once- or twice-weekly sessions under her supervision, working towards a particular goal. All the goals which Christine mentioned – reducing heart

A biofeedback machine in use. Goggles contain leds which flash in synchronism with sounds in the headphones, both being programmed by the hand control unit.

rate, muscle tension, or "substance dependency" – were concrete and practical.

Besides having advantages for the user, this emphasis on use of the machines under controlled conditions may help to save the manufacturers' skins. Already most devices are sold with blanket warnings that they should not be used by epileptics, people with pacemakers, pregnant women or people under the influence of drugs.

The issue of safety is a vexed one. Used under normal circumstances, the machines are beneficial – a powerful, non-addictive tranquilliser without side effects. However, when some machines are being marketed as a drug substitute, the fine distinction between use and misuse may not be obvious to users.

Perhaps because of their reputation as "legal psychedelics", there is widespread speculation about attempted bans on the machines. However, spokespeople at both the Federal Drugs Authority in the USA and the Department of Health in this country told me that they thought legislation would be impossible.

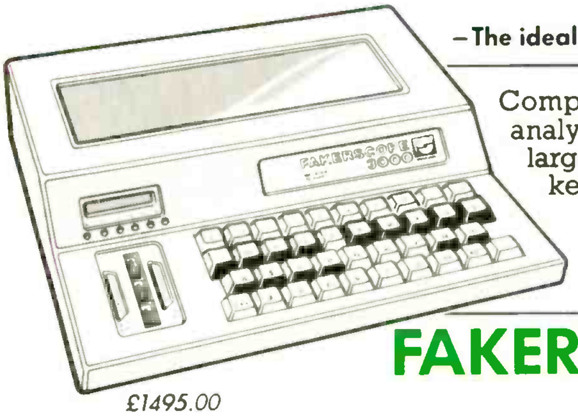
Rather than worrying about losing their new toys, people in clubland would do better to heed the warnings that started the rumours of government interference in the first place. Lynne Hendricks of NRI points out that the greatest risks come from use of the machines while the brain chemistry is abnormal – as it is on drugs or alcohol, for instance.

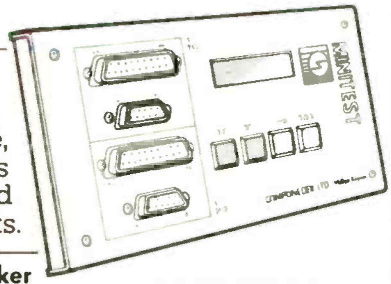
Mental engineering

However tricky they may be to deal with, the issues raised by the present generation of machines are as nothing to the moral problems arising from next-generation machines like Ted Alsop's Brain Booster. The booster – known, to its inventor's chagrin, as the God Box – subjects the brain to two different frequencies of CES via two different sets of electrodes. Interaction between the two can stimulate a precise target within the brain.

Alsop is using the device to "normalise" brain function. Recently, he has taken to "normalising" the damaged brains of some stroke victims, and reports early, spectacular successes. He told me, "The brain is a simple, stupid device which we can train to fire more regularly, to produce a certain kind of waves ... any way we want it. Everyone's brain has abnormalities – using the device we can bring them back up to 100% functionality, or perhaps even more than 100%."

William Meuster





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AUDIO PREAMPLIFIER DESIGN

John Linsley Hood follows his earlier series on the evolution of audio power amplifier design with a look at the development of preamplifiers from the 1960s to the present day

The purpose of a preamplifier is to select a signal from any desired input channel, to adjust its amplitude/frequency characteristics if necessary, to amplify it to the 0.52V RMS level required to drive a power amplifier and to provide an output at an adequately low impedance level.

It is taken for granted that this signal manipulation and amplification will be done without significantly impairing the distortion or signal:noise ratio of the signal, though the weight attached to the term "significant" may be a matter for debate between designers.

It is said that there are bigger differences in the "sound" of preamplifiers than there are between comparably well designed power amplifiers. If this is the case, the probable tonal differences arise in the various parts of the circuit in which the gain/frequency response is deliberately modified, of which the major one is the record replay equalisation circuitry.

Record replay equalisation characteristics

Various combinations of recording pre-emphasis and replay de-emphasis have been proposed for use with record reproduction, of which the most important is that in accordance with the RIAA:BS1928/1965 specification, in that it has been generally adopted for use with 33 and 45rpm vinyl discs.

This proposed characteristic was based on a recognition of the practical realities of disc manufacture and reproduction, using velocity sensitive (electromagnetic) cutter and replay heads; I will examine these constraints in greater detail later on, in relation to their effect on "headroom".

In its original form, the RIAA specification called for a replay characteristic of the form shown in **Fig. 1**, in which the shape of the replay response was defined by three time constants: 3180µs, 318µs and 75µs. There has been a recent amendment to this, in acknowledgement of the inevitable VLF noise present on disc replay, to include an additional LF roll-off defined by the time constant 7950µs, as shown in the dashed-line curve in Fig. 1.

The need for the rising replay gain characteristic below 1kHz is imposed by the typical maximum allowable LP/EP groove separation of 0.01cm, which limits the magnitude of the permissible recording cutter excursion, with a consequent linear reduction in replay stylus velocity with decreasing frequency.

The concept of HF recording preemphasis, followed by replay de-emphasis, was initially adopted for 78rpm records, so that the treble cut on replay would lessen the irritating audible "hiss", due to the emery powder loading of the shellac discs, and has

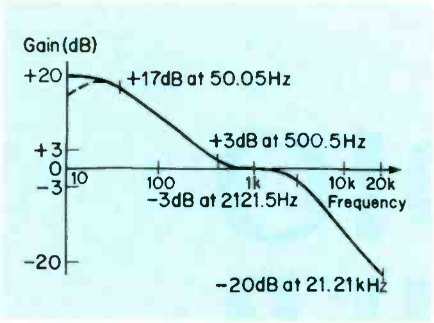


Fig. 1. Record replay characteristic to RIAA:BS1928/1965 specification

Fig. 2. Possible RIAA equalisation circuit arrangements. R_3C_3 in (g) form a 75μs lag network, as does the second stage in (h). Dotted networks in this form are simply HF filters.

been retained even in the case of the much quieter vinyl surfaces. The most common 78rpm replay equalisation specification is similar to that of the RIAA but with time constants of 3180μs, 450μs to 1kHz, and then 50μs to 20kHz.

Replay equalisation circuitry

Various possible circuit arrangements will generate the required RIAA replay curve for velocity-sensitive pickup transducers and are shown in **Fig. 2**. Of these, the simplest are the two "passive" equalisation networks at (a) and (b), though for accuracy in frequency response they require that the source impedance is very low, and the load impedance is very high in relation to R_1.

The required component values for R_1, R_2, C_1 and C_2 were derived by Livy[1] in terms of time constants and quoted in a somewhat more digestible form by Baxandall[2], in the course of an excellent analysis of the various RIAA equalisation options.

Using the formulae quoted by Baxandall, applicable to the layouts of Figs 2(a) and 2(c),

$R_1/R_2 = 6.818$

$C_1.R_1 = 2187\mu s$

$C_2.R_2 = 109\mu s$.

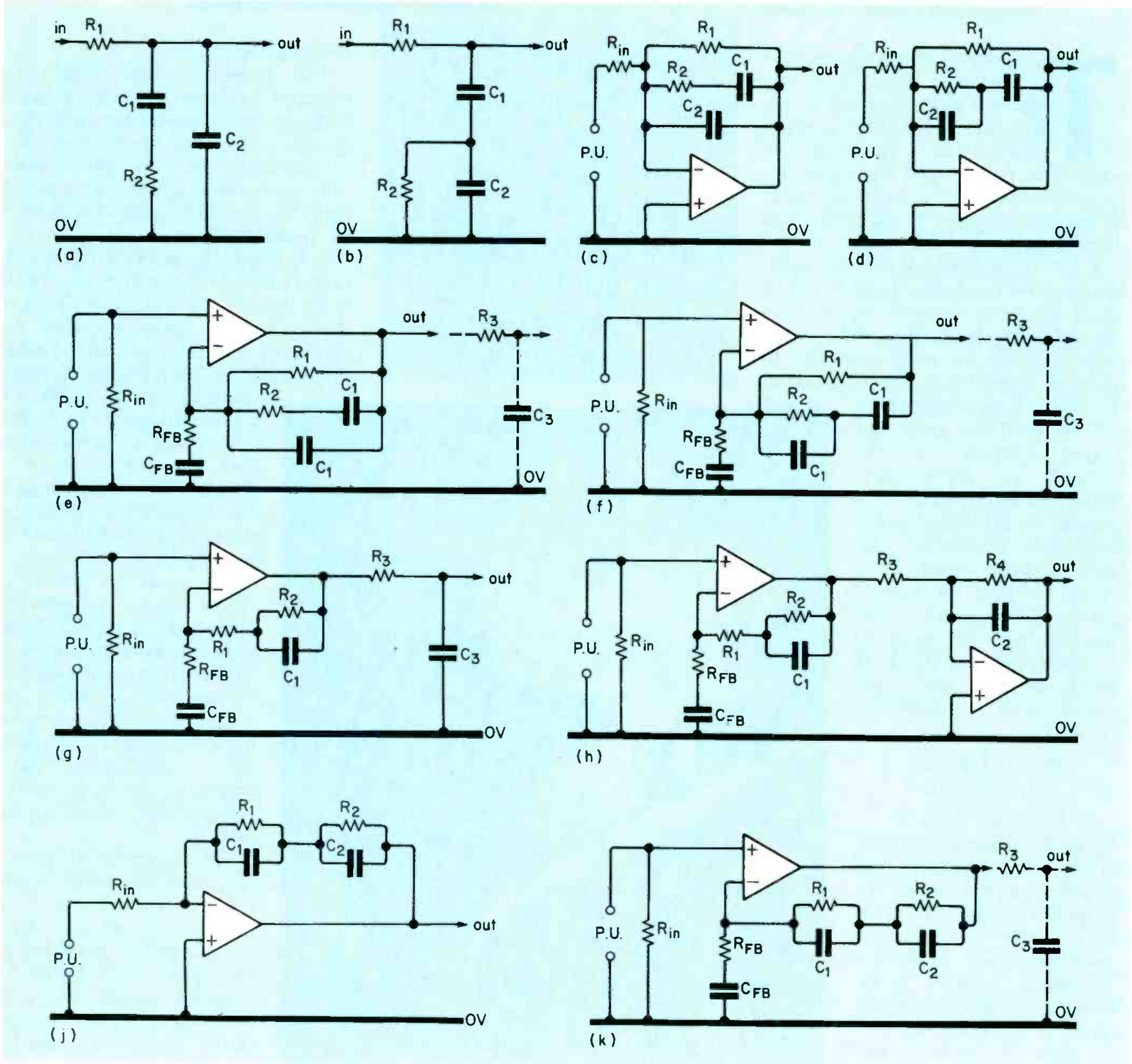
For the layouts of 2(b) and 2(d), the appropriate values will be

$R_1/R_2 = 12.38$

$C_1.R_1 = 2937\mu s$

$C_2.R_2 = 81.1\mu s$.

The active layouts of 2(c) and 2(d), in which a good quality operational amplifier circuit is used as the gain block, do



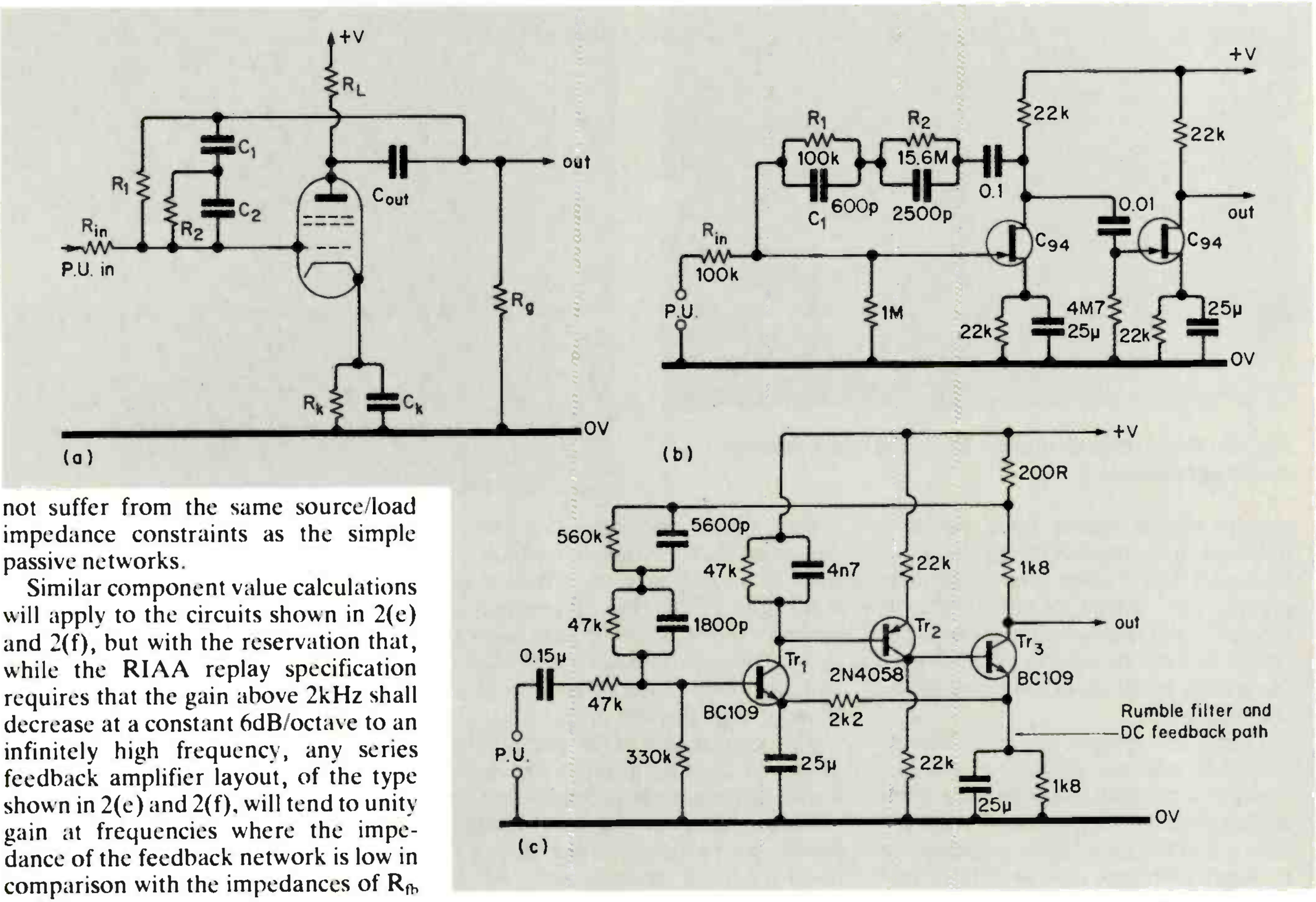


Fig. 3. Shunt-feedback RIAA equalising arrangements by Livy (a), James (b) and Linsley Hood (c).

not suffer from the same source/load impedance constraints as the simple passive networks.

Similar component value calculations will apply to the circuits shown in 2(e) and 2(f), but with the reservation that, while the RIAA replay specification requires that the gain above 2kHz shall decrease at a constant 6dB/octave to an infinitely high frequency, any series feedback amplifier layout, of the type shown in 2(e) and 2(f), will tend to unity gain at frequencies where the impedance of the feedback network is low in comparison with the impedances of R_{fb} and C_{fb}.

This leads to a tonal difference between simple shunt-feedback and series-feedback RIAA circuits, which may be partly explained by the different frequency distribution characteristics of the residual noise, and by the different transient characteristics of the two circuits, consequent on the residual HF flattening of the series-feedback response curve; a difference which I illustrated by oscilloscope waveform photographs in an earlier article[3].

Baxandall[2] points out, however, that this deficiency can be remedied by the use of an additional RC lag network, as shown in dotted lines on the drawings, to "top up" the HF attenuation characteristics of the circuit; this addition is now commonly used by the more perfectionist manufacturers.

In the layouts shown in 2(c)-2(k), the resistor R_{in} is the load resistor specified for the pick-up cartridge employed and is typically 47kΩ for a moving-magnet or variable-reluctance cartridge.

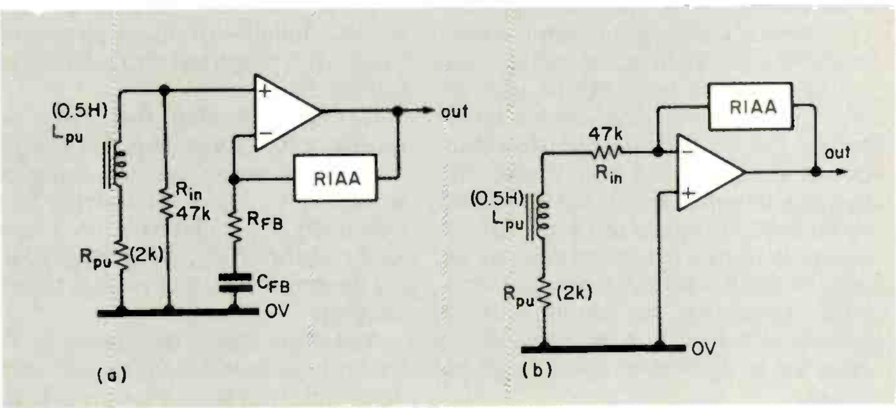
This shortcoming in series-feedback systems, that the gain curve will tend to unity at high frequencies, can be avoided by the division of the equalisation circuit into two parts, using a series-feedback input stage, as shown in 2(g) and 2(h), to handle that part of the frequency spectrum between 20Hz and 1kHz, followed by either a passive lag network, or an active integrator, to provide the required roll-off in gain between 1kHz and 20kHz. However, it should be remembered, in the case of the circuit of 2(g), that the output time constant (75µs) will be modified by the load impedance R_1 and will be $(R_1/R_3)C_3$ rather than just R_3C_3.

Practical circuit layouts

In valve-operated RIAA equalisation stages, it was conventional practice to use shunt feedback around a single, high-gain, pentode amplifying stage in the way indicated by Livy[1] and shown in **Fig.3(a)**. An equivalent FET circuit was shown by James[4] (3(b)), and in circuits using a single junction-transistor gain stage by Tobey and Dinsdale[5] and Carter and Tharma[6], although in all these cases the stage gain would be much less than that given by a pentode.

Since I thought that the advantages of shunt feedback outweighed the small

Fig. 4. Influence of pickup coil inductance on input circuit impedance.



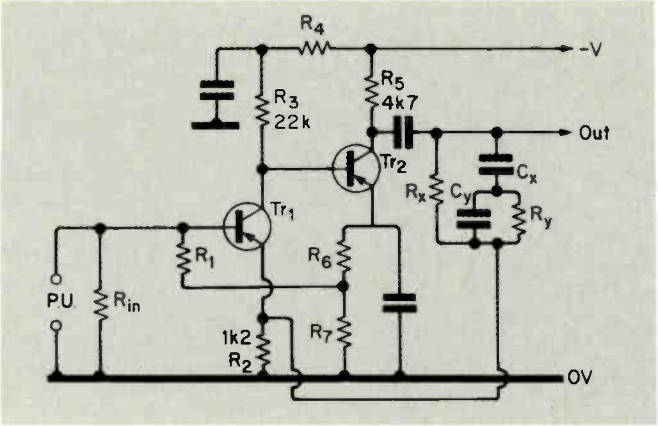
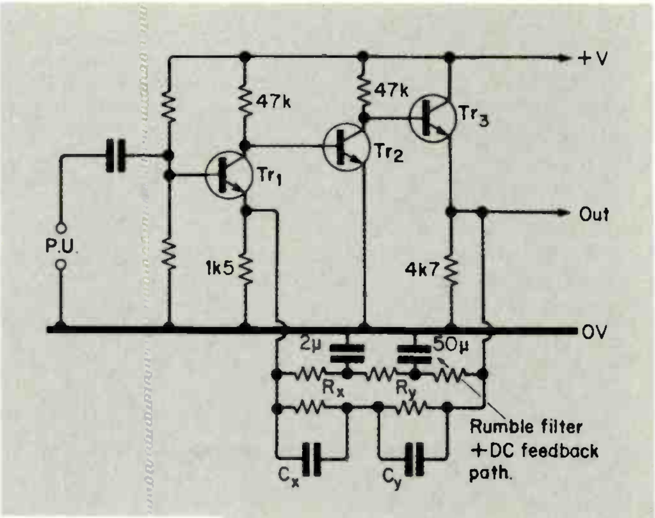


Fig. 5. RIAA circuit due to Dinsdale, which became an industry standard.



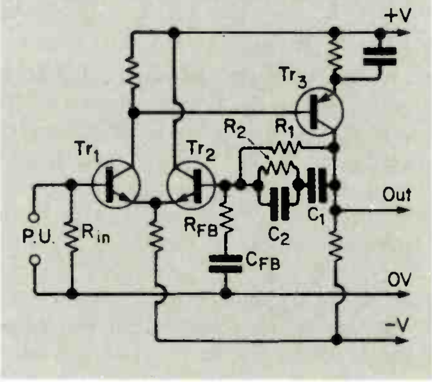


Fig. 6. A circuit by Bailey, in which the loading effect of the equalising network is eliminated, is shown at (a). Circuit at (b) is an attempt to divorce the base circuitry of Tr_1 from the feedback network.

penalty of the poorer noise figure, I followed these models in the design of the input RIAA stage used in an early preamplifier design of my own[7], although I used the three-transistor input circuit of 3(c) to provide a higher gain for greater accuracy in the equalisation characteristics.

These advantages are that shunt-feedback systems offer the simplest means of obtaining correct equalisation at the HF end of the pass-band; that they offer a much higher degree of immunity to input overload due to "clicks and plops" on the record; and that in theory[8] they allow a lower level of harmonic distortion.

However, all of these shunt-feedback systems suffer from the fact that the circuit noise figure is influenced by the presence of the input pickup load resistor R_{in}, which is typically of the order of 47kΩ. They therefore have a somewhat higher wide-band noise figure than an equivalent series-feedback circuit of the kind shown in 2(f), where the input resistor R_{in} is shunted by the pickup cartridge, which may have a winding resistance of 2kΩ or less, giving a much lower DC input circuit resistance.

Simple noise voltage calculations would show that a shunt-feedback circuit, with a 47kΩ input resistor, would have an equivalent mean input noise voltage, at room temperature, of some 4μV, measured over a 20kHz bandwidth; the equivalent series-feedback circuit exhibits some 0.8μV with the same input load resistor, but is shunted by the 2kΩ pickup coil resistance. These figures indicate a maximum possible s:n ratio of 54dB with reference to a 2mV input signal for the shunt-feedback system, in comparison with a 68dB s:n ratio for an equivalent series-feedback system.

Such simple calculations neglect two important factors, that the RIAA gain stage does not have an effective gain bandwidth of 20kHz – in practice it is probably less than one tenth of this – and that the pickup cartridge is likely to have an inductance of the order of 0.5H, as shown in **Figs 4(a)** and **(b)**.

This causes the input circuit impedance to rise with input frequency, which consequently increases the output noise voltage in the series-feedback circuit, but reduces it in the case of the shunt-feedback arrangement, so that the difference in background noise between the two circuits is a good bit lower than the assumed 14dB.

Nevertheless, equipment reviewers would be likely to measure and quote static s:n values with the "phono" inputs short-circuited, rather than with a pickup cartridge connected; this consideration caused most manufacturers to adopt series-feedback RIAA input circuitry of the type shown in 4(a) in equipment offered from the mid 1960s onwards.

A good example of contemporary phono input amplifier circuitry is that shown in a design due to Dinsdale[9], shown in simplified form in **Fig.5**, and virtually all commercial amplifiers offered at that time adopted a similar layout, though with silicon planar transistor types progressively replacing germanium ones.

A drawback with this early two-transistor RIAA circuit is that at higher audio frequencies the equalising network, R_x C_x C_y in series with R_2, is effectively in parallel with the collector load resistor of Tr_2, substantially limiting the possible output voltage swing at this point.

An improvement was shown by Bailey[10], who elaborated the circuit into the three-transistor form shown in **Fig. 6(a)**, with a low output-impedance emitter follower, Tr_3, to drive the RIAA network. This also allowed a much greater gain in the amplifying stages, which improved the accuracy of the correction characteristics and lowered the distortion of the circuit, especially at the extremes of the audio pass band.

Until recently, this three-transistor series feedback layout was the preferred RIAA input circuit in most commercial audio equipment. However, the layout still suffers from a more subtle drawback in that, since the negative feedback is applied between the emitter and base of Tr_1, the components in the base circuit are effectively in the feedback path. The use of the input longtailed pair configuration shown in 6(b) lessens the problem, but does not entirely solve it.

Some recent commercial designs have adopted two-element equalisation circuit layouts of the types shown in 2(g) and 2(h), with an increasing reliance on high-quality, low-noise, linear IC op-amps as the gain blocks. Although Quad has mainly chosen a single-stage op-amp-based equalisation layout, of the type shown in 2(k) – with a small output CR lag circuit to trim the HF end of the response curve – in one version of the 44 control unit RIAA input circuit it also uses a two-element equalisation system of the type shown in 2(g).

In all its current designs, Quad employs the ingenious low-noise, fully symmetrical, two-transistor head amplifier layout shown in **Fig. 7**, which allows the use of a normal fet input op-amp as the second gain stage, even for very sensitive microphone inputs.

The only other major innovation I have found among contemporary commercial circuitry is that used by Rotel in the RCi-870 and in all its recent designs, in which a low-noise NE5534AN op-amp is used as a flat frequency-response input gain stage, followed by a simple shunt-feedback RIAA circuit of the type shown in 2(d). This is reminiscent of the layout adopted by Cambridge Audio in the late 1960s.

Provided that the input overload and noise figure requirements can be met by the input gain stage, this layout can offer an almost perfect solution to the requirements of the RIAA equalisation stage, particularly since the gain of the input gain stage can be adjusted with ease to suit a wide range of input signal levels.

Most of the recent designs for RIAA equalisation systems described by independent engineers employ gain blocks based on discrete components for use with higher supply voltage rails, to allow greater overload headroom than is possible with standard ICs – which will mainly be designed to operate between ±15V rails. Increasingly elaborate circuit layouts are used to achieve higher open-loop gain and lower harmonic distortion.

Some typical examples have been shown by Self[11], myself[12,13] and Marsh[14]. This approach has also been adopted in units offered by Pioneer (C-90BK; etc.), Technics (SU-V50, etc.) and Marantz (PM949, etc.). Circuit layouts of the type shown in 2(e) and 2(f), but with highly elaborate discrete-component gain blocks, appear to be the most common current trend in high-quality commercial designs.

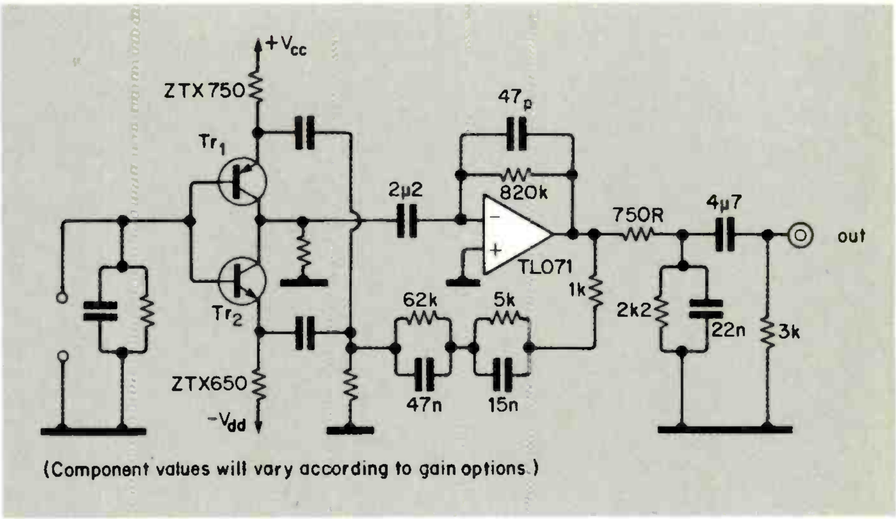


Fig. 7. Typical current Quad RIAA input circuit arrangement.

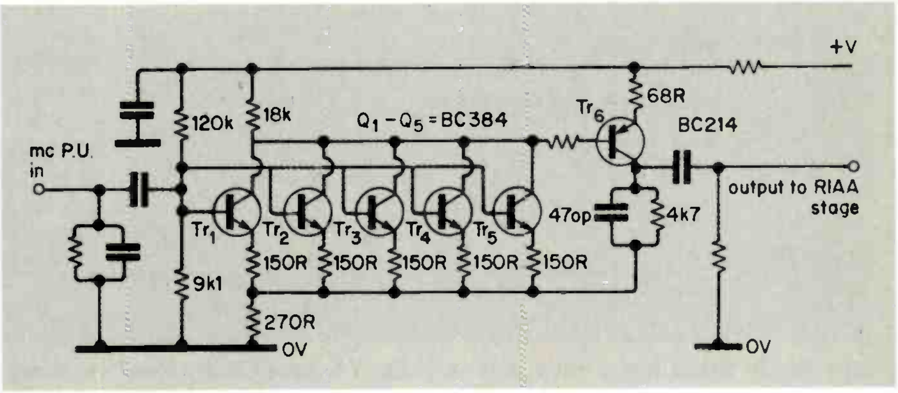


Fig. 8. One method, due to Naim, of obtaining low-noise input. Small-signal transistors in parallel maintain a low effective input noise resistance.

Moving coil head amplifiers

The major advantage of the moving-coil (MC) pick-up cartridge over the more common moving-magnet (MM) or variable-reluctance (VR) types is that the coils have a much lower inductance than the typical 0.3-1H for a fixed coil system, which gives the MC design a flatter and more extended HF response. The more intimate relationship between the stylus assembly and the coil system also allows better stereo channel separation, (typically 30-40dB *vs* 20-30dB for VR and MM types).

The low inductance of the pick-up coils in MC designs makes the performance of the cartridge much less dependent on the amplifier input load impedance, typically of the order of 100Ω, and on its input capacitance, including that of the connecting leads.

Measurements of my own[15] also showed that typical off-record harmonic distortion figures from a range of MC cartridges were rather lower than those from fixed-coil systems, though all these figures could be drastically worsened by small errors in the pickup cartridge alignment.

These factors, coupled with apparently better dynamic characteristics, have made MC designs the preferred cartridge type for hi-fi aficionados, in spite of the fact that their output voltage

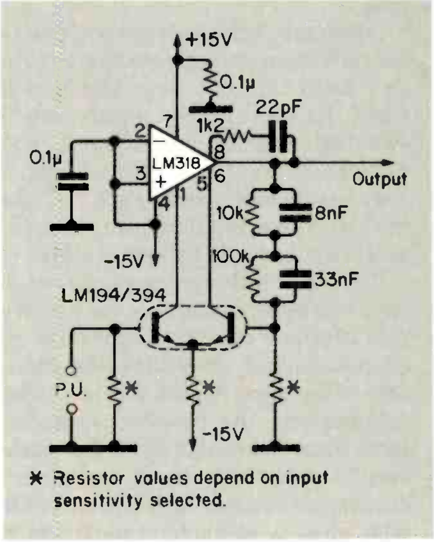


Fig. 9. Similar solution to that shown in Fig. 8, in which the "supermatch pair" contains many paralleled transistors.

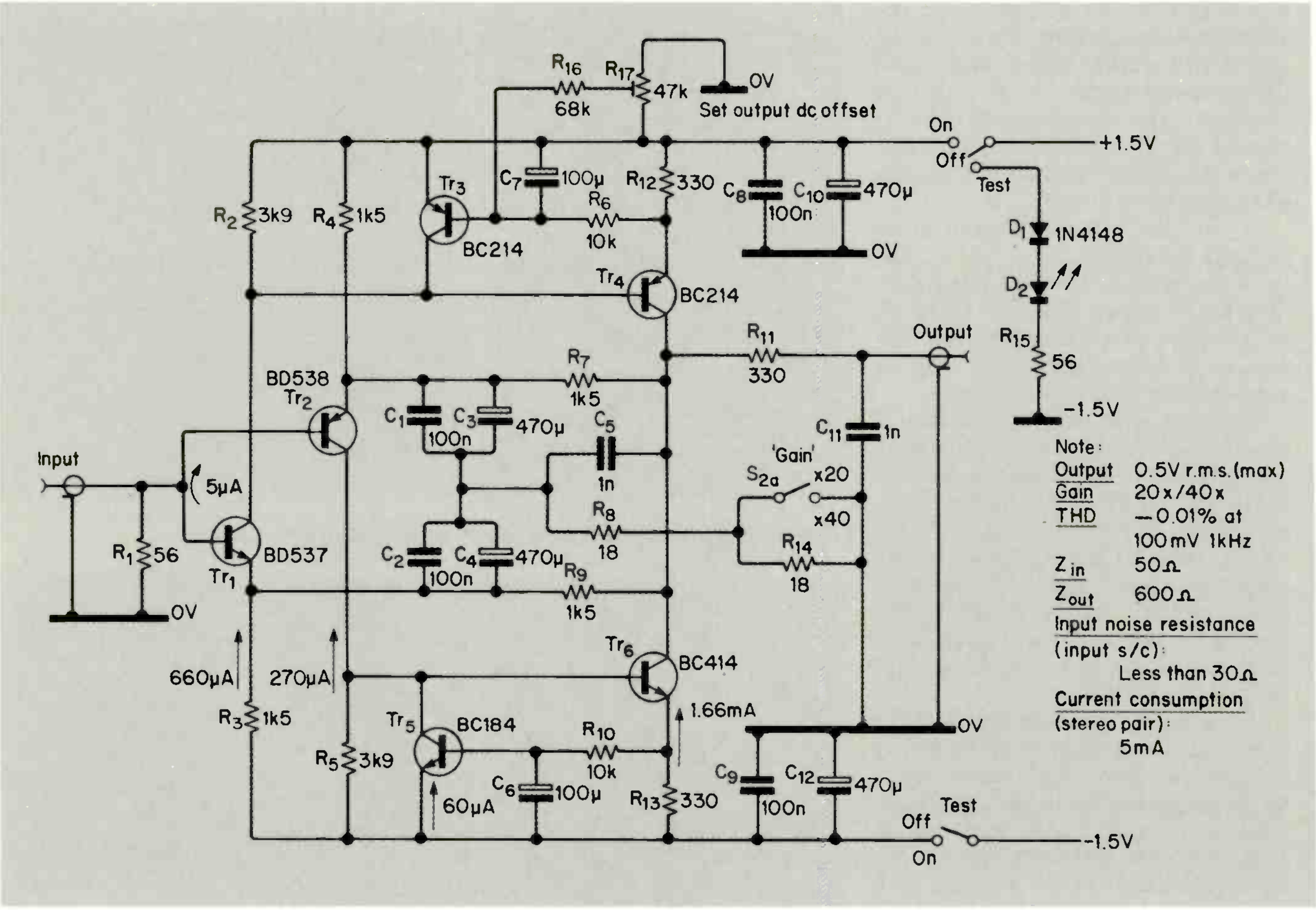


Fig. 10. John Linsley Hood's own design of 1985 for a low-noise microphone head amplifier using small power transistors.

may be 20 times lower than that of typical fixed coil units. Most high-quality preamplifiers now offer optional high-sensitivity, low-noise phono inputs.

Although the most common practice for such input circuits is simply to provide a head amplifier stage ahead of the main RIAA circuit, which can be switched into use as required, some manufacturers, such as Quad (Fig. 7), have sufficient confidence in their normal RIAA input circuitry simply to offer switched gain options for this.

The major design requirement for very low noise circuitry is the preservation of a low effective input noise resistance, mainly determined by the nature of the input device. Review articles summarising the possible approaches have been published by "John Barleycorn"[16], who also shows a number of commercial circuit layouts, and Self[17], who gives a valuable comparison between the input noise figures of a number of semiconductor types.

In general, excluding the simple option of a 20:1 input step-up transformer, the choices are the use of a number of identical small-signal transistors connected in parallel, as in the Naim NAC20 shown in **Fig. 8**, or a specially made ultra-low noise device such as the National Semiconductor LM194/394, an IC in which a large number of identical devices are parallel connected on the same chip. A suggested circuit is shown in **Fig. 9**.

Alternatively, some types of small power transistors, such as the BD435, BD537 and BD538, will give an adequately low input impedance and noise level. A typical circuit design of this type[18] is shown in **Fig. 10**.

In the next part of this article I will look at some of the other aspects of preamplifier design, such as headroom, filter circuitry and tone controls. ■

This series of articles on the evolution of audio preamplifier design forms, in conjunction with John Linsley Hood's earlier series on audio power amplifiers (November, December 1989 and January 1990), a virtually complete resumé of the subject from the 1950s to the present day.

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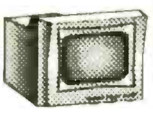

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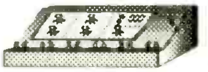

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CIRCLE ENQUIRY NO. 106 ON BACK PAGE

INTERFACING WITH C

PART 3

Howard Hutchings' continuing series on the use of C by electronics engineers indroduces transducer elements into software based data acquisition. Copies of the software listings for the entire series are now available on disk. Please see page 519 for details.

Data capture using CGA graphics

IBM compatible colour graphics adapters (CGA, VGA and EGA) are readily accessible using Microsoft C. **Listing 2.3** shows how a real-time CGA line graph can be incorporated into the data logging example and paves the way for the more sophisticated signal processing applications to be presented later. The graphics library is contained in the header file graph.h: the program must include the compiler directive #include<graph.h>. To enter the graph plotting routine use the _setvideomode function, which selects the appropriate screen mode for the particular combination of adapter (video card) and display (monitor).

Controlling the coordinate

The x and y axes are drawn using the _moveto(x,y) and _lineto(x,y) functions. No drawing takes place using the _moveto() function, which relocates the current position to the coordinates(x,y). The _lineto() function draws a line from the current position to the coordinates (x,y). Referring to listing 2.3 and Table 2.1 notice that the mode name _MRES4COLOR displays four colours using 320*200 pixels. In this mode the screen is divided up into 320 (0 to 319) horizontal points, and 200 (0 to 199) vertical points.

Unfortunately the "physical coordinate

Table 2.1 Manifest constants for screen mode

Mode	Type	Size	Colours	Adapter
_DEFAULTMODE		Hardware default mode		
_TEXTBW40	M/T	40*25	16	CGA
_TEXTC40	C/T	40*25	16	CGA
_TEXTBW80	M/T	80*25	16	CGA
_TEXTC80	C/T	80*25	16	CGA
_MRES4COLOR	C/G	320*200	4	CGA
_MRESNCOLOR	M/G	320*200	4	CGA
_HRESBW	M/G	640*200	2	CGA
_TEXTMONO	M/T	80*25	1	MA
_MRES16COLOR	C/G	320*200	16	EGA
_HRES16COLOR	C/G	640*200	16	EGA
_ERESNOCOLOR	M/T	640*350	1	EGA
_ERESCOLOR	C/G	640*350	64	EGA
_VRES2COLOR	C/G	640*480	2	VGA
_VRES16COLOR	C/G	640*480	16	VGA
_MRES256COLOR	C/G	320*200	256	VGA

Notes
(1) M indicates monochrome, C indicates colour, T indicates text and G indicates graphics.
(2) For text modes, size is given in characters (columns*rows). For graphics modes, size is given in pixels (horizontal*vertical).
(3) For monochrome displays, the number of colours is the number of grey shades.
(4) Adapters are the IBM (and compatible) Monochrome Adapter MA Colour Graphics Adapter CGA, Enhanced Graphics Adapter EGA and Video Graphics Adapter VGA.

system" of the IBM PC locates the origin (0,0) at the upper left hand corner of the screen. The majority of engineering applications will be plotted in the first quadrant, where both x and y are positive. Placing the origin in the bottom left hand corner requires a little arithmetic: as illustrated by the construction of the x and y axes, together with the modified y coordinate of the analogue voltage function. The effects of the video mode on the screen size, together with the associated coordinate system, are summarised in **Fig. 2.13**.

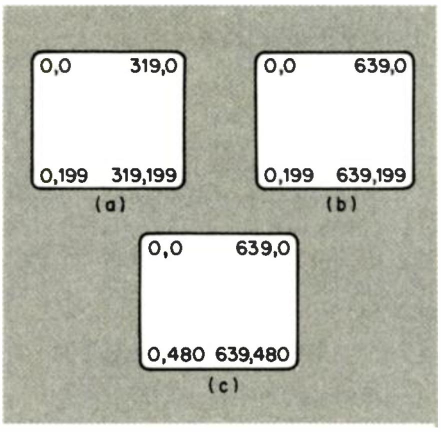

Fig. 2.13. Pixel map for a)CGA b)EGA c)VGA video mode functions shown in Table 2.1.

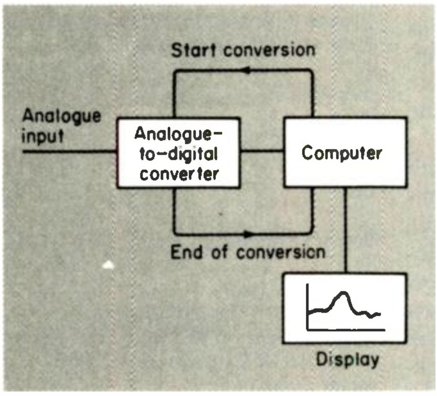

Fig. 2.14. Converter block diagram.

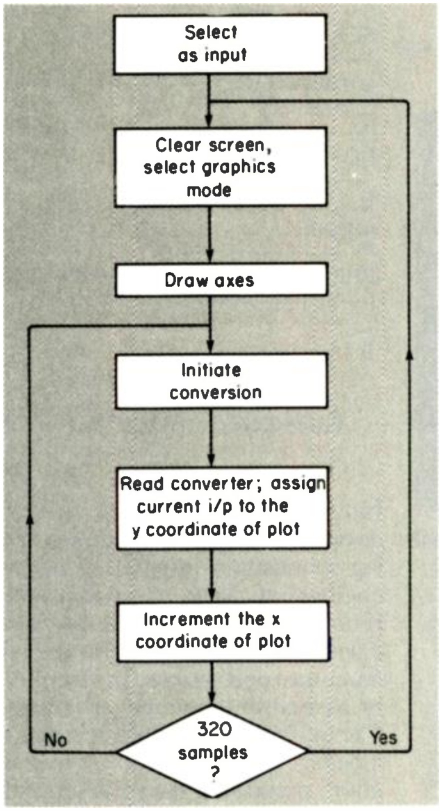

Fig. 2.15. Flowchart for Listing 2.3.

Listing 2.3. Program to synchronize A-to-D (0-10V) and graphically display 320 points.

```
/**************************
* CAPTURE 320 SAMPLES AND *
* DISPLAY GRAPHICALLY IN *
* CGA MODE *
**************************/
#include<stdio.h>
#include<graph.h>
#include<conio.h>
#define BASE 512
#define START 0
main()
{
int x,y;
float word;
unsigned int lower _bits,upper _bits,flag;
outp(BASE,0);
/*------------
SELECT CHANNEL
------------*/
for(;;)
{
_ setvideomode( _DEFAULTMODE);
_ setvideomode( _MRES4COLOR);
_ clearscreen( _GCLEARSCREEN);
/*--------------------
ORGANISE THE VIDEO MODE
--------------------*/
_ moveto(0,199);
_ lineto(319,199);
_ moveto(0,199);
_ lineto(0,0);
/*------------
DRAW X & Y AXES
--------------*/
for(x = 0;x <= 319;x+ +)
{
outp(BASE + 1,START);
/*-------------
START CONVERSION
---------------*/
do
{
flag = inp(BASE + 3);
}
while(32 & flag);
lower _ bits = inp(BASE + 2);
upper _ bits = inp(BASE + 3);
word = ((15 & upper _ bits) * 256) +
lower _ bits;
y = (int)200 * (1 - (word / 4095));
_ lineto(x,y);
}
getch();
/*----------------------------
PRESS ANY KEY TO REFRESH SCREEN
----------------------------*/
}
}
```

Data capture with EGA graphics

Modifying listing 2.3 for use with an EGA card is simply achieved by changing the constant in the _setvideomode() function, to _ HRES16COLOR. This mode provides 16 colours as shown in Table 2.2, together with a 640*200 pixel screen size. Reference to the system of coordinates shown in Fig. 2.11(b), indicates the necessary modifications to the horizontal axis, and to the variable (x) to capture 640 samples. Incorporating the _moveto(x,y) function immediately before _lineto(x,y) modifies the graphical display to a series of dots. **(Figure 2.16 and Fig. 2.17.)**

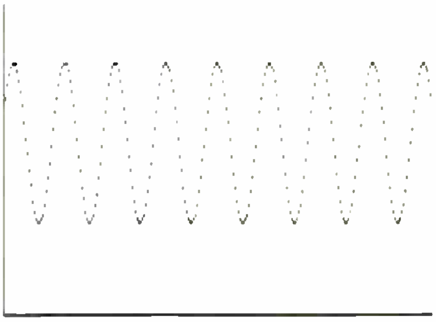

Fig. 2.16. The effect of Listing 2.3: screen dump of 4V p-p sinewave 50Hz using CGA mode.

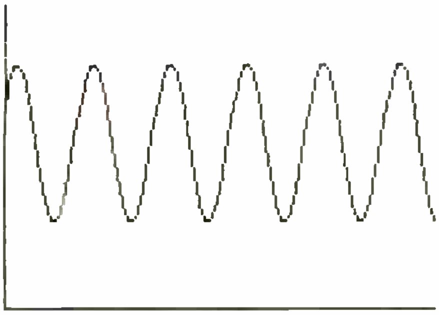

Fig. 2.17. The effect of Listing 2.4: screen dump of 4V p-p sinewave 50Hz using EGA mode.

Combining text and graphics is a useful feature because it allows the programmer to annotate axes and provide captions, thereby improving the clarity of the displayed data. **Listing 2.4**, designed to run EGA, shows how the title of the graph is located on the screen using the _ settextposition() function, written in the program as: _settextposition(4,3). The text to be displayed at that position is controlled (in this example), by _outtext("Analogue voltage(0-10V)").

Background and foreground colour

To specify the colour of the title, use the _settextcolor() function. The program colours the text cyan using _settextcolor(3).

Colouring the background dark grey is achieved using the _setbkcolor() function, written as _setbkcolor(_GRAY). The graph is plotted in light yellow using the function _setcolor(14).

Reading Table 2.2 in conjunction with listing 2.4 establishes the relationships between the colour, colour text mode number and the colour constant. Microsoft C is rather idiosyncratic in this respect, requiring the colour of the text and foreground to be specified using colour text numbers, yet allowing the background to be defined by the colour constant.

Table 2.2. Colour text mode numbers and colour constants

Colour	Colour text mode number	Colour constant
Black	0	_BLACK
Blue	1	_BLUE
Green	2	_GREEN
Cyan	3	_CYAN
Red	4	_RED
Magenta	5	_MAGENTA
Brown	6	_BROWN
White	7	_WHITE
Dark grey	8	_GRAY
Light blue	9	_LIGHTBLUE
Light green	10	_LIGHTGREEN
Light cyan	11	_LIGHTCYAN
Light red	12	_LIGHTRED
Light magenta	13	_LIGHTMAGENTA
Light yellow	14	_LIGHTYELLOW
Bright white	15	_BRIGHTWHITE

Listing 2.4. Program to synchronise A-to-D (0-10V) EGA mode.

```
/**************************
* CAPTURE 640 SAMPLES AND *
* DISPLAY GRAPHICALLY *
* USING EGA MODE *
***************************/
#include<stdio.h>
#include<graph.h>
#include<conio.h>
#define BASE 512
#define START 0
main()
{
int x,y;
float word;
unsigned int lower _bits,upper _bits,flag;
outp(BASE,0);
/*------------
SELECT CHANNEL
-------------*/
for(;;)
{
_setvideomode(_DEFAULTMODE);
_setvideomode( _HRES16COLOR);
_clearscreen( _GCLEARSCREEN);
_setbkcolor(_GRAY);
_moveto(0,199);
_lineto(639,199);
_moveto(0,199);
_lineto(0,0);
/*------------
DRAW X & Y AXES
---------------*/
_settextposition(4,3);
_settextcolor(3);
_outtext("Analogue voltage (0-10V)");
for(x = 0;x <= 639;x++)
{
outp(BASE + 1,START);
/*--------------
START CONVERSION
---------------*/
do
{
flag = inp(BASE + 3);
}
while(32 & flag);
lower _bits = inp(BASE + 2);
upper _bits = inp(BASE + 3);
word = ((15 & upper _bits) * 256) +
lower _ bits;
y = (int)200 * (1 - (word / 4095));
_ setcolor(14);
/*------------------
SET FOREGROUND COLOUR
--------------------*/
_moveto(x,y);
_lineto(x,y);
/*-----------
DOTTED DISPLAY
-------------*/
}
getch();
/*---------------------------
PRESS ANY KEY TO REFRESH SCREEN
------------------------------*/
}
}
```

Transducer interfacing with C

Interfacing measurement and control devices to a digital computer is an inviting proposition using C. It allows the engineer to write successful software rapidly, which will monitor and linearise a process without becoming immersed or distracted by the fine detail of assembly language programming. The mathematical characteristics of the language make it ideal for this application, permitting the solution of engineering problems which would be virtually intractable using assembly code.

I want to connect a non-linear transducer, in this case a thermistor, to a digital computer, **Fig. 2.18**. The program will process the sampled input voltage and display the temperature in degrees Celsius. The problem breaks down to this: relating the transducer's characteristics to the byte orientated world of the digital computer; using software to linearise the response and provide suitable signal conditioning. Since the problem is almost completely solved by the software, very simple electronics is required — a major plus. It is also a good way to learn about C.

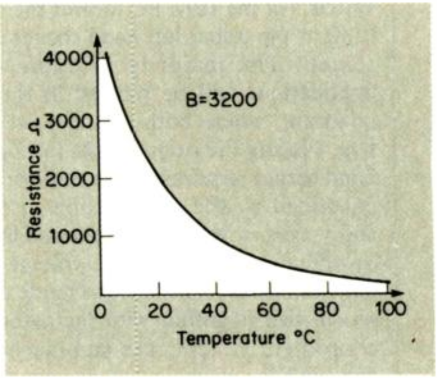

Fig. 2.19. Thermistor GL23 characteristics.

The relationship between the resistance R and the temperature T is given by the expression:

$$R = A \exp (B/T)$$

where R is measured in ohms
T is measured in kelvins ie (273 + °C)
A and B are constants

When the resistance R_0 is known at a particular temperature T_0, we may write:

$$R_0 = A \exp (B/T_0)$$

Dividing the first equation by the second and simplifying gives a more useful form of equation:

$$R(T) = R_0 \exp B(1/T - 1/T_0)$$

This form of resistance-temperature relationship is particularly useful when the characteristic temperature B is known, together with concurrent values of R_0 and T_0. We can use this equation to predict how the resistance will vary with temperature. **Table 2.3** column (2) has the details.

Conditioning the signal voltage

Connecting the thermistor in series with

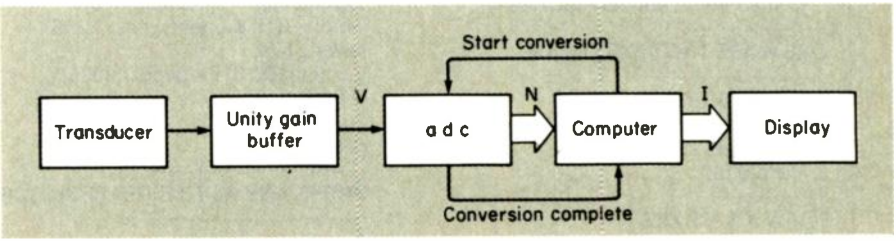

Fig. 2.18. Transducer interface system diagram.

Continued over page ▶

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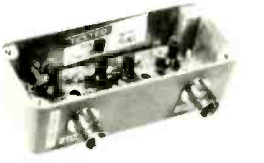
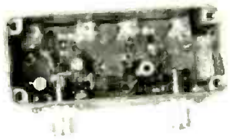

TYPE 9006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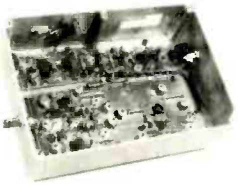
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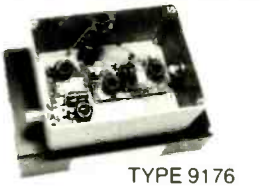
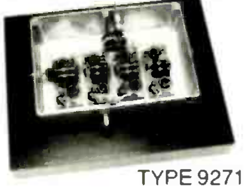

TYPE 9176


TYPE 9271

TYPE 9247. 4 watts output 1-50MHz 13dB gain £135
TYPE 9051. 4 watts output 20-200MHz 13dB gain £135
TYPE 9176. 4 watts output 1-50MHz 26dB gain £285
TYPE 9177. 4 watts output 20-200MHz 26dB gain £285
TYPE 9173. 20 watts output 1-50MHz 10dB gain £340
TYPE 9174. 20 watts output 20-200MHz 10dB gain £340
TYPE 9271. 40 watts output 1-50MHz 10dB gain £680
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TYPE 9235. Mains power supply unit for above amplifiers £180

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

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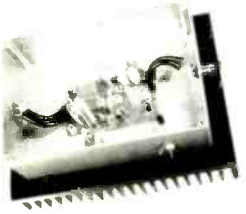
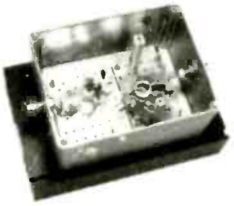
TYPE 9302 100KHz-1GHz NF 2dB at 500MHz. Gain 30dB. Power output +12.5dBm, 18mW **£150**
TYPE 9303 100KHz-2GHz NF 3.5dB at 500MHz. Gain 20dB. Power output +24dBm, 250mW **£235**
TYPE 9008 Gasfet. 100MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Power output +18dBm, 65mW **£150**
TYPE 9009 Gasfet. 100KHz-400MHz NF 2.8dB at 300MHz. Gain 20dB. Power output +20dBm, 100mW **£150**


TYPE 9263

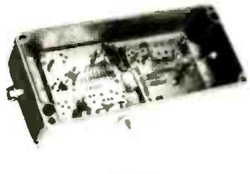

TYPE 9259

TELEVISION LINEAR POWER AMPLIFIERS

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

TYPE 9252. 10mW input, 500mW output £280
TYPE 9259. 500mW input, 3 watts output £320
TYPE 9262 500mW input, 10 watts output £580
TYPE 9263. 2-3 watts input, 15 watts output £440
TYPE 9266 10 watts input, 50 watts output £1,745

See below for Television Amplifiers in bands I & III.


TYPE 9105


TYPE 9158/9235

TMOS RF LINEAR POWER AMPLIFIERS

Tuned to your specified frequency in the range 20-250MHz. or your specified channels in bands I or III. 24V + DC supply.

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TYPE 9106 500mW input. 10 watts output £310
TYPE 9155. 1 watt input. 30 watts output £360
TYPE 9158. 5 watts input. 70 watts output £490

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a constant current generator set to 2.246mA matches the maximum voltage developed across the transducer to the maximum input range of the A-to-D. This avoids loss of significance. Multiplying the constant current (I) by the resistance of the thermistor R(T) gives the voltages shown in column (3).

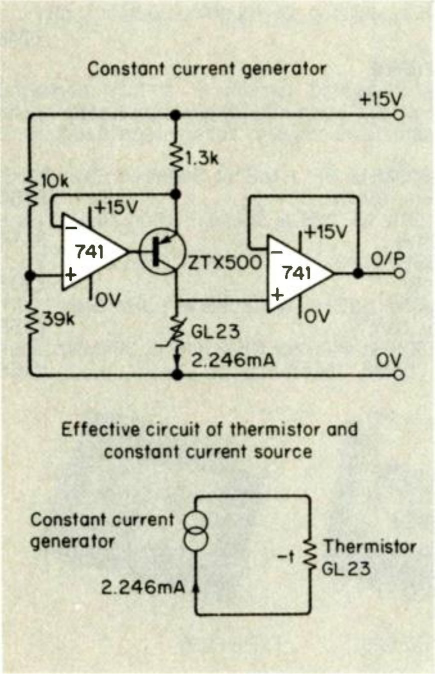

Fig. 2.20. Constant current generator for GL23 thermistor.

The analogue voltage developed across the transducer (V) is translated into a 12-bit data word (N) by the A-to-D converter. Since the transfer characteristic of the A-to-D is linear, simple ratio and proportion may be used to relate these quantities.

$$N/4095 = V/10$$

Table 2.3 summarises these results, demonstrating the relationship between the captured data word (N) and the temperature (T) over the range 0 to 100°C.

Table 2.3. Showing how the digital output from the A-to-D varies with temperature

Temperature °C	Thermistor resistance ohms	Analogue voltage V	Digital N
0	4451	10.0	4095
10	2942	6.61	2706
20	2000	4.49	1838
30	1395	3.13	1281
40	995	2.23	913
50	725	1.63	667
60	539	1.21	495
70	407	0.91	372
80	312	0.70	286
90	243	0.54	221
100	192	0.43	176

Simplifying program development

Large programs frequently require considerable development which may be simplified by bottom up design. This usually involves constructing the program in compartments of well tried and tested code which eventually bolt together to provide the final program. The example hopefully demonstrates how the temperature display program may be built up from smaller fragments. We consider this useful because the linearisation code was the untried software structure. The control of the A-to-D and graph plotting routine had already been used successfully.

Referring to Table 2.3 we can relate the temperature of the thermistor (T) to the denary integer (N), processed by the program. This means that by simulating the output of the A-to-D using the scanf() function, we can test the program construction without the complication of external hardware, simply by reading numbers input from the keyboard. In this way we reduce the possible sources of error and can rapidly test the structure of the software.

To establish the relationship between the temperature (T) and the output of the A-to-D converter (N) requires a systematic approach, followed by a little algebra. First we re-arrange the thermistor equation:

$$R(T) = R_0 \exp B(1/T - 1/T_0)$$

This expresses the temperature (T) in terms of the resistance variable R(T). Recognising that the computer does not read resistance at the input port, we must express R(T) in terms of (N) using:

$$I.R(T)/10 = N/4095$$

We leave you to confirm the algebra, preferring instead to present the C program which does the work for us. Successful compilation requires the inclusion of the header file math.h, which contains a library of common mathematical functions including log(), the natural logarithm function. Notice the called function R is declared as a double.

Listing 2.5 Linearising the thermistor characteristic using software

```
/************************
* LINEARISING GL23 AND *
* SIMULATING 12-BIT ADC*
************************/
#include<stdio.h>
#include<math.h>
#define To 273
#define B 3200
#define Ro 2000
main()
{
int n;
double R,T;
for(;;)
{
scanf("%d",&n);
/*-------------------
SIMULATE 12-BIT ADC
--------------------*/
R = 1.0869 * n / Ro;
T = 1 / (log(R) / B + 0.003413) – To;
printf("temperature:%f\n",T);
}
}
```

Displaying temperature using EGA graphics

Listing 2.6 linearises the response of the thermistor GL23 and displays temperature graphically using 640 samples, over the range 0-100°C. Calibration of the system is straightforward: simply replace the thermistor with a decade resistance box. Table 2.3 relates resistance to temperature over the range of interest.

Listing 2.6 Displaying temperature graphically 0 to 100°C – EGA mode

```
/**********************
* DIGITAL THERMOMETER *
* (0–100)CELSIUS GL23 *
**********************/
#include<stdio.h>
#include<graph.h>
#include<conio.h>
#include<math.h>
#define BASE 512
#define START 0
#define To 273
#define B 3200
#define Ro 2000
main()
{
int x,y,word;
double R, T;
unsigned int lower_bits,upper_bits,flag;
outp(BASE,2);
/*-----------
SELECT CHANNEL
-------------*/
for(;;)
{
_setvideomode(_DEFAULTMODE);
_setvideomode(_HRES16COLOR);
/*-------
EGA MODE -----------*/
_clearscreen(_GCLEARSCREEN);
_setbkcolor(_GRAY);
_moveto(0,199);
_lineto(639,199);
_moveto(0,199);
_lineto(0,0);
/*------------
DRAW X & Y AXES
--------------*/
_settextcolor(3);
_settextposition(4,3);
_outtext("Temperature(0-100) celsius");
/*--------------------
COLOUR AND POSITION TEXT
----------------------*/
```

```
for(x = 0;x <= 639;x++)
{
outp(BASE+1,START);
/*--------------
START CONVERSION
----------------*/
do
{
flag = inp(BASE+3);
}
while(32 & flag);
lower_bits = inp(BASE+2);
upper_bits = inp(BASE+3);
word = ((15 & upper_bits) * 256) +
lower_bits;
R = 1.0869 * word / Ro;
T = 1 / (log(R) / B + 0.003413) - To;
y = 2 * (100 - T);
/*----------------
SCALE Y COORDINATE
------------------*/
_setcolor(14);
_moveto(x,y);
_lineto(x,y);
}
getch();
/*----------------------------
PRESS ANY KEY TO REFRESH SCREEN
------------------------------*/
}
}
```

Trying fancier software

The flexibility of the personal computer allows the introduction of an averaging mechanism into the program to reduce the effects of random noise. This simple digital filter is easy to understand and, when incorporated into the digital thermometer system, provides a useful experimental vehicle to demonstrate principles.

Signal averaging is an attractive method of recovering wanted data corrupted by noise. A graphical representation of the signal processing system is shown in **Fig. 2.21**.

The advantages of bringing the A-to-D under software control will now be apparent. Because the conversion process is synchronised with the main program, it becomes a simple matter to organise the software so that the current input becomes the previous input, one sample later. Adding the current input x(n) to the previous input x(n – 1) and then dividing by two completes the signal processing y(n). The response of the thermistor is relatively slow compared with the rate of sampling which means that the wanted signal is virtually stationary by comparison. The addition of sequential samples allows the signal characteristics to emerge as the noise effectively fades away.

Listing 2.7. Signal averaging y(n) = 0.5 * (x(n) + x(n – 1))

```
/*************************
* 2 TERM MOVING AVERAGER *
**************************/
#include<stdio.h>
#include<conio.h>
#define BASE 512
/*------------------------
BASE ADDRESS OF PORT-MAPPED
MULTIPLEXED A-to-D
---------------------------*/
#define START 0
main()
{
unsigned int lower_bits,upper_bits,flag;
float new_input,old_input,average;
for(;;)
{
outp(BASE,0);
/*--------------------
SELECT CHANNEL No. 0–23
----------------------*/
outp(BASE+1,START);
/*----------------
INITIATE CONVERSION
------------------*/
do
{
flag = inp(BASE+3);
}
while(32 & flag);
/*---------
FLAG RAISED?
-----------*/
lower_bits = inp(BASE+2);
upper_bits = inp(BASE+3);
new_input = ((15 & upper_bits) * 256) +
lower_bits;
/*------------------
CONDITION 12-BIT WORD
--------------------*/
average = 0.5 * (new_input + old_input);
printf("Average o/p:%f\n",average);
old_input = new_input;
/*---------
SHUFFLE DATA
-----------*/
}
}
```

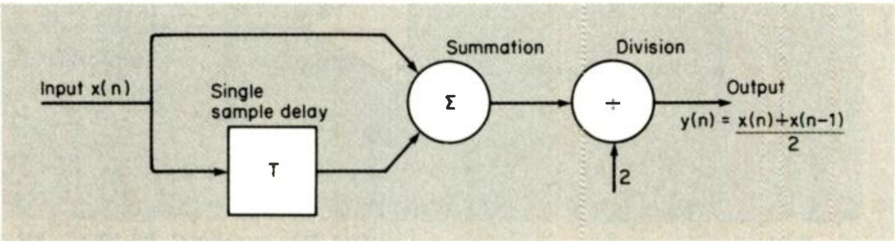

Fig. 2.21. System diagram for a 2-term moving averager.

Introducing random noise

Demonstration of the signal processing characteristics shown in Fig. 2.21 requires the addition of random noise to the input signal. A suitable circuit is shown in **Fig. 2.22**. The 5837 digital noise generator produces pulses of amplitude 10V, with durations that are random integer multiples of 20μs. Feeding the random output signal through a 10kΩ potentiometer allows the amplitude of the noise to be attenuated before addition to the output of the temperature transducer, in the summing amplifier/low-pass filter.

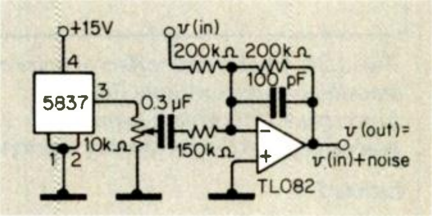

Fig. 2.22. Random noise generator and summing amplifier.

There is no need to restrict the averaging module design to two terms. We show a 5-term moving averager, **Fig. 2.23 and listing 2.8**.

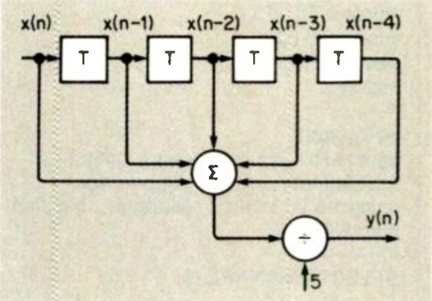

Fig. 2.23. System diagram of a 5-term moving averager.

Starting from the left hand side, the current input from the A-to-D x(n) progressively moves along the "tapped delay line", one sampling interval at a time. Summing the sequential terms, up to and including the fifth term: x(n – 4); before dividing by 5 completes the signal processing.

y(n) = 0.2 * (x(n) + x(n – 1) + x(n – 2) + x(n – 3) + x(n – 4))

With careful design this algorithm can be implemented as a real-time digital filter and may be used to smooth the composite output from the digital thermometer/random noise generator as shown in listing 2.8. Examination of **Fig. 2.24** discloses the effects of the moving averager – before and after processing a signal equivalent to 30°C.

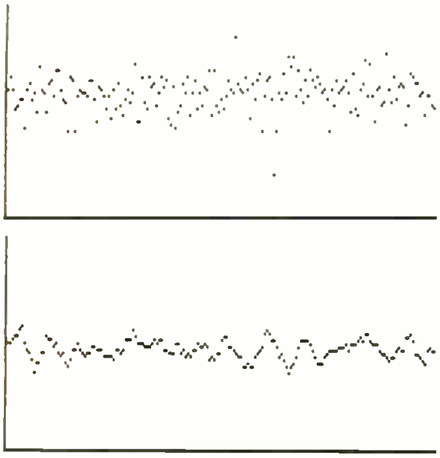

Fig. 2.24. Upper trace: effect of noise on transducer output without filtering. Lower trace: transducer output after processing with 5-term moving averager.

Listing 2.8

```
/**************************
* 5 TERM MOVING AVERAGER *
* PLUS DIGITAL THERMOMETER *
**************************/
#include<stdio.h>
#include<graph.h>
#include<conio.h>
#include<math.h>
#define BASE 512
#define START 0
#define To 273
#define B 3200
#define Ro 2000
main()
{
int x,y,word;
double R,T,input _0,input _1,input _2;
double input _3,input _4,average;
unsigned int lower _bits,upper _bits,flag;
outp(BASE,0);
/*-----------------
SELECT CHANNEL No.
------------------*/
for(;;)
{
_setvideomode(_DEFAULTMODE);
_setvideomode(_HRES16COLOR);
/*--------
EGA MODE
---------*/
_clearscreen(_GCLEARSCREEN);
_setbkcolor(_GRAY);
_moveto(0,199);
_lineto(639,199);
_moveto(0,199);
_lineto(0,0);
/*-------------
DRAW X & Y AXES
---------------*/
_settextcolor(3);
_settextposition(4,3);
_outtext("Temperature(0-100) celsius");
/*----------------------
COLOUR AND POSITION TEXT
------------------------*/
for(;;)
{
outp(BASE+1,START);
/*---------------
START CONVERSION
----------------*/
do
{
flag = inp(BASE+3);
}
while(32 & flag);
lower _bits = inp(BASE+2);
upper _ bits = inp(BASE+3);
input _0 = ((15 & upper _bits) * 256) +
lower _bits;
average = 0.2 *
(input _0+input _1+input _2+input
_3+input _4);
R = 1.0869 * average / Ro;
T = 1 / (log(R) / B + 0.003413) – To;
y = 2 * (100 – T);
/*-----------
SCALE Y AXIS
------------*/
_setcolor(14);
_moveto(x,y);
_lineto(x,y);
input _4 = input _3;
input _3 = input _2;
input _2 = input _1;
input _1 = input _0;
}
getch();
/*-----------------------------
PRESS ANY KEY TO REFRESH SCREEN
-------------------------------*/
}
}
```

A linear transducer

Temperature measurement using the GL23 is a useful introduction to interfacing. The example identifies the relationship between transducer and processed output using C. Unfortunately variations between thermistors make calibration a problem and the real world may demand a more robust engineering solution.

Analog Devices AD590KH is a current transducer which sources 1μA/K over the range −50°C to 150°C. The linearity is particularly good and, using the circuit shown in **Fig. 2.25**, requires only 2-point calibration, producing an output of 100 mV/°C over the range 0-100°C. Evidently this approach is a compromise, trading a complete software solution against elaborate hardware with rudimentary software.

Measurement of light intensity

Darkness falls, a shadow passes the window. "DANGER INTRUDER ALERT" prints the computer, the alarm sounds. How is it done? The principles outlined in the preceding paragraphs can be incorporated into the design and development of a light intensity measurement system. Luminance is a measure of the brightness or illumination of a surface, measured in lumens per square metre or lux.

A cadmium sulphide photo conductive cell ORP12 has a spectral response very similar to that of the human eye, making it ideal for visible sensing circuits.

Table 2.4. Typical figures of illumination

Light source	Approximate illumination (lux)
Bright sunlight	30,000
Fluorescent lighting	500
60W lamp at 1 metre	50
Moonlight	0.1

Statement of the problem

I want to interface a light dependent resistor with the computer, so that the intensity of light falling on the transducer is displayed in lux on the screen. Because I intend to monitor light intensity continually, the program will run in real time.

To keep the electronics as simple as possible we will use software to linearise the response of the transducer. The relationship between the resistance in kΩ and the illumination, I, in lux is shown in **Fig. 2.26**. Using the graph we may deduce that:

$$I = 125.1R^{-1.097}\ \text{lux}$$

where R is the cell resistance in kΩ

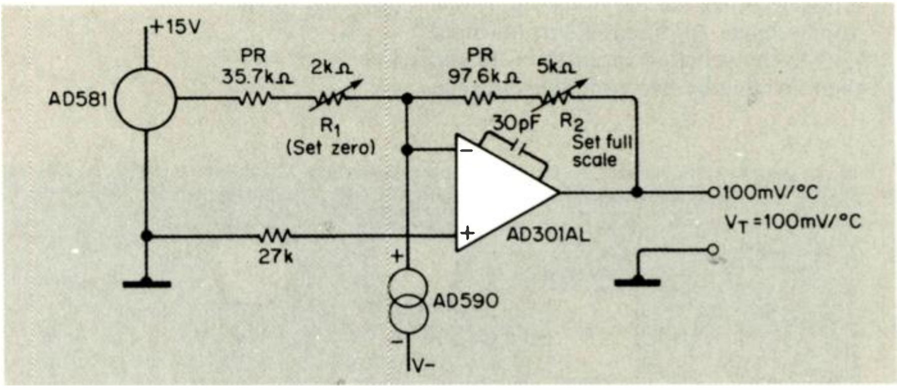

Fig. 2.25. Temperature measurement using AD590. R1 sets for 0°C, R2 100°C. PR = precision resistor.

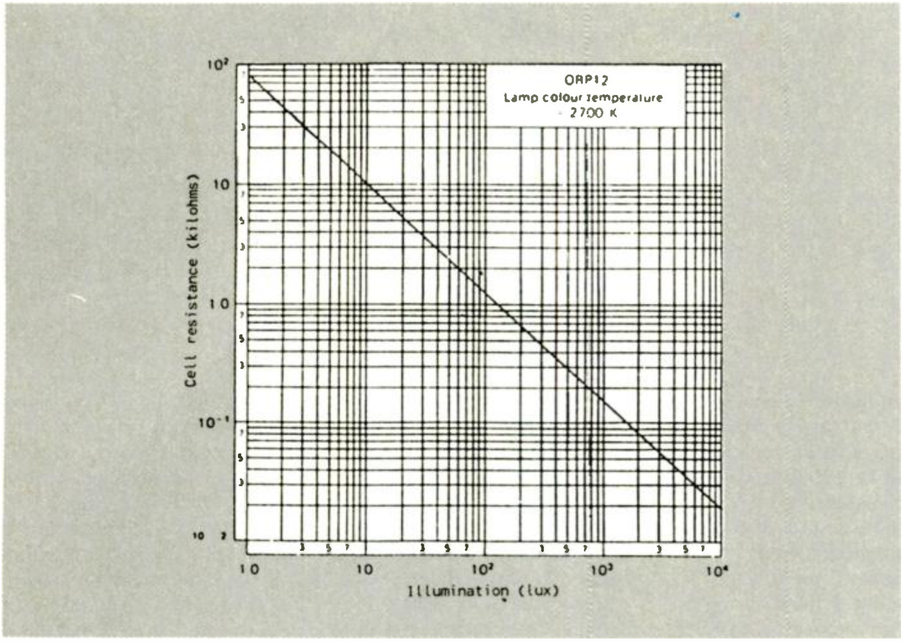

Fig. 2.26. Relationship between light intensity I and resistance R.

The transducer circuit is simply the ORP12 in series with a 200Ω resistor. As shown in **Fig. 2.27** this series combination is connected across a 10V DC supply, the voltage across R being processed into digital form by the 12-bit A-to-D converter. To compute the monitored light intensity, we must first establish the relationship between N (the output from the A-to-D) and the light intensity I. The voltage processed by the A-to-D is simply:

$$Vo = \frac{10 \times 200}{200 + R} \text{volts}$$

Re-arrange the light intensity equation and substitute for R, so that:

$$Vo = \frac{10 \times 200}{200 + 1000(125.1 / I)^{0.9115}} \text{volts}$$

The analogue voltage Vo is translated into a 12-bit data word N – using ratio and proportion we conclude that:

$$N / 4095 = Vo / 10$$

The illumination I is given in terms of the data word N by the expression:

$$I = \frac{125.1}{(819 / N - 0.2)^{1.097}}$$

C handles expressions such as these with ease, effectively linearising the response in a single line. Table 2.5 reviews the relationship between the illumination I and the data word N over the range 0.1 to 5000 lux.

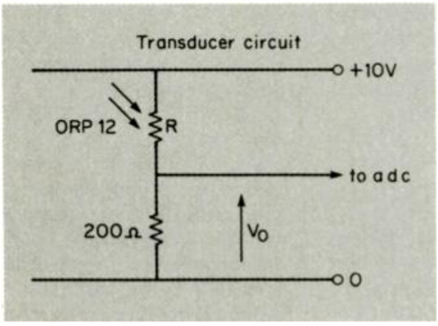

Fig. 2.27. Transducer circuit.

Table 2.5. Showing how the output from the A-to-D varies with light intensity.

Illumination lux	Cell resistance kΩ	Analogue voltage volts	Digital N
0.1	665.5	0.003	1
10	10.003	0.196	80
50	2.3069	0.7976	326
100	1.2264	1.402	574
500	0.2828	4.142	1696
1000	0.1503	5.709	2337
2000	0.0799	7.145	2926
5000	0.0274	8.793	3600

Adopting the system diagram shown in Fig. 2.18 together with the appropriate A-to-D control software makes a complete program description unnecessary. We prefer instead to show that part which linearises the transducer response with data generated synthetically using the keyboard, **listing 2.9.**

Listing 2.9.

```
................................
' LINEARISING ORP12 AND '
' SIMULATING 12-BIT ADC '
· USING THE KEYBOARD ·

................................/
#include < stdio.h >
-------------------------------------------*/
parameter = (double) 819 /n-0.2;
denominator = pow (parameter, 1.097);
/*-----------------------------------------
RAISE PARAMETER TO THE POWER 1.097
-------------------------------------------*/
I = 125.1/denominator;
printf("Lux = %fn",I);
}
}
# include <math.h>
main()
{
int n;
double I, parameter, denominator;
for (;;)
{
scanf ("%d",&n);
/*------------------------------------------
SIMULATE 12 BIT ADC:KEYBOARD
```

References

(1) F. Shoreys. New approaches to high-speed high-resolution analogue to digital conversion. Electronics and Power Measurement. February 1982.
(2) Data acquisition using the IBM PC. Electronics and Wireless World. March 1989.
(3) N. Barkakati. The Waites Group's Essential Guide to Microsoft C. (Graphics chapters 17 – 19). Howard Sams & Company. 1989.
(4) M. Koen. Comparing ADC architectures is a designer's best bet. Electronic Design. January 1987
(5) Microsoft Quick C Programmers Guide. (Chapter 4 Graphics Quick Start). Microsoft 1987.
(6) Linear Design Seminar. Analog Devices. 1987.
(7) P. A. Lynn. Electronic signals and systems. Macmillan 1987.

Interfacing with C

Put to the test

The only satisfactory criterion for a reference power amplifier is, surely, that it should be as faithful, i.e. accurate, as possible.

David Hafler, in a long, logical and very lucidly expressed letter in the September 1987 issue of *Hi-Fi News*, totally devoid of commercial bias in its arguments, concludes by saying, "It would seem now that the concept that the Colloms rating system is infallible must be scrutinised. There is an easy way to do this, a way which I do not think Mr Colloms will dare try — rate all amplifiers on a double-blind basis."

And Martin Colloms, in his reply in the December 1987 issue, says, ". . . I am getting tired of the oft heard demand to 'prove it' so far as my subjective test results and resulting comments on sound quality are concerned ... The technique of blind listening comparisons is extremely costly and quite out of the question for regular magazine reviews ... I choose to decline David Hafler's challenge for the moment."

I can see no good reason why blind listening comparisons should be "extremely costly". They can even be done by a reviewer working on his own, using a high-grade automatic random switching unit, thorough precautions being taken to avoid any little switching noises or other effects giving tiny identification clues. It really is simply nonsense to pretend that a bit of simple switching cannot be achieved without audible quality degradation — see David Hafler's letter.

Martin has blamed the Hafler switching unit, etc., for obliterating the differences he otherwise claims to have heard between the Hafler and reference amplifiers. These differences he interprets as shortcomings of the Hafler amplifier and says they include, "failure to reproduce the full scale and weight of the bass with sufficient authority, midrange colouration, a touch of nasality, treble with added mild brittleness and not fully integrated with the midrange ... noticeably withdrawn in respect of dynamic life and programme contrasts."

In my experience the above are not the kind of audible defects exhibited by amplifiers with slightly less than ideal performance. They sound more as if they ought to relate to a moving-coil microphone, or perhaps a transistor portable, than to an amplifier which has been demonstrated to have no audible imperfections!

The differential test is a far more sensitive way to discriminate between amplifiers than any straightforward comparative test can ever be. When it is carried out on first-rate amplifiers it establishes, with no reasonable grounds whatever for doubt, that such amplifiers are so free from audible defects, sometimes with a large margin to spare, that if, by the waving of a magic wand, they could suddenly be rendered absolutely perfect, then no change at all in the quality of the music reproduction would be heard, no matter how "golden eared" the listeners nor how high quality the programme source.

Since no further improvement in achievable sound quality is in fact possible so far as low output impedance audio power amplifiers are concerned, future progress in their design ought to be mainly related to simplicity, reliability, efficiency, size and cost.

Though Martin Colloms appears to believe sincerely in the reliability of his subjective numerical rating procedure, confidence in such methods has been shown to be unjustified not only by the nulling or differential tests referred to above, but also by careful independent comparative tests. I refer particularly to those organised by Quad (see *Hi-Fi News*, June 1978) and more recently by the American *Stereo Review* (see their January 1987 issue).

The American tests involved six makes of amplifier, ranging from a pair of Futterman valve amplifiers at $6000 per channel to a Pioneer receiver priced at $220. The associated items were of luxurious "audiophile" class.

Before the blind tests were done, the 25 listeners, both "believers" and "sceptics", were allowed to listen at leisure to the various amplifiers, knowing which they were listening to. Almost all said they heard differences, even the sceptics, and comments were made such as, "This amplifier's ability to increase sound-stage width was amazing ... great ambience retrieval" (Futterman); or, "Constricted sound, seems distorted ..." (Pioneer). The language used was generally rather similar to that in Martin's reviews.

For the actual tests, listeners were given the choice of using an A/B/X comparator with hand-held control, or having the amplifiers changed (invisibly) by cable-swapping. Most opted for the comparator, though nine of them chose to augment these tests with cable-swapping ones.

Out of the 772 choices made, 388 were correct (50.3%). No single listener got more than 63% nor less than 38% correct. On the Futterman versus Pioneer comparison (55:1 price ratio!) there were 114 correct choices out of 212 (54%).

The author of the article concludes, "All interpretations of these results, therefore, lead to the conclusion that correct choices were made totally by chance — there were no audible differences to be heard."

Martin Colloms has himself organised two amplifier assessment trials. One was in 1978 (see *Hi-Fi News*, November 1978), involving Quad, Naim and TVA (valve) amplifiers and a total of 13 panellists. In his own words at the end of his article about the tests, "these results ... support the thesis that good power amplifiers — with the emphasis on 'good' — all sound much the same."

The nulling or differential test when conducted as above on a listening basis I have been inclined to call a subjective test. David Hafler calls it objective, since little subjective skill is required to decide whether a difference sound is heard or not. This is an arguable point. However, if a difference is heard, an oscilloscope may be used to investigate the nature of the difference signal in more detail, both with programme input and with various test signals. (The broadband nulling technique is a good one to use for distortion investigations. It has the advantage that the true distortion waveform is displayed, unaffected by the phase characteristic of a notch filter, and the requirements for very low distortion and noise in the test oscillator are also much relaxed.)

The following point may not be significant, but I think it should be mentioned nevertheless. Martin's statistician, in the May 1986 *Hi-Fi News* report, says, "I have assumed that if there were no difference between the amplifiers, so that the listeners were merely guessing, then the probability of saying 'similar' or 'different' is 50:50." However, since all the listeners are trying as hard as they can to hear small differences, it could well be that some of them will say they have heard a difference more often than not, even if no actual difference exists.

Continued over page ►

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CIRCLE ENQUIRY NO. 108 ON BACK PAGE

Now Martin says the orders of presentation of the two amplifiers adopted were ABAB, ABBA and BAAB. If these were equally frequent, and a listener (to take an extreme case) said he heard a difference every time, he would score 7 correct answers out of 9 even if there were no genuinely audible difference between the amplifiers. Clearly such an extreme case as this would not occur, but a tendency for more than 50% correct answers to be produced would only be reliably avoided by arranging for there to be equal numbers of "similar" and "different" presentations.

Martin's Table 2 implies that there were also some AAAB and BBBA presentations, in addition to the above ones which he specifically mentions. Perhaps there were sufficient of these to achieve an overall equality of "similar" and "different" presentations, but I am left wondering.

All this at least illustrates how careful one has to be when conducting such statistical trials. It would be very interesting to investigate the results obtained in a complete trial in which, unknown to the panellists, no amplifier changes whatever were made!

The panellists were also asked to score each presentation numerically, from 0 to 10, for sound quality. All one could do was to consider how the reproduction seemed to compare with the best reproduction one could imagine, or perhaps with live concert sound, and write down a number, say 5. But one felt very uncertain, and might well have put down, say, 4 or 6 on another day.

Of course, any notion that perfect amplifiers would yield 10 marks is absurd, since many items other than power amplifiers are involved in a complete audio recording and playback system. The average results showed that two panels thought amplifier B was better and one panel thought A was better.

A letter from James Moir in the June 1986 issue of *Hi-Fi News*, on sound quality in AES demonstrations, relates to the Colloms tests in the context of the last paragraph.

Though I had meant to comment on various detailed circuit points in John Linsley Hood's articles (November and December 1989 and January 1990), I think space will now permit only one such comment.

It relates to the explanation of current-dumping amplifiers on p.1166 of the December article, where it is wrongly stated that the dumper transistors must have identical characteristics for the distortion theoretically to vanish completely. The distortion-nulling condition is in fact quite independent of the dumper characteristics — the greater the dumper transmission the more the extra feedback, to an exactly compensating degree. The statement, relating to Fig. 6, that the slope from M' to N' must be the same as that from N to M, is likewise incorrect.

For detailed comments on McLoughlin's other objections to the circuit, which were mostly not valid ones, see letters from Peter Walker and myself in your December 1983 issue.

Peter J. Baxandall
Malvern
Worcs.

Boring bang

There is one detail that K.P. Wood ("Boring story", *EW+WW*, January 1990) does not mention in the rail cutting exercise with gun cotton — surely the operation is all but silent.

Thus the necessary inertial mass must be that of the surrounding atmosphere, stiff as concrete at the very high wavefront velocities involved.

Perhaps somebody entitled to access to a vacuum chamber in, say, a space research establishment would care (or dare) to perform the experimental proof *in vacuo*? I'll go so far as offering a length of rail!

J. C. Baumeister
Chantraine
France

Inertial hypothesis

I have never seen or heard a really clear explanation of the concept of inertia force, even after reading the Hypothesis article (*EW+WW*, January 1990). Inertia force is surely an artifice, a convenience to transform the mathematics of a mechanical situation into a more readily imagined frame of reference.

A real force is one which arises through a mechanism of interaction between two masses (often but not necessarily different bodies). All forces are twinned but to take one twin and create a notional triplet for it is a precedent for chaos. Why not invent sibling forces *ad infinitum?* What work are these forces expected to do?

Consider two bodies E and M interacting through the mutual mechanism G. They therefore affect each other simultaneously and concurrently, whenever (and as soon as) G is in effect. This is not to be confused with instantaneous reaction of M to E, so no speed-of-light paradox need be envisaged.

In the case outlined in Hypothesis, the Moon stays in orbit around the Earth because the real and mutual gravitational force is precisely sufficient to provide the constant acceleration of the Moon towards the Earth which achieves the orbit witnessed. Perturbation of the combined body which takes into account the constant acceleration of the Earth towards the Moon is usually ignored (usually by taking the Earth or the Earth's surface as a reference frame). This effect (and that of other bodies) could be included in the analysis if desired.

Inertia force is therefore an optional convenience of notation, akin to centrifugal force, and merely "assists" those wishing to transform their analysis into a different framework. The same transform concept is used in impact analysis.

Unfortunately these conveniences usually confuse the analysis rather than aid it.

Simon P. Pengelly
Tonbridge
Kent

Not proven

The crossed field antenna may or may not work. I believe that no convincing theoretical or practical evidence has yet appeared to support it, despite the fact that three years have gone by since its announcement.

The "theoretical" justifications given by Hately and others (*EW+WW*, March 1989) have consisted of quoting Maxwell's equations from a textbook and attempting to apply them with little or no understanding. The practical results produced by C. Wells with his powdered milk drum technology (*EW+WW*, November 1989) are worthless because any radio amateur knows that contacts can be made on 7MHz with "British, Irish and European stations" using less than 10W, rather than the 100W that Mr Wells quotes.

My own opinion as an antenna engineer is that the antenna has a loss of very roughly 20dB. Nothing magic is going on and antennas that are small compared with the wavelength

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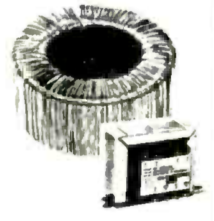

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625	30.06	27.05	19.84	18.79	16.98	15.78	15.03
750	38.42	34.58	25.36	24.01	21.71	20.17	19.21
800	43.96	39.56	29.01	27.48	24.84	23.08	21.98
1000	53.54	48.19	35.34	33.46	30.25	28.11	26.77
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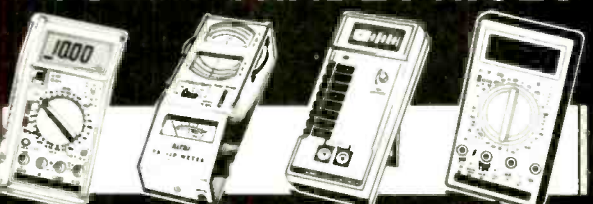

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always tend to be lossy. Mr Hately's patent application of December 1986 lends weight to this by admitting that the antenna is lossy when used as a receiving antenna. The Principle of Reciprocity for antennas is well-known (although apparently not to the proponents of the CFA), and can be paraphrased to state that the gain or loss of an antenna is the same whether the antenna is used to transmit or to receive.

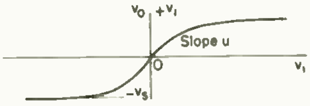
Why, after three years, has nobody conducted a proper experiment to measure the radiated field strength at a set of points in the far-field region of the antenna, and relate the results to the total power fed into the antenna? This universally accepted procedure is the first and most basic test that any antenna must pass. Until it is done, anything else is a waste of time.

A. G. P. Boswell
Great Baddow
Chelmsford
Essex

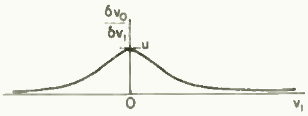
Whence the Gaussian distribution?

A note on the physical meaning of the Gaussian error curve for the average of large numbers. In modelling the susceptibility of a feedback amplifier system realistically we must take into account the finite saturation range of the output node near the supply lines (assumed symmetrical).

The curve of v_o as a function of v_i is linear for small signals but tends to $\pm V_s$ at large amplitudes.



The derivative of this saturation curve gives the voltage susceptibility.



This type of curve describes the gain characteristic of real, symmetrically designed amplifiers. The gain falls to zero near input saturation, so a carefully designed system can be used as a signal compressor.

The finite saturation model can also be used in the theoretical calculation of the susceptibility of regenerative amplifiers; the sensitivity to external stimuli decreases as feedback coupling increases, until self-sustaining oscillations occur, limiting near the supply lines with virtually zero susceptibility. The remaining small susceptibility factor gives the oscillator "capture range".

Directly equivalent is the theoretical modelling of magnetic systems arranged in crystal lattice patterns for simpler arithmetic. The saturation curve is $\tanh(x)$ so the derivative is $\operatorname{sech}^2(x)$.

However, in carrying this analogy over to the statistics of large numbers of randomly dispersed particles interacting, the bell-shaped curve will tend to the Gaussian form e^{-x^2} as we derive mathematically from discrete probability distributions. From the engineering approach we can understand the physical reason why it would have any well-defined shape at all if we could integrate it to obtain the saturation curve in an algebraic closed formula. (It is tabulated numerically for statistics.)

The small-signal susceptibility gives the "most likely" or most significant response in contributing to the statistical measures, whereas large deviations from the mean correspond to effective "saturations" locally of the atomic interactions. Interatomic coupling and bulk susceptibility is reduced. Therefore the mechanism whereby populations (from atoms to genes) regress to the mean of the Gaussian envelope curve is understood in terms of this physical process of the saturation curve integral, making any other options nonviable.

P. J. Ratcliffe
Stevenage
Hertfordshire

A sixth sense?

We know that the entire electrical activity of a brain takes place at microwatt power levels, and even motor nerve signals to major muscles are at the milliwatt level although they control a muscular effort equivalent to hundreds of watts.

The nervous system relays sensory perception of the world to the brain as microvolt impulses — is it feasible that it can also detect the earth's ambient electric field, which has existed since the dawn of life?

Some forms of life can. Trees and plants use the natural potential gradient that extends from the surface to the ionosphere as a reference vertical to supplement the cues they get from root sensors and daylight. In high latitudes, the natural electrical field concentrated near the poles by the magnetosphere has been shown to act as an important flora growth stimulator during the short summers, and crop trials in the USA and the UK have shown increased yields under artificial electrification.

Despite precedent, very little has been done to test how human beings are affected by electrostatic fields. Circumstantial evidence suggests we are sensitive. Many people complain of headache or aches and pains when the weather is thundery, and the alien ionised atmosphere in many buildings provides a ready market for negative ion generators to try to bring the "good life" into the office.

Testing people's reactions to artificial electric fields is not too difficult. In a series of tests published over ten years ago, I described how people found it difficult to stand upright under a charged high-voltage (2000V) wire with their eyes closed. A positive voltage has little effect until it rises to several times the natural level, with large differences in sensitivity between individuals.

It is likely that the reported ill effects of overhead power lines are another example of sensitivity. Although the nervous system reacts too slowly to follow the alternating current waveform, any form factor asymmetry will be perceived as an unnatural polarised field and will have an effect.

If most people are found to be sensitive, there is a potential commercial spin-off in fitting negatively charged or earthed overhead grids in offices and stores to create an "outdoor" electric field, and cure the sick building syndrome.

It would be rewarding to add a sixth to mankind's other attributes, before moving on to show how it explains other problems.

Anthony Hopwood
Upton-on-Severn
Worcester

Eddystone

Having owned one or more Eddystone receivers since 1952, and being one who enjoys not just owning but also using them, I have decided to form an Eddystone Users Group. From contacts I already have there would seem to be a need for such a group.

Continued over page ▶

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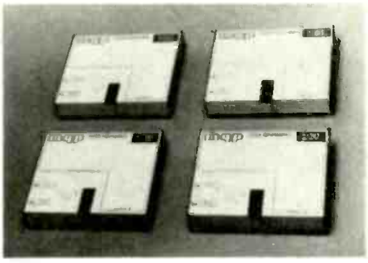

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1	A	2	10.25	2.20
2	M	4	13.17	2.53
3	P	6	19.05	2.64
4	S	8	21.72	2.75
5		10	27.46	3.19
6		12	31.32	3.41
8		16	44.04	4.12
10		20	51.28	4.40
12		24	59.09	5.22

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500	41.91	4.23
1000	76.01	5.33
1500	96.04	6.54
2000	117.96	7.61
3000	165.41	O/A
6000	353.43	O/A

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

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

96/48V or 36-0-36V (2 x 36/48V Secs) 36, 48, 60, 72, 84, 96V or 36-0-36V or 48-0-48V

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

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350	14.05	2.75
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1000	34.93	3.68
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2000	60.41	5.11
3000	102.72	6.32
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5000	155.28	O/A
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During a recent visit to the Eddystone factory I obtained agreement to use facts and data from their manuals in a group newsletter. This would be sent to members on a non-profit basis, with only a nominal charge for post and printing.

Those interested should contact the author,

W. E. Moore,
112 Edgeside Lane
Waterfoot
Rossendale, BB4 9TR.

Non-ionising radiation

In all the comments on the adverse effects of 50Hz radiation I have seen no reference to electric traction systems.

The published reports refer to power distribution which, typically, has the go and return circuits in close proximity, giving a large amount of field cancellation.

In traction systems the two circuits are widely spaced with the passenger vehicles actually travelling between them, in the maximum field. Have these fields been measured? They appear to be strong since metal objects several metres away may be felt vibrating at 50Hz.

R. G. Silson
Tring
Herts

Researchers working in Philadelphia have investigated leukaemia clusters occurring alongside overhead electric railway tracks. The clusters show a very substantial excess although the statistical sample is small – Ed.

It is all very well to claim that non-ionising radiation will double your chances of acute myeloid leukemia, but what are your chances of acquiring this disorder in the first place?

Personally, I disregard warnings of this sort if the chance is less than that of being struck by lightning.

Joel S. Look
Pawtucket
Rhode Island, USA.

You may well be right although I wouldn't live beneath a powerline run. Would you? — ed.

Misquoted

Simon Best quotes me (*EW+WW*, March 1990) as saying that the NRPB guidance[1] on time varying electromagnetic field exposure is due for revision this year.

No revision is intended, although we will probably issue revised guidance[2] on exposure to magnetic resonance imaging procedures in medical practice.

Simon Best must have misunderstood what I said to him in a brief telephone conversation during which he failed to mention that he was preparing an article for your journal.

Dr J. A. Dennis
NRPB, Didcot

References

1. Guidance as to Restrictions on Exposures of Time Varying Electromagnetic Fields and the Recommendations of the International Non-Ionizing Radiation Committee. NRPB-GS11 (1989).
2. Advice on Acceptable Limits of Exposure to Nuclear Magnetic Resonance Clinical Imaging. NRPB-ASP5 (1984).

Lamp inverter

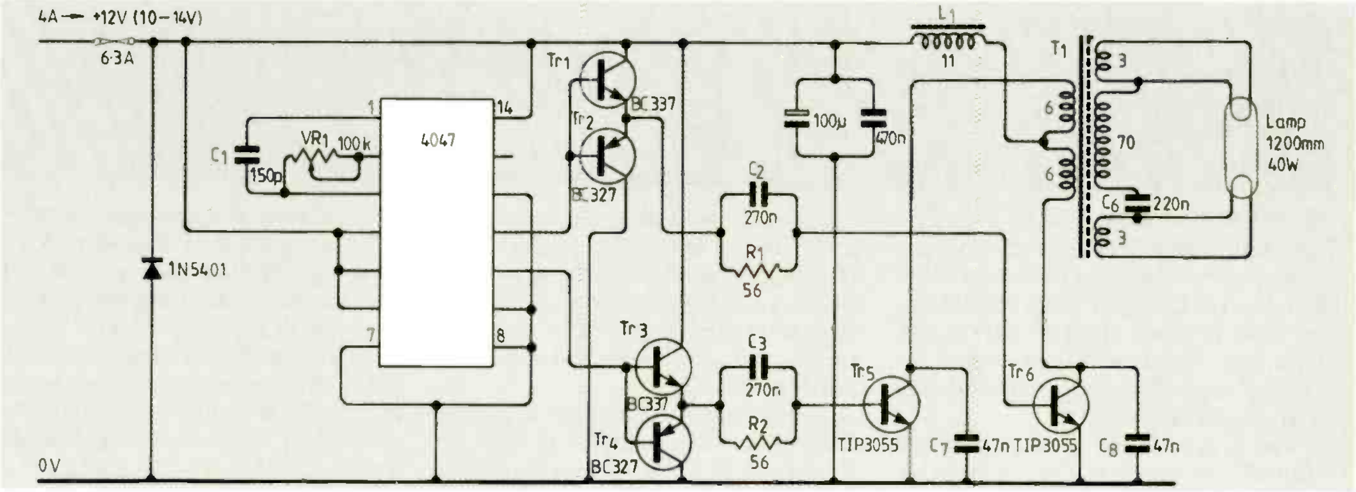
This circuit was designed to run a full size 40W fluorescent lamp from a 12V car battery supply.

The 4047 produces two complementary square waves at about 25kHz. These are buffered by the complementary pairs of transistors to drive Tr5 and Tr6 in push-pull. C7 and 8 slug the voltage spikes.

The lamp current is controlled by a combination of C6, the turns ratio of the transformer, the air gap in the core and the inductance of L1. The air gap and series inductance have particular influence on the starting voltage and may be adjusted to suit a variety of lamps. Vr1 sets the operating frequency. When operating correctly, the circuit draws around 4A.

L1 comprised 11 turns of 1.5mm wire on a 5cm length of 9.5mm diameter ferrite rod. T1 primary has 12 turns of 1mm wire centre-tapped, the secondary comprising 70 turns of 0.75mm wound in three layers. Cores were FX2243 with 0.4mm air gaps separating the poles.

Paul Bennett
Stoke Gifford
Bristol



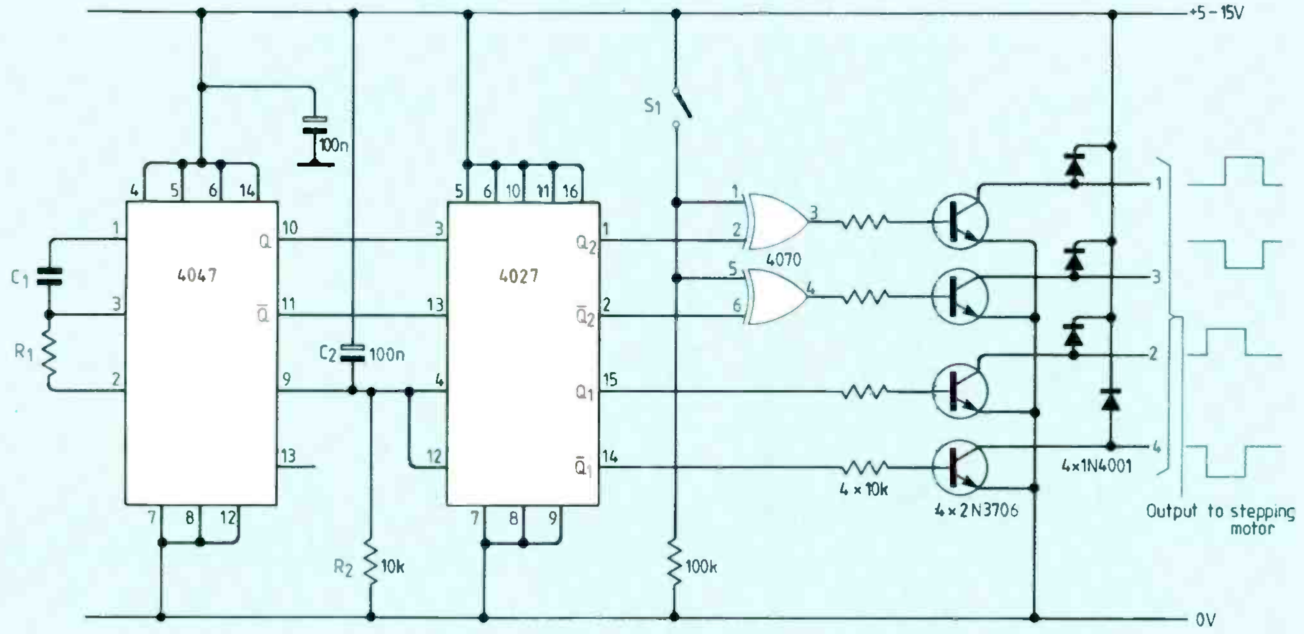
Easy steps

This circuit is intended to drive a small stepping motor at a constant, accurate speed. The motor forms part of the drive platform of an astronomical telescope but it would serve equally well in other mechanisms.

R1 and C1 should be chosen in accordance with the desired motor speed using the formula 1/2.2RC steps per sec where R1 has a value between 10kΩ and 1MΩ, and C is greater than 100pF. R2 and C2 provide a reset pulse to the 4047 multivibrator and 4027 flip-flops at switch-on without which the motor could rotate in either direction. The 4070 ex-or gates and switch S1 allow the motor to be reversed.

2N3706 output transistors are suitable for motor phase currents of up to 200mA, above which they should be substituted by higher current devices.

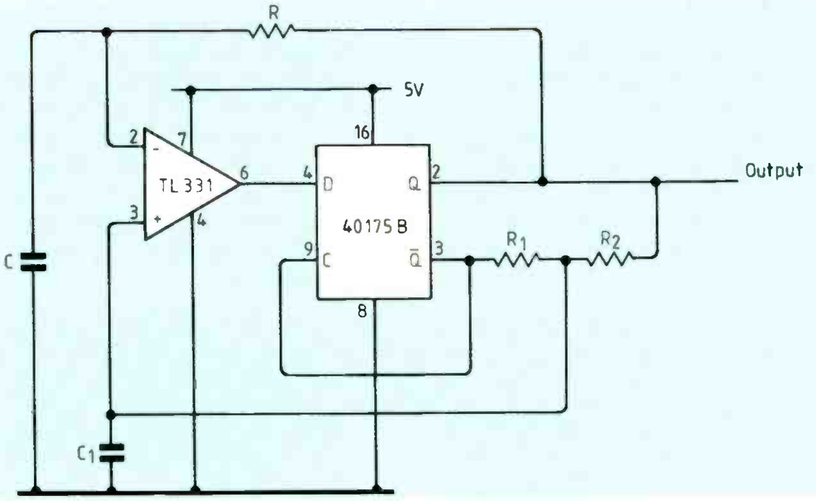
Andrew Mark
West Moor
Newcastle upon Tyne



Flip-flop oscillator

A flip-flop linked up to a comparator provides an excellent astable oscillator with inherently equal mark-space ratio. Deriving both timing and reference voltages from the logic outputs of the flip-flop removes timing sensitivity to supply variations. Capacitor C1 decouples the comparator reference input.

Kamil Kraus
33701 Rokycany
Czechoslovakia



MODERN 90 degree VDU tubes do not require East West geometry correction; however, many 110 degree tubes still do. As 110 degree tubes are becoming more common place for VDU terminals, a requirement has again arisen for a simple, cost effective EW dynamic line by line width modulator.

The simple circuit shown gives pin cushion correction, with capabilities for anti-breathing (picture size variation with EHT compensation), line by line geometry modulation and feedforward HT hum modulation cancellation.

This is achieved using just one main active device and is novel in that a field parabola is obtained from integrating the field coil ramp current.

The idea is based around a standard line output stage but with the addition of D2, C2 in series with the efficiency diode D1 and line tuning C1. The ratio C3/C4 should be approximately 1:4, as should C1(C1+C2): /adjust / L to correct the line tuning frequency.

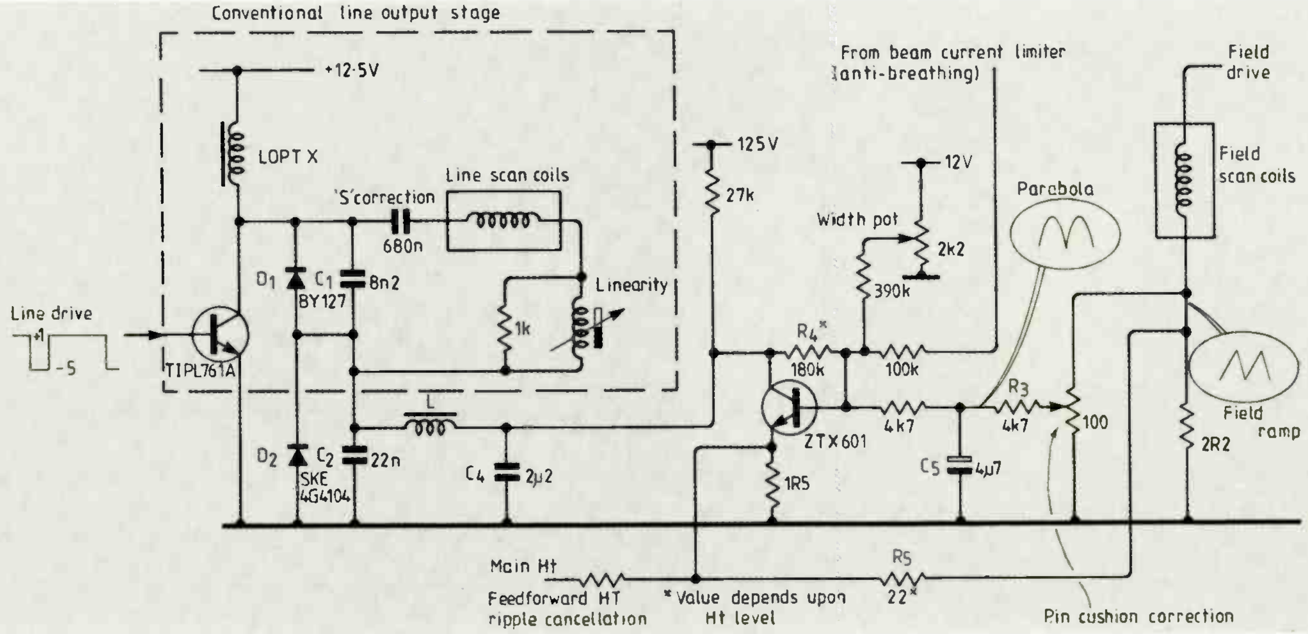
Dynamic width variation without altering EHT or line tuning is achieved by adjusting the amount of energy stored in the 'S' correction capacitor C3. During flyback the magnetic field collapses around the scan coils and energy is transferred to C3.

During forward scan time when the efficiency diode pair D1,2 conducts, C3 is held across the scan coils producing the first half of scan. Changing the level of charge on C3 will therefore change the width of the following forward scan. During flyback, energy lost in the system is made up from energy stored in the line output transformer; this energy is divided between C3 and C4. If a variable current generator, (in this case a transistor) is placed across C4 then a variable amount of energy will be stored in C3. This gives dynamic width control without altering EHT or flyback tuning. The addition of C2 reduces circuit capacitance but is counterbalanced by the inclusion of L increasing the total inductance, maintaining constant tuning.

Tr1 is configured as a virtual earth inverting amplifier: the static DC width, field parabola, anti-breathing and feedback signals are all summed at the transistor's base. Width compensation due to HT changes, including that caused by HT ripple, is fed into the emitter terminal along with a field sawtooth, which is subtracted from the parabola.

The ramp current via R5 is subtracted from the parabola to correct for tilt in the parabola waveform. R4, R5 may need adjustment for different types of tubes and scan coils, etc, but the values given provide a guide. R3, C5 integrates the field ramp and also helps to reduce line pulse ripple. An additional HF feedback capacitor may be placed across R4 to reduce line components which can influence the interlacing.

Les Sage
Bingley
Yorks.



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output
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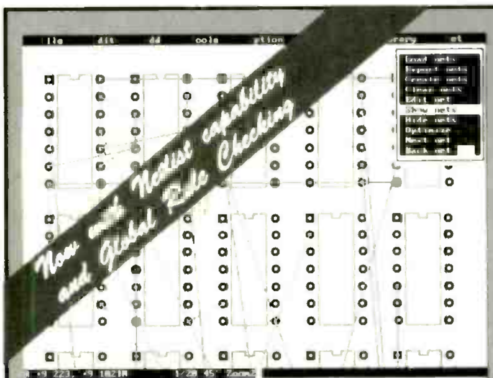
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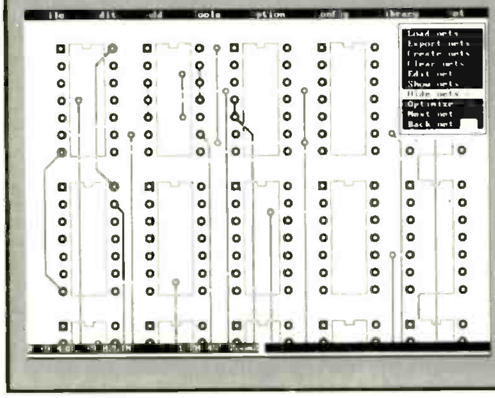
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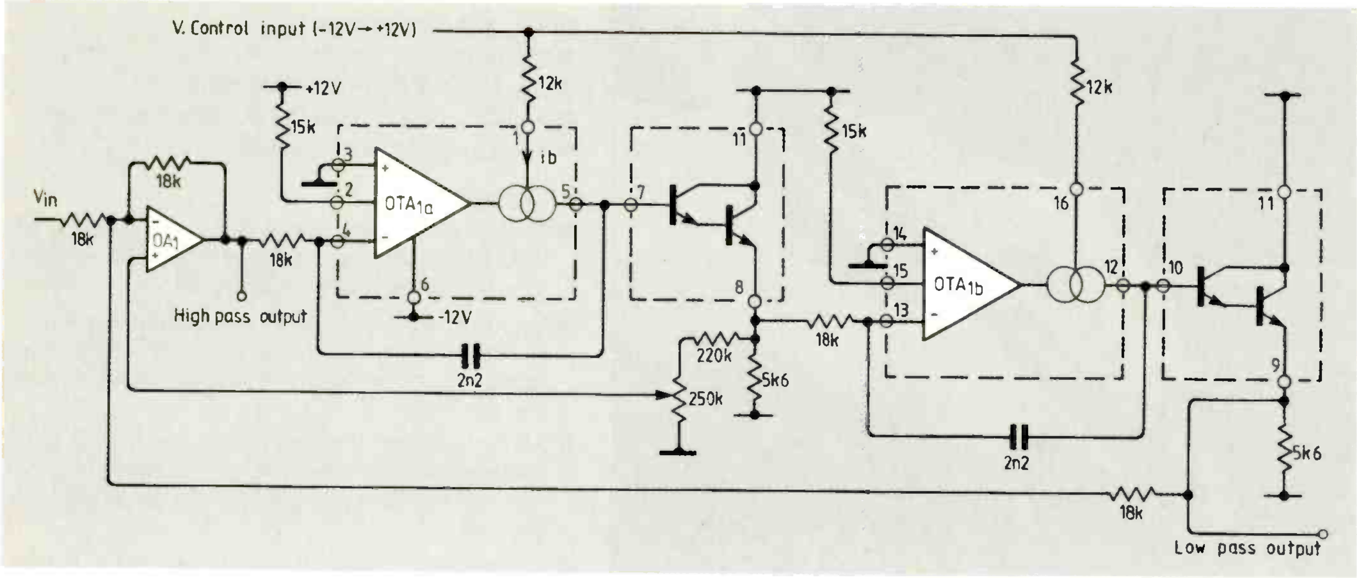


State variable filter

This circuit is based on the mixer integrator state variable filter and uses a dual transconductance amplifier for controlled integration.

High pass, band pass and low pass outputs are available simultaneously. A notch may be produced by summing the high and low pass outputs together.

The control voltage changes the rate at which the capacitors charge and discharge thus causing the frequency response to vary accordingly. The damping factor can be controlled by adjusting the 250k potentiometer which sends a fraction of the voltage at pin 8 of OTA1 to the non-inverting input of the input op-amp.

S A Birchall
Stoke-on-Trent
Staffordshire

Don't waste ideas

We prefer circuit ideas contributions with neat drawings and widely-spaced typescripts but we would rather have scribbles on the back of an envelope than let good ideas be wasted.

We pay for all published circuit ideas. You can expect a minimum of £15, increasing to £40 for the best ones.

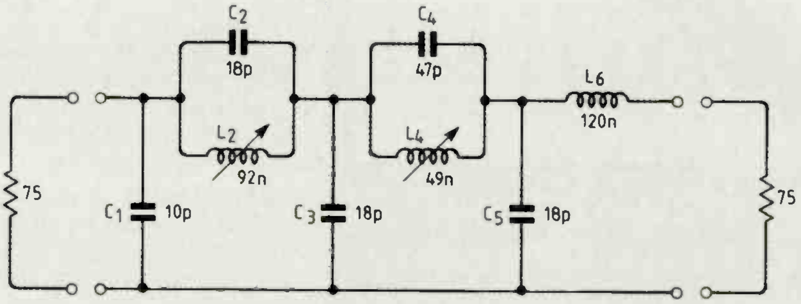
Elliptic filter for FM radio

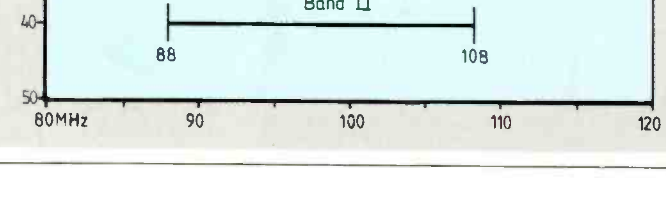
Proliferating Band II local radio stations may cause reception problems for existing stations if the receiver is close to a new transmitter. Modern receivers should be immune but, if not, this low pass filter may help.

The filter is 6th order elliptic with two finite frequency transmission zeros, passing frequencies up to 98 MHz (−3dB). A modest 15-20 dB rejection in the upper part of Band II attenuates new local radio frequencies without preventing reception. Group delay variation in any radio channel is negligible (‹ 5nS).

Inductors L2 and L4 are 2¾ and 2 turns of 26 swg on a 5.33 mm former (Cambion). L6 is a fixed choke. Construction without test gear is practical, but if available L4 can be trimmed to precisely place a rejection notch at an interfering frequency.

K Williams
Wells
Somerset





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Refer Electronics World + Wireless World March 1989 216-218 & Nov. 1989 pp 1109-1111 March 1990 253-255

NEWSFLASH – Successful experimental broadcast of 30kW on MEDIUM WAVE from the ground 2 metres high, 4 metres wide ground plane radiating on 350 metres.

Proprietor: Maurice C. Hately, M Sc FIEE Chartered Electrical Engineer (GM3HAT)

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Ultra-rapid NiCd charger.

There are many portable equipment applications using nickel cadmium batteries in which charging can be a problem. The difficulty becomes apparent when the voltage of the batteries to be charged exceeds that of the charging source, typically a 12V car battery. This note suggests a design for an ultra-fast nickel-cadmium battery charger capable of completely charging eight to 12 batteries at 1.2 to 1.8Ah in 30 to 45 minutes. This is currently possible due to the use by battery manufacturers of new sintered electrode technology which allows rapid charging cycles.

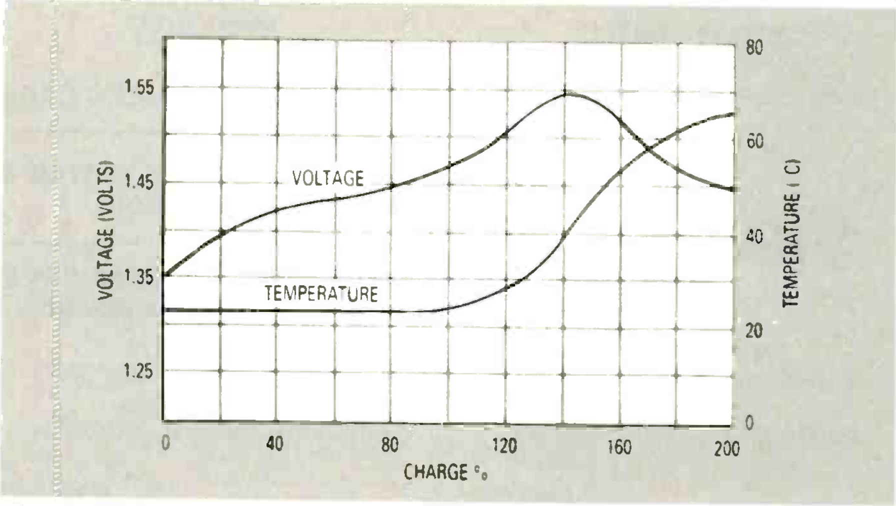


Fig. 1 NiCd battery charging characteristics

Specifications

10 to 14V input voltage; 1 to 3.5A constant output current; 20V maximum output voltage; automatic shut-off; supply reversal protection; full output protection.

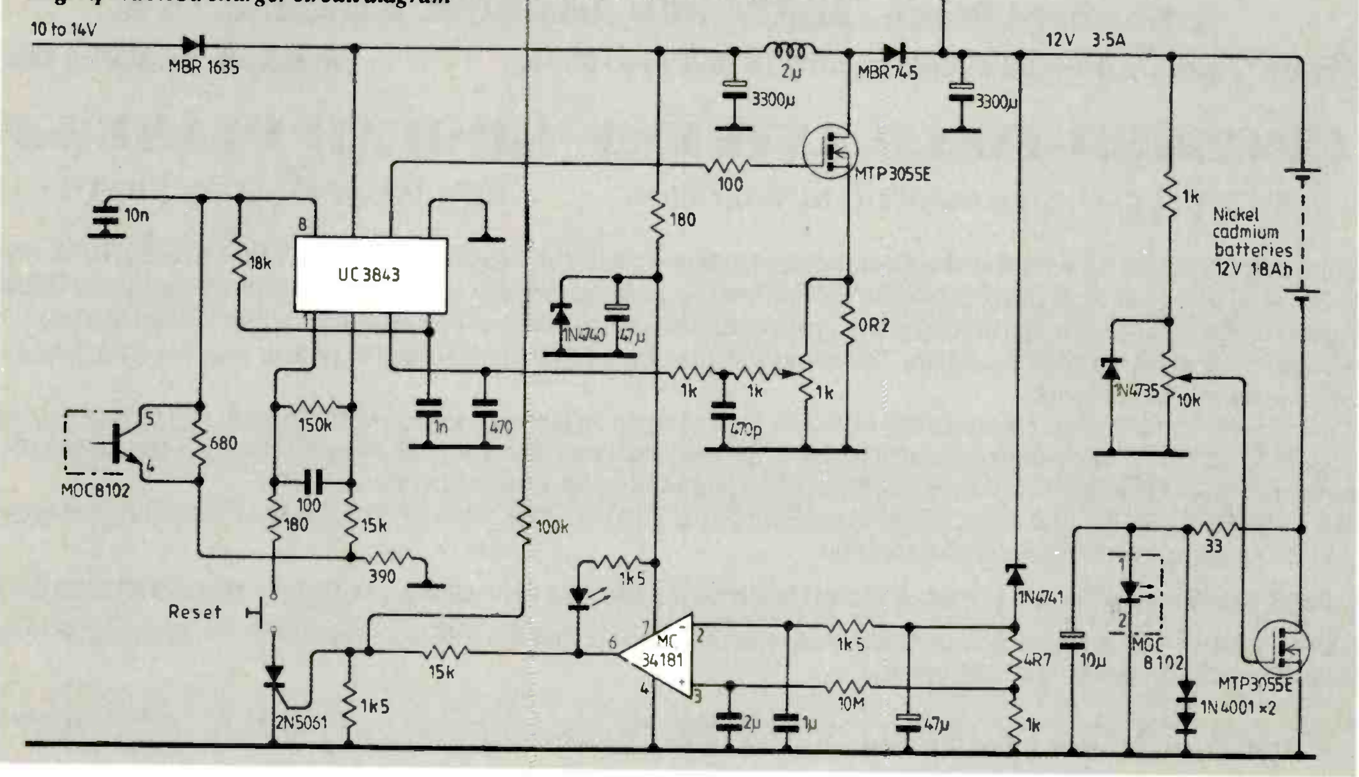
A nickel-cadium battery must be charged with a constant current and is completely charged when it receives 140% of rated ampere hour charge. The variation of the battery voltage as a function of the charge depends upon the state of the charge as well as the temperature. When charging is completed, the temperature rises rapidly and, if the battery charger is not shut off, the batteries are destroyed.

This design provides for these requirements by including a constant-current regulator and a switch-mode converter to increase the charging voltage when the voltage of the batteries under charge exceeds 10V. The end-of-charging detection system uses the principle that, when fully charged, the battery temperature increases concomitant with a decrease in battery voltage (see **Fig.1**).

This regulator uses a MTP3055E power mosfet which has a variable operating point for adjustment of the charging current. This current is relatively independent of the drain-source voltage when V_{DS} exceeds 2V.

Continued over page ►

High speed NiCd charger circuit diagram



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Wirtschaftsdienst	F7b spec. 300 Bd ASCII
Sport Information	F7b spec. 300 Bd ASCII
Autospec Bauer	ITA 2 including the 2 modes
SPREAD 21 and SPREAD 51	
DUPLEX ARQ Artrac	ITA 2
TWINPLEX	F7b-1 and F7b-2 Duplex ARQ
ASCII	
Baudot	ITA 2 plus all kinds of **BitInversion**, any speed
ARQ	CCIR 476, CCIR 625 mode A
ARQ-S	ARQ 1000S
ARQ-Swe	CCIR 518 variant
ARQ-E	ARQ 1000 ITA 2-p Duplex
ARQ-N	ITA 2 Duplex
ARQ-E3	CCIR 519 ITA 3
ARQ-6	5/6 character 90 and 98
TDM 242	CCIR 242 2/4 channels
TDM 342	CCIR 342 2/4 channels
FEC-A	FEC 100 (A) ITA 2-p FEC Broadcast
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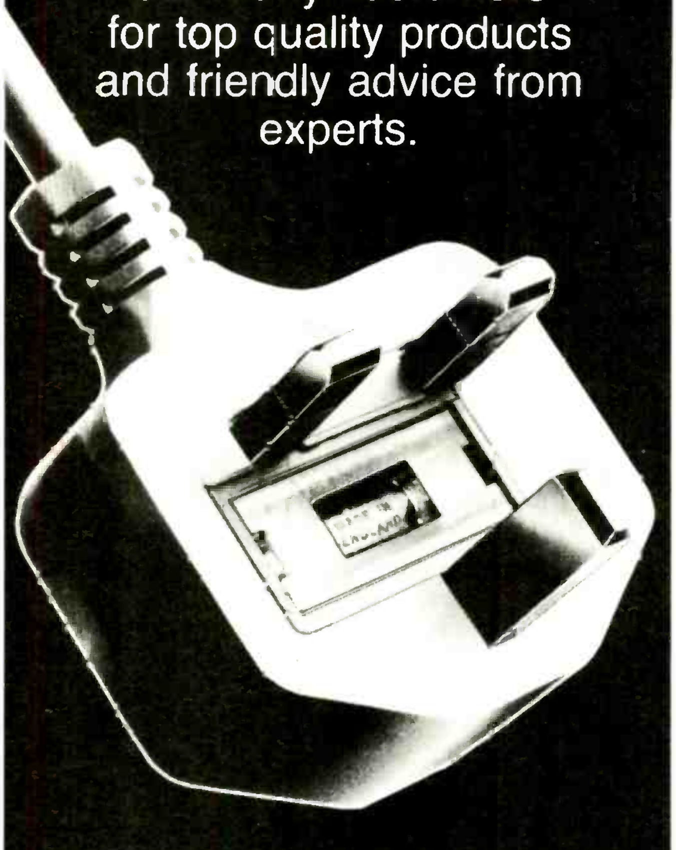

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The converter is used to increase the charging voltage so that the current regulator always has an input of at least 2V. It uses the Motorola UC3843 produced specifically for automotive applications. This chip works in conjunction with a second MTP3055E, a MBR745 Schottky diode and a 25μH inductor. The operating frequency is 100kHz.

A MOC8102 optocoupler monitors the voltage applied to the current regulator and brings this information to the error amplifier of the UC3843. When a decrease in voltage is sensed, the UC3843 reacts to maintain the minimum voltage at the input of the current regulator. This reduces power dissipation in the linear current regulator to a minimum. The output voltage of the switch-mode converter is therefore floating and stays at 2V above the voltage of the batteries to be charged.

If at some instant the batteries to be charged are not connected, the output voltage can exceed 40V. Should this happen, a 2N5061 thyristor, sensitive to overvoltage, immediately turns off the converter.

The combination of the MC34181 operational amplifier and the 2N5061 thyristor provides control of output voltage and automatic shut off at full charge. The MC34181 j-fet op-amp is used as a comparator in the battery charger. Its inverting input is connected to the battery voltage minus the drop provided by the 11V zener diode. The non-inverting input is at a lower voltage due to the 4.7Ω resistor blocking the amplifier in its low-level state. The output from this comparator also drives a led, indicating that charging is taking place.

When the voltage of the batteries under charge decreases (which happens at full charge) the non-inverting input does not have time to vary due to the large 20s time constant. However, the inverting input varies rapidly due to its small time constant, forcing the op-amp to toggle, shutting off the led and turning on the thyristor. The switchmode converter then turns off and charging is completed.

The MBR1635 diode is used to protect the battery charger against polarity inversions. If the output of the charger is short circuited, the output current is still limited but the regulator receives 12V, causing it to heat up. Short-circuits should therefore be avoided or be of short duration.

Derived from Motorola application note EB126

Motorola, Motorola House, 69 Buckingham Street, Aylesbury, Bucks HP20 2NF. Phone 0296 395252. ■

18-bit D to A converter for x8 over-sampling

The PCM61P is an 18-bit, pin compatible replacement for the widely used 16-bit PCM56P. The addition of two extra bits reduces the level of both harmonics and noise in CD audio applications using the PCM56P. The PCM61P includes an internal reference and output op-amp.

The device is capable of 8-times oversampling (single channel). Manufacturer Burr-Brown says that it meets its specifications without an external output de-glitcher. The device block diagram is shown in **Fig. 1**.

Maximum clock rate

The 16.9MHz stated maximum clock rate for the device is derived by multiplying the standard audio sample rate of 44.1kHz by 16 (for 16x oversampling) multiplied by audio word bit length in use, in this case 24. Thus 44.1kHz x 16 x 24 = 16.9MHz. Note that this clock rate accommodates a 24-bit word length, even though only 18 bits are in actual use.

MSB error adjustment procedure

The MSB error of the PCM61P can be adjusted to make the differential linearity error (DLE) at bipolar zero (BPZ) essentially zero. This is important when the signal output levels are very low, because zero crossing noise (DLE at BPZ) becomes very significant when compared to the small code changes occurring in the LSB portion of the converter. Static adjustment of DLE at BPZ can be made with extra circuitry shown in **Fig. 2.**

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

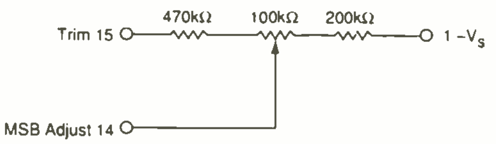
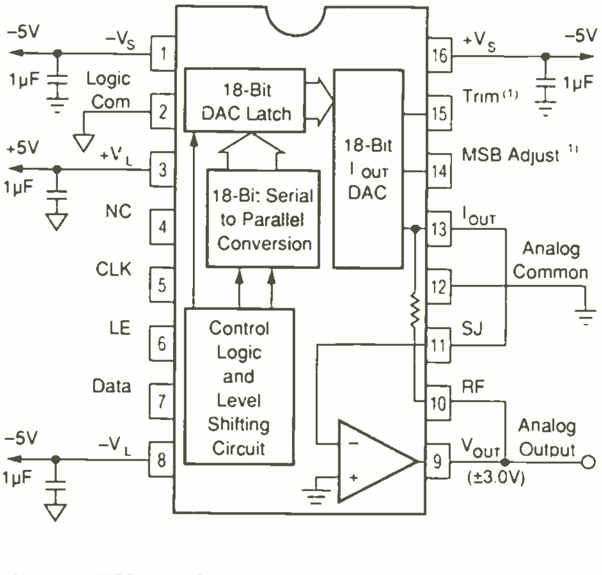


Fig.2

Fig.1



Note: (1) MSB error (Bipolar Zero differential linearity error) can be adjusted to zero using the external circuit shown in Figure 2

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PCL-720	32 Chn D/IP, 32 Chn D/OP, 3 Chn Counter
PCL-726	6 Chn 12Bit D/A, 16 D/IP, 16 D/OP
PCL-725	8 Chn Relay Actuator, 8 Chn opto-isolated I/P
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CIRCLE ENQUIRY NO. 116 ON BACK PAGE

ANTENNA DESIGN ON A PC

Ian White reviews a pair of antenna modelling packages covering wire and Yagi arrays.

In my review of MININEC in *EW+WW*, December 1989, I recommended as best value an enhanced version of MININEC by the Californian programmer Brian Beezley. This review gives further details of his 'MN' program, and of a completely new program – the Yagi Optimiser.

Antenna modelling by MN

MININEC is a program for modelling wire or rod antennas, adapted for the PC from the well-established Numerical Electromagnetics Code (NEC) for mainframe computers. Both NEC and MININEC use the Method of Moments technique to compute the interactions between individual segments of the antenna array, and for many purposes MININEC is almost as accurate as NEC. But MININEC can be extremely awkward and tedious to use, especially for iterative development work. By building a convenient menu-driven 'shell' around the older program, and adding many other useful facilities, Beezley has greatly enhanced the productivity of MININEC for antenna modelling on a PC.

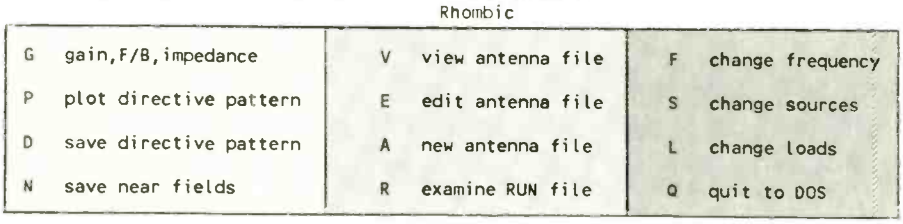
When MN is started up, it loads a disk file describing the antenna and its surroundings. The menu of options then available is shown in **Fig. 1**. The central column includes various file-management options (missing from MININEC), including the opportunity to examine the RUN file – the secret of MN's ease of use. MN avoids MININEC's bad habit of inundating the user with screens of information, and instead records all that information in the background as a RUN file. In many cases, the RUN file can be ignored because MN summarises all the important results: but if you do need more detail, the 'R' menu option lets you browse through the RUN file at leisure.

Operating environment

MN and YO require an IBM-compatible PC with 512K of free memory and a CGA, EGA, VGA or HGC display. A maths coprocessor is highly desirable to speed the calculations, though both programs will run without one. A version of YO is available which runs somewhat faster without a coprocessor. Pattern plots can be printed on a 9-pin or 24-pin dot matrix printer.

The programs and documentation supplied on diskette are not copy-protected, and can be copied onto a hard disk. However, a transferable 'key' allows only one copy of the program to be used at a time. The key can be transported only on the original program diskette, so it is important to specify whether 5¼in or 3½in format is required.

Fig. 1. Main menu of the MN program. The title line of the current antenna file is displayed above the menu box.



```
                              Rhombic
  G  gain,F/B,impedance        V  view antenna file      F  change frequency
  P  plot directive pattern    E  edit antenna file      S  change sources
  D  save directive pattern    A  new antenna file       L  change loads
  N  save near fields          R  examine RUN file       Q  quit to DOS
```

The main options for antenna modelling are G (gain, front/back ratio and feed impedance), and P (plot antenna pattern). MN is somewhat faster than MININEC, and gives good estimates of the time each calculation will take. If an antenna is to be modelled above ground, this must be indicated in the antenna description file. Full details of height and ground characteristics may be written into the file, or entered and varied at run-time. The F option permits manual frequency scanning, while L and S allow you to change the locations of any additional load impedances, or the location of the feedpoint.

The PLOT (P) option of MN is very powerful. It displays E-plane and H-plane patterns on a graphics screen in polar or rectangular co-ordinates, with facilities for instant comparison against another antenna. **Figure 2** shows examples, obtained using the screen-printing facilities provided.

The great advantage of Beezley's MN program over the old MININEC is its ease of use. MN is a program for practising engineers, who would have no time for the old-fashioned 'hacker's interface' of MININEC. With full documentation on disk, plus a generous library of examples, MN represents excellent value for money to the professional or advanced amateur user.

YO – the Yagi Optimiser

For almost any purpose requiring an HF, VHF or UHF beam antenna, the

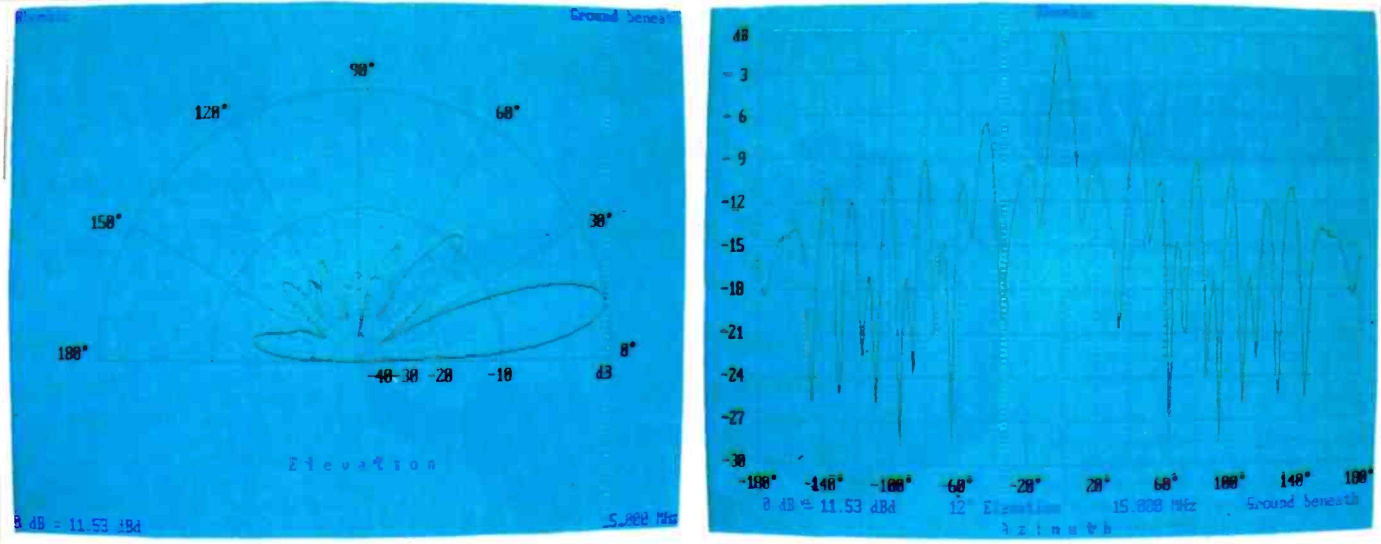


Fig. 2. Typical plots from MN. At (a) is the E-plane pattern of a rhombic antenna above lossy ground (rectangular co-ordinates option), while (b) shows the H-plane pattern of the same antenna, in polar co-ordinates.

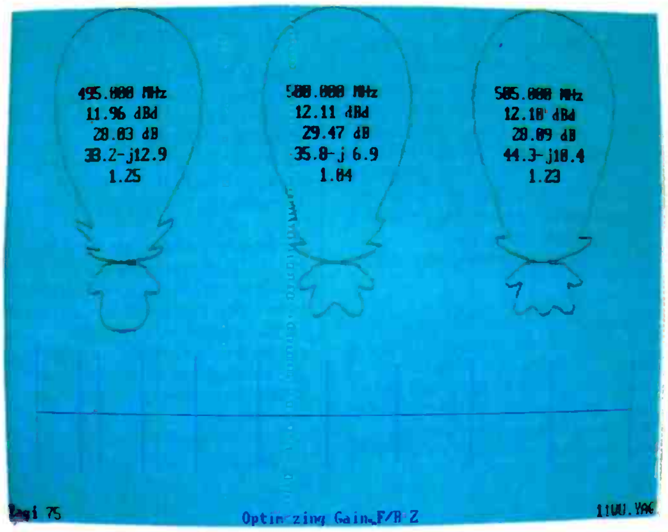

```
495.000 MHz    500.000 MHz    505.000 MHz
 11.96 dBd      12.11 dBd      12.10 dBd
  28.83 dB       29.47 dB       28.09 dB
 33.2-j12.9     35.8-j 6.9     44.3-j10.4
    1.25           1.04           1.23
```

Fig. 3. YO screen during optimisation of an 11-element Yagi, broadbanded across three frequencies. As the design is continually being altered and re-evaluated, the screen changes to display the new performance data and geometry.

Yagi is the obvious choice. Simple to build and to mass-produce, the Yagi can also be simple to design, because many different combinations of element lengths and spacings will produce some semblance of a beam antenna. But the optimisation and accurate performance measurement of a multi-element Yagi array can be a formidable task, and most existing Yagi designs fall far short of optimum. While computer programs such as NEC and MININEC can help with the performance evaluation, Beezley's YO program takes the process a step further. By itself adjusting the element lengths and spacings, YO can turn a mediocre Yagi into an optimised design.

The heart of YO is a very fast Method of Moments calculation routine, streamlined for the particular geometry of the Yagi antenna. An initial Yagi design can be optimised for gain, a clean polar pattern, a conveniently high feedpoint impedance, or any weighted combination of these attributes. The Yagi can be optimised either at a single frequency, or to give broadband performance across three selected frequencies. A further option is to optimise stacked pairs of Yagis, taking full account of their interactions, and the same facility can also be used to optimise a single Yagi mounted close to reflecting ground.

As YO works its way through intermediate geometries towards the optimum, you can watch the screen display change (**Fig. 3**), updating the polar patterns and performance data of the Yagi, together with a sketch of its geometry. Optimisation can be paused at any point, either to display a detailed polar diagram using the same plotting facilities as MN (**Fig. 2**), to save the intermediate design to disk, or to adjust the optimisation parameters. Another option is to 'tweak' the individual element lengths and positions by hand, after which the automatic optimisation can be resumed.

All types of computer optimisation tend to be narrow-sighted – they search rapidly and methodically for improvements but, unlike a human designer, they have no intuitive vision of what the optimum should look like. Therefore some human intervention may still be required, to guide the optimisation in a direction which the designer 'knows' is right. YO makes up for its own lack of intuition by the speed with which it can evaluate one trial design after another, and the clarity with which it presents the results to the user. You very quickly discover whether your intuition can match the methodical speed of YO!

The calculation routines used in YO give results closely comparable to those from MININEC and MN, though some approximations have been made in YO to improve the speed of iteration. It may thus be useful to check the results periodically against the slower but more accurate MN. And eventually, of course, you have to check the Yagi's performance in real life. Before reaching that stage, however, YO could have saved you a great deal of time, effort and money. ■

Dr Ian F. White is a freelance technical author and consultant.

Products and prices

MN version 3.00 is available at $110, and YO version 3.00 at $130. Enquire about upgrades from previous versions, and the faster no-coprocessor version of YO. The minimum order quantity for corporate purchasers is two copies of either program.

Simplified versions of both programs, MNjr and YOjr, are available at $55 and $65 respectively, in one-off quantities to individual (non-corporate) purchasers only.

All the programs are available direct from Brian Beezley, 507½ Taylor Street, Vista, California 92084, USA. Orders must be in US funds, prepaid. Outside the USA, add $5 for airmail.

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Custom process. ES2 is making a 1.0μm process available to its customers. Reduction to 1.0μm geometry allows the company to manufacture faster custom silicon chips in any prototype and production quantities as required by the individual customer. European Silicon Structures, 0344 525252.

Gate arrays. Seiko Epson claims its new low power, low voltage family of c-mos gate arrays for battery-driven systems are unique in operating down to 0.9V. Other features include densities up to 8000 equivalent gates, and a wide range of packaging options to 208 pins. Hero Electronics, 0525 405015.

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

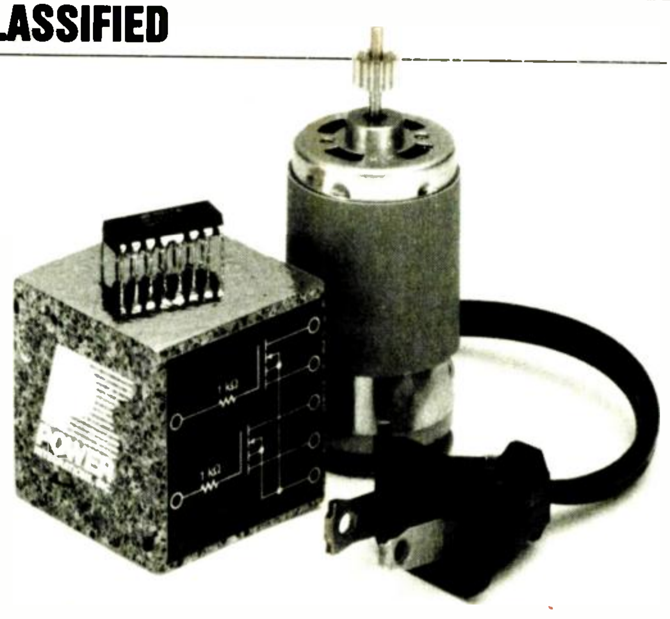
D-to-A converters. Amplicon Liveline's PC24/25 four-channel 12-bit D-to-A converters feature voltage or process industry 2 to 20mA current loop outputs. Output from any dac can be configured as unipolar 0 to 2.5V and 0 to 10V or bipolar ±2.5V and ±10V. For unipolar operation, unipolar binary coding is used. For bipolar operation, offset binary coding is employed. 2's complement coding can be accommodated. Amplicon Liveline, 0273 570220.

8-bit dac. PMI has introduced a quad 8-bit c-mos D-to-A converter with an internal 10V reference. The DAC8426 contains a switched dac and output buffer amplifiers. Operation from a single 15V power supply at 180mW minimises system power consumption. Precision Monolithics, 0101 408 562 7254.

Linear integrated circuits

8-pin amplifier. AMP02 from PMI is an instrumentation amplifier in an 8-pin plastic minidip. Features include internal overload protection to 60V with power on or off, single external resistor required to set the gain, and set gain of unity if no external resistor is used. Arrow Electronics (UK) Ltd, 0234 270777.

GaAs amplifiers. Hewlett Packard's HMMC5022 and 5026 are claimed to be the first GaAs MMIC amplifiers to operate at up to 26.5GHz (5026), said to be ideal for wideband cascadable gain and gain control. Typical applications include gain stages for EW, ECM, radar, instrumentation and telecommunications systems. They use seven mesfet cascade gain stages to achieve flat response up to 22GHz and 26.5GHz respectively. Typical gain figure is 9.5dB, with a virtually flat response to ±1dB over the full bandwidth. Anglia Microwaves Ltd, 0277 630000.



Power transistor arrays for motor control by Power Integration

Hybrid ICs. Hybrid ICs are available from Japanese manufacturer Rohm in five types varying in integration, operating conditions, price and delivery. BX Series are IC chips, transistors, diodes, resistors and capacitors mounted on a PCB. BY and BZ Series use thick-film technology. In the BW Series, any component can be mounted on the board. The BP Series are general-purpose hybrids. Powersolve Electronics Ltd, 0635 521858.

Op-amp. The OP61 from Precision Monolithics is a low-noise operational amplifier with a high gain/bandwidth product of 200MHz at 1MHz. Noise is 3nV/√Hz at 1kHz, open-loop gain is 400V/mV and offset voltage is 200μV typical. Precision Monolithics, 0101 408 562 7254.

Op-amp. PMI has launched the SSM2131, a fast JFET input operational amplifier with low distortion, high slew rate, and fast settling time. It offers a symmetric 50V/μs slew rate for low distortion and is internally compensated for unit gain operation. Unity gain stability, full-power bandwidth of 800kHz, and ability to handle transient overloads make it suitable for high performance audio amplifier circuits. Precision Monolithics, 0101 408 562 7254.

TV stereo decoders. Siemens claims its TDA6600 series of chips offers, among other features, the best decoding reliability available. The chips – TDA6610, TDA6611 and TDA6620 – combine decoder functions, previously provided on two chips, on a single device with 18 or 28 pins (the two-chip set had 52 single pins). The external components required for functions such as pitch control or stereo expansion are replaced by one capacitor. Siemens, 0932 752323.

Memory chips

4Mbit d-ram. Available now is NEC's 4Mbit d-ram either as 4M x 1-bit (uPD4241000) or 1M x 4-bit (uPD4244000). Access times of 80, 100 or 120ns give minimum read-write cycle times of 160, 190 and 220ns respectively. A fast-page mode option is available for either format. VSI, 0279 35477.

Microprocessors and controllers

8-bit microcontrollers. VSI has introduced 8-bit microcontrollers that incorporate the speed and low power operation of risc and c-mos plus the time-saving flexibility of eprom on the same chip. They sell for less than £2 in a one-time programmable package, and contain customer-defined eprom, ram, high current drive I/O lines, a realtime clocked timer counter with prescaler, watchdog times and an 8-bit CPU. VSI, 0279 35477.

Oscillators

Clock oscillators. Developed as stable timebase generators for battery-powered smart munitions, M-tron ML micropower realtime oscillators provide a cost-effective solution to clock requirements as low as 2Hz for portable instrumentation in any environment. They use a 32.768kHz tuning fork crystal as the primary timebase. M-tron Industries Inc, 0101 605 665 9321.

Programmable controllers

Programmable analogue controller. A distributed control and data acquisition product, the GIC14000, will communicate with various protocols and can be used to upgrade an existing system for monitoring, closed-loop control and data collection. An analogue and logic input/output device, it can be programmed by the user in a high-level language to perform complex control strategies. Using the isolated RS485 communications port, up to 45 GICs can be networked on the same serial link with one host computer or programmable control. It also functions as an independent microcontroller for monitoring and multiple closed-loop control. 4D Controls, 0872 552784.

Transistor arrays. Power Integrations has introduced the PWR-NCH201 and PWR-NCH401 transistor arrays which provide 5V control of low on-resistance, high-voltage outputs. Outputs can be controlled independently or combined to provide extra current-handling capability. They offer a current mirror as standard, making them suitable for the bottom half of a bridge in a motor-control circuit. Power Integrations Inc, 0101 415 960 3572.

Transistor modules. Using the die designed and diffused by Semefab (Scotland), Semelab is introducing a range of high-energy power modules. The range will extend from single active Darlington devices to bridge and half-bridge configurations. Electrical ratings up to 1000A and 1kV will be featured. Semelab Ltd, 0455 554711.

PASSIVE

Connectors and cabling

Cable meters. Out now are two wire and cable measuring meters for handling the more slippery insulating materials on extruded wires and cables. For use independently with an optional floor or bench stand, or with reeling and dereeling equipment, they will measure wire and cable up to 200mm in diameter using the metric SMMU or 7/8in diameter using the imperial SMIU unit. Eraser International Ltd, 0264 51347.

Audio cable. From Gotham comes an unbalanced professional audio cable packed in a dispenser box, featuring low noise and high RF protection. GAC1 has two individual shields covering a special conductive PVC layer which grounds any static energy created by movement of the cable. F. W. O. Bauch Ltd, 01-953 0091.

Displays

Plasma display. A DC plasma display screen in the Panasonic range, the MD480L640PG3, has a 640 x 480 pixel panel with 0.36mm pixel spacing in vertical and horizontal planes. This allows true graphics to be presented, as well as alphanumeric characters, on a full 11½in screen. The module incorporates a self-centring facility for 640 x 350 or 640 x 400 input formats. Craft Data Ltd, 0494 778235.

Displays. After-market F-STN displays for fitting to Sanyo TN and STN modules offer higher contrast ratios and a truly black-on-white appearance. EL backlighting and extended temperature versions are available, and the modules can be powered by a single-rail supply. Tempatron Ltd, 0734 596161.

Alphanumeric displays. The range of Sanyo alphanumeric LCD modules from Tempatron has display formats from 8 characters x 1 line to 80 characters x 4 lines, in a range of 34 modules, each with at least six combinations of technology, backlighting and supply voltages. All have on-board control LSI, making interfacing with 4- or 8-bit MPUs easy. All displays are compact and lightweight, with low power consumption. Tempatron Ltd, 0734 596161.

Filters

Video filter. A video filter set, said to be introduced to meet market demand, meets CCIR recommendation 601 and is claimed to be completely industry compatible. Faraday Technology, 0782 661501.

PIONEERS

J. W. Mauchly and J. P. Eckert The men who made Eniac

Eckert & Mauchly. Courtesy of Unisys Ltd.

One of the war's top secrets ... was announced here tonight." So said the *New York Times* when revealing the first general-purpose electronic digital computer, the Eniac, which was unveiled on St. Valentine's Day, 1946. "Apart from the mechanical devices associated with it," the newspaper continued, "nothing inside its 18,000 vacuum tubes and several miles of wiring moves except the tiniest elements of matter — electrons."

What the *Times* did not reveal, though, was the sea of troubles through which the inventors had fought to get their ideas accepted.

Eniac was conceived and built between 1943 and 1946 by John W. Mauchly and J. Presper Eckert and their team at the Moore School of Electrical Engineering at the University of Pennsylvania. For a just over a decade it was used on a variety of mathematical problems, including some for the development of the H-bomb, before it was dismantled. Parts are preserved at the Moore School, the Smithsonian Institute and at other sites in the USA.

Mauchly was the main inspiration behind the project, overseeing the mathematics and functions to be performed, while Eckert designed the electronics. "If it hadn't been for him [Eckert] as chief engineer," wrote Mauchly, "I doubt we would have succeeded in building the Eniac."

John William Mauchly was born in Cincinnatti, the son of a physicist who worked at the Carnegie Institution in Washington, D.C. After gaining a PhD from Johns Hopkins University, Baltimore, in 1932 he joined Ursinus College near Philadelphia and became Head of the Physics Department. A project on weather prediction convinced him of the need for better ways of analysing vast amounts of data and he realised that such analysis would require a high-speed computer the like of which did not exist. Writing in 1975 he harked back to his early hopes of making a better weather forecast — "These hopes have never been fully realised," he observed.[1] "Perhaps with a better computer..."

Mauchly had built circuits as a boy and knew of physicists using electronic counters. With valves costing little more than relays (which others were then using for calculating machines) but operating 1000 times faster, he saw that the future lay with fully electronic systems. So, "I started assembling a little bit of equipment in the laboratory, which," as his departmental budget was stretched to the limit, "I had to pay for out of my own pocket." His first thought was to increase his salary so he could spend more money on equipment. But it was not a salary rise that changed things, it was the outbreak of the war.

By 1940 the US government was spending money on training people in the new skills for the war effort. Mauchly attended a course at the University of Pennsylvania where he met Eckert, a recent graduate, who had been drafted in to act as a lab instructor. Instead of repeating lab exercises he could already do Mauchly chatted with Eckert about his ideas for using electronics to do arithmetic. Eckert, recalled Mauchly, "was the one person who was encouraging in those days." But for him, Mauchly may never have proceeded.

The other outcome of that summer course was that Mauchly was invited to join the staff at the Moore School of Electrical Engineering. Many lecturers were being called to active duty but, as Mauchly put it, "I knew something about electronics," so, "I jumped at the chance."

The Moore School possessed a mechanical difference analyser which had been pressed into service calculating ballistics tables for the Army. Meanwhile a small army of people (one of whom, Kathleen McNulty, was to become his wife) was grinding away with mechanical calculators doing the same job. Despite all their efforts, the mountain of work continued to grow. Mauchly believed that his machine would do the job 1000 times faster, if only he could get it built.

At first the Army showed no interest. After all, no machine with hundreds, let alone thousands, of vacuum tubes could possibly work. Even if it did the war would be won before it was built.

But by 1943 that attitude had changed and it was decided to take another look at a memo Mauchly had written in 1942 outlining his ideas. When no-one could find a copy of the memo it was reconstructed from his secretary's shorthand notes!

A contract was drawn up with both parties wanting a general-purpose machine, not one solely dedicated to calculating ballistics tables. After all, there was still the weather forecast to do. Staff were recruited and trained, and design and construction began. Mauchly recalled, "The biggest single task that faced us was to achieve a degree of reliability that, so far as I know, had never before been required of an electronic system of that size and complexity." It was a task for Eckert.

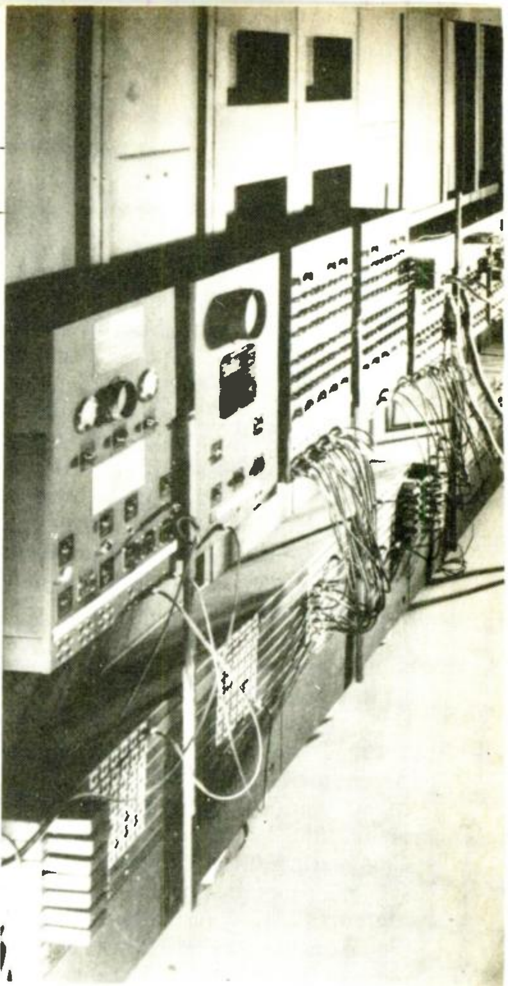
Specially made high-reliability components would not be available in the quantities needed, and they could not afford them anyway, so Presper Eckert saw the problem as one of circuit design. Only common components would be used: standard 50 cent valves, ± 10% carbon resistors at 2 cents each, etc. Further, using "cut-and-try" testing, the circuits were designed to accept very wide component tolerances. Components themselves were operated well below their normal ratings: anode voltages 50% below their rated maxima for instance, with currents below 25% of maximum. If a ¼W resistor was needed, then a ½W or sometimes a 1W was used. "We just took flying guesses," Mauchly recalled, "and did as much testing as we had time for."

The contract was signed in June 1943, the machine being constructed over the next 18 months with many 80-hour weeks involved. When finished, someone claimed it could compute the trajectory of a shell faster than the shell could fly it, but by then the war was over.

The inventors had already turned their thoughts to the commercial prospects for a large computer, and in 1944 they filed for a patent. Immediately an argument blew up over the university's rights to the patent, and although the question was settled quickly it left a lingering rift described 25 years later as a "cleavage in our group." [2] Just a month after the dedication of Eniac in 1946 all employees of the university were asked to sign a patent release form. Among those who refused were Eckert and Mauchly — they resigned, but as far as they were concerned they had been sacked.[2]

IBM was quick to offer positions to them both, and Eckert was also head-hunted by John von Neumann of Princeton's Institute for Advanced Study. However, Mauchly persuaded him to develop their ideas jointly as a commercial project. They already knew that the US Weather Bureau and the Census Bureau were interested. Backing was sought from Wall Street financiers but, "We were dismissed by some of the biggest venture capitalists after a 10-minute hearing."

The Census Bureau decided to go ahead and in April 1946 it acquired $300,000 for computer development, but government bureaucracy grinds slowly. A consultant was hired to study the proposals and a pilot study authorised in September of that year. Then a subcommittee of the National Research Council, consisting of leading figures in the calculator/computer field, gave an unenthusiastic report on the proposals for the full machine. One member commented on this "foolishness with Eckert and Mauchly."[2]



General view of the Eniac. Courtesy of the Moore School of Electrical Engineering, University of Pennsylvania.

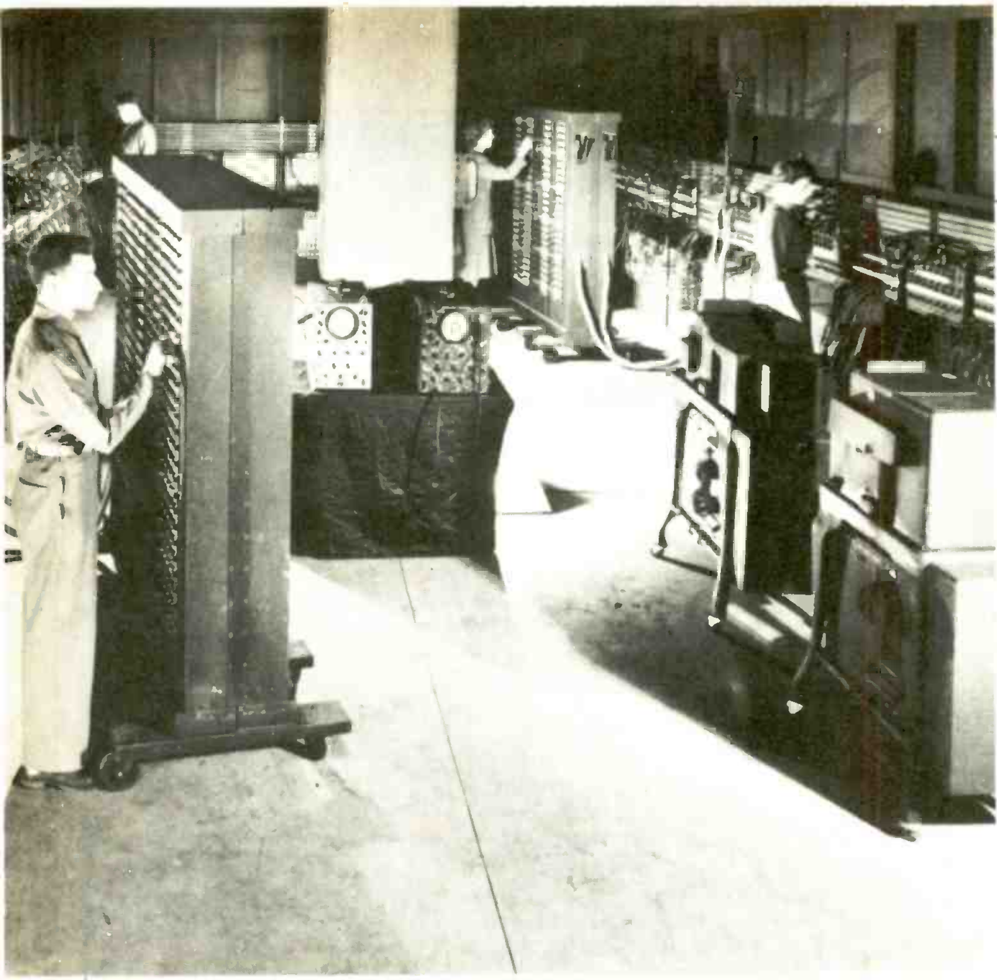
But in June 1948 a fixed-fee contract was signed, with periodic checks which determined if the next payment would be made. For the small Electronic Control Co. that had been formed, it all meant extra delays, but at least the Universal Automatic Computer, or Univac, was underway. Unlike Eniac, Univac was to have a stored program.

Univac was completed in 1951 and delivered to the Bureau of Census, but the path to completion was tortuous. It involved temporary loss of security clearance due to supposed Communist connections, making a small $100,000 Binac computer (at a loss) for the Northrop Aircraft Co. to ease cash-flow problems, a change of status and name (to Eckert-Mauchly Computer Corp.) to raise equity, contracts for two more Univacs, and a financial saviour who died in an air crash with the finance effectively dying with him. Throughout,

Eniac — facts and figures

Weight:	30 tons
Room size:	30 x 50ft
Power Consumption:	150kW
Components:	18,000 valves 70,000 resistors 10,000 capacitors 6,000 switches 500,000 soldered joints
Cost:	About $400,000
Speed	Clock 100kHz 5000 additions/subtractions per sec.
Radix:	ten
Completed:	1946

Patent declared invalid in 1973, in favour of John Vincent Atanasoff of Iowa State College.



If you hate the flashing lights which are essential parts of computers in science fiction films, blame Eniac. Tiny bulbs were used in the machine to help keep track of information flow as a check for faulty valves. For the 1946 demonstration the lights were emphasised by covering them with translucent hemispheres — made from table tennis balls.

Mauchly and Eckert on the Lunar Rover. Mauchly was once quoted as saying, "We thought of most uses, but not landing on the moon." Courtesy of Unisys Ltd.

the computer pioneers lurched from one financial crisis to another.

When they were on the brink of bankruptcy several firms were approached in an attempt to sell out. On February 1, 1950, Remington Rand agreed to buy. Both men stayed with the Univac division but it was the start of an ownership saga. Remington Rand merged with Sperry Corporation in 1955, producing a Sperry-Univac division. Then in 1986 Sperry merged with Burroughs to become Unisys, which now claims to be the second-largest computer company in the world.

John Adam Presper Eckert, better known as "Pres", is a native of Philadelphia. Born on April 1919, he was brought up at Mt. Airy, North Carolina, the only child of Jack and Ethel Eckert. At eight he built his own crystal radio on a pencil and hid it in his desk at school. By 13 he had moved on to valve sets, having the previous year won a prize at a Philadelphia hobby fair for a magnetically controlled boat.

His genius for electronics obviously began early, and in his youth he lived near where Philo T. Farnsworth did his pioneering work on television.

Eckert enrolled in the business school at the University of Pennsylvania but left after only three days. "They were putting me to sleep," he said. Changing subject, he opted for physics, "but they wouldn't take me so I enrolled in electrical engineering which was the next best thing."[3]

After graduating with a bachelor's degree he took a graduate fellowship and received his master's degree in 1943. His varied work included a device for detecting small magnetic fields, used by the US Navy for magnetic mine detection.

In 1952, quite soon after the Eckert-Mauchly company was sold, Eckert's wife, Hester, died from a head injury. He was left to bring up two sons, the younger little more than one year old.[3] In just four years he had lost his wife, major contracts and company. It was determination, he says, that kept him going. He remarried, this time to Judith Rewalt, had another son and a daughter, and rose to be vice-president of the Sperry-Univac division of Sperry Corp.

Mauchly stayed with Univac for ten years, leaving in 1959 to form a consultancy — Mauchly Associates. He returned as a consultant in 1973, having founded in 1967 a computer consultancy called Dynatrend. Like most other successful engineering pioneers he received his share of awards and honours.

He died while undergoing heart surgery in Philadelphia on January 8, 1980, aged 72. At his funeral service, Eckert spoke of the inspiration Mauchly gave to others. He was, "One of the most brilliant people I ever knew." More important, he added, "He was a *good* man." ■

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1. J. W. Mauchly, "Mauchly on the trials of building Eniac," *IEEE Spectrum*, April 1975, pp70-76.
2. N. Stern, "From Eniac to Univac," *IEEE Spectrum*, Dec 1981, pp61-69.
3. H. Martin, "The man who built Eniac," *Corporate Monthly*, Sept 1984, pp24-27.

The author would like to thank the Moore School of Electrical Engineering and Unisys Ltd. for information provided. Tony Atherton's book, From Compass to Computer: A history of electrical and electronic engineering, *was published in 1984 by MacMillan Press.*

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CIRCLE ENQUIRY NO. 151 ON BACK PAGE

Automation in TV production and playout

"In the 1990s, viewers will receive the benefit of hundreds of distribution channels on cable and DBS. To be viable, services that populate these new channels must find the least expensive production methods . . . As audiences fractionalise, revenues decline, and debt increases, many traditional TV organisations will find it necessary to reduce their production and operating costs . . . Full production automation and the use of consumer-grade equipment will play significant roles as the new and traditional TV organisations struggle to prosper in the next decade." This American view was put forward by Thomas R. Wolzien, senior vice-president of NBC Cable at an IEE colloquium: "Television Automation: Today's Technology, Tomorrow's Opportunities."

While UK television has not yet been remoulded in the American pattern, it became clear that computerised automation of newsrooms is rapidly becoming established in the UK, both for national and regional operations. Automation is now extending into the areas of network presentation and control. Typically, staffing levels are being reduced by roughly a half, although the new satellite channels of Sky, BSB etc and the independent production and facilities houses are at present absorbing, if only on a contract basis, redundant staff.

Firms such as Basys, Dynatech Newstar, Odetics, Sony and Ampex are offering and installing systems or sub-systems based on computer-controlled video-cassette players, library management systems etc. The new four-channel Sky centre in Isleworth makes extensive use of the Sony Library Management System for playing out Betacam-S 0.8in format cassettes. Increasingly, such cassettes, developed from consumer-type VHS and Betacam formats – and later digital D-2 cassettes – seem set to replace for playout and production the current 1in reel-to-reel machines.

In describing current progress in the automation of BBC News and Current Affairs operations at a cost of about £1.5-million, Roy Vitty (BBC) stressed that automation can result in lower costs, fewer staff and greater reliability for management; fewer errors and more sophistication for programme makers; more job satisfaction, greater job security and more pay for staff; and greater sales and product opportunities for the broadcast industry. But he also admitted: "There will inevitably be staff worries about loss of jobs, loss of income, a real concern for a possible reduction in quality and reliability of output and a perception that the skills they have developed will not be of value in the future . . . In journalistic areas particularly, there would be concern about inadequate training and the ability to carry out the extra responsibilities involved and of the need for a better understanding of technical matters. All this boils down to the need for good management...with a high emphasis on staff consultation and training and a realisation that at least some of the savings will need to be given back to the staff in some way. The step-by-step approach would also enable problems and teething troubles with equipment, software and systems to be dealt with on a small scale before they become problems on a large scale."

Channel 4, which pioneered automated playout in the UK with CATS (Computer-Aided Transmission System) is in progress of replacing CATS with an in-house PIRATE system (Programme Instructions Retrieval in an Automated TV Environment) which will allow 24h continuous scheduling as well as linking to air-time sales and commercial scheduling systems. Also being developed is BOSS (Broadcast Operation Support System) based on MicroVAX but achieving real-time control via a transputer network with no theoretical limit to the number of controlled devices, as well as providing a powerful means of introducing fault tolerance into the system. Martin Connelly (C4) stressed that "Before any automation system is on-air it *must* be thoroughly tested, debugged and the human part of the interface totally programmed to understand the system and its operation."

Across the Channel, an interesting computerised programme-sequencing system has recently been installed for the French-language channel of the Belgian RTBF. This is based on the Sony BVC-1000 Library Management System for the play-out of all recorded programmes, whether short commercials or full-length feature films. The system has four built-in Betacam-SP players and three external VTRs, two reel-to-reel format-C machines and one for Betacam cassettes. These are coupled to a library system that can carry 1006 small cassettes (maximum play-time 30 minutes) and up to 56 large 100-minute cassettes.

The control system uses the time-codes on the tapes and a bar-code on each cassette or a similar "label" on the open-reel tapes by means of a computer data file containing start and finish times. Back-up is provided by recording future sequences on one of the external machines which then plays out the tape synchronously with the on-air cassette. Should the automatic system fail, the operator can switch immediately to the external machine.

New attack on pirate broadcasting

Although the complex and lengthy (160 pages) Broadcasting Bill, as presented to Parliament, contains little reference to future engineering changes, Part VII includes proposed changes to Section 1 of the Wireless Telegraphy Act 1949, intended to strengthen the provisions against pirate transmissions. It creates the offence of keeping a wireless telegraphy station and apparatus "available for unauthorized use"; and the offence of "allowing premises to be used for the purpose of unlawful broadcast from any other place". The new clauses thus enable, if approved, action to be taken against the studios linked by microwave to an unattended transmitter, as well as against the occupiers.

The Bill proposes to make the BBC responsible for issuing and renewal of TV licences, although presumably the enforcement of licensing, including the right of entry into homes, will remain with the DTI.

Although not part of the Bill in its present form, it appears that the IBA Engineering Division will formally become part of the DTI as from January 1991 later to be privatised.

Broadcasting is written by Pat Hawker.

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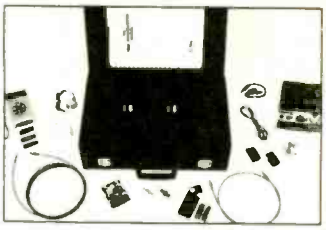

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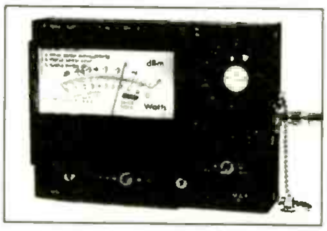

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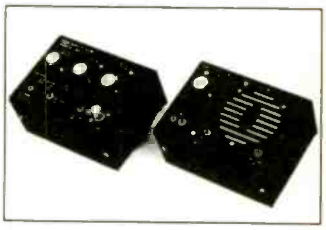

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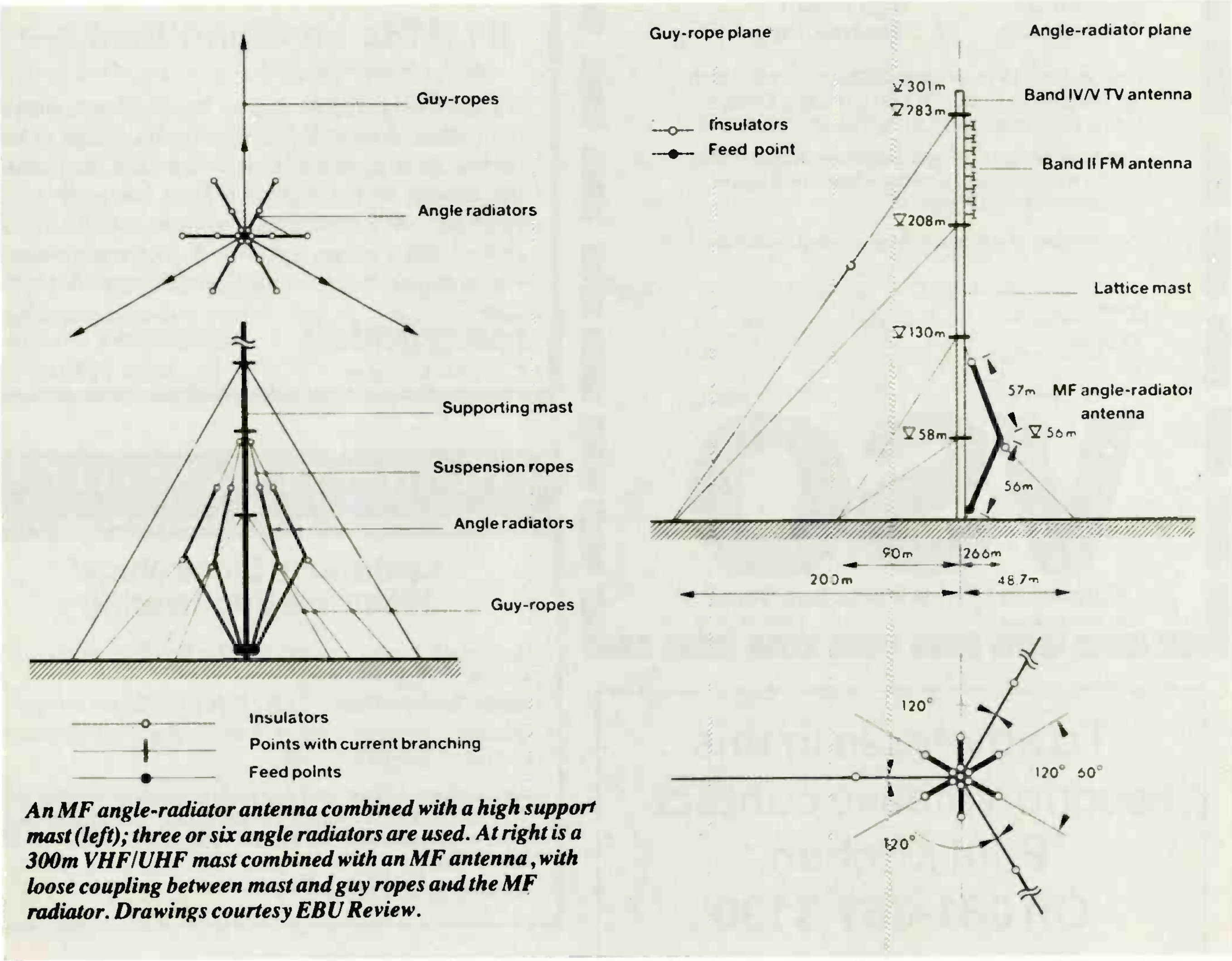
MF antennas on high VHF/UHF masts

In the UK, it is generally considered impractical to support medium-wave broadcasting antennas from the same high masts used for television broadcasting. This is partly due to the close electromagnetic coupling (with MF channels falling within the transmission bandwidth of a TV signal) and partly because of the disturbances that affect the radiation characteristics of the MF antenna. Furthermore, VHF/UHF support masts do not have the extensive ground systems required for MF monopoles and the guy wires may have resonances that change the MF radiation pattern.

In *EBU Review – Technical No 235* – June 1989 (published December 1989 as the EBU technical Centre strives to make good the delay to its publications brought about by the dispersal of part of its activities to Geneva), G. Potschkat and Dr W. Tippe of IRT describe a novel MF "angle-radiator" antenna designed in such a way that the supporting structure is in effect, supplemented by a complete earth network, making it possible to combine an MF antenna with an existing VHF/UHF mast. The special arrangement and shape of the angle-radiators leads to fairly loose coupling between the MF antenna and the mast and the guywires. The MF antenna may be designed to provide omni-directional characteristics, or alternatively directivity can be achieved by adding one or two passive elements serving as reflector or director to the single supporting mast, or by phasing the feed currents to the individual angle radiators, permitting front-to-back ratios of better than –10dB to be achieved.

Design principles of this MF antenna have been established using the NEC Method of Moments computer software and by model measurements at test frequencies of 100 and 200MHz. Two full-scale antennas have been constructed around masts with different numbers of guys, with NEC and model optimisation. With grounded support masts, the integrated antenna is well protected against lightning. Electrostatic charges built-up during thunderstorms leak directly to earth via the grounded mast and grounded guywires. Since the mast remains earthed, it is claimed that riggers can safely climb to the VHF/UHF antennas without having to close down the MF transmissions. ■



An MF angle-radiator antenna combined with a high support mast (left); three or six angle radiators are used. At right is a 300m VHF/UHF mast combined with an MF antenna, with loose coupling between mast and guy ropes and the MF radiator. Drawings courtesy EBU Review.

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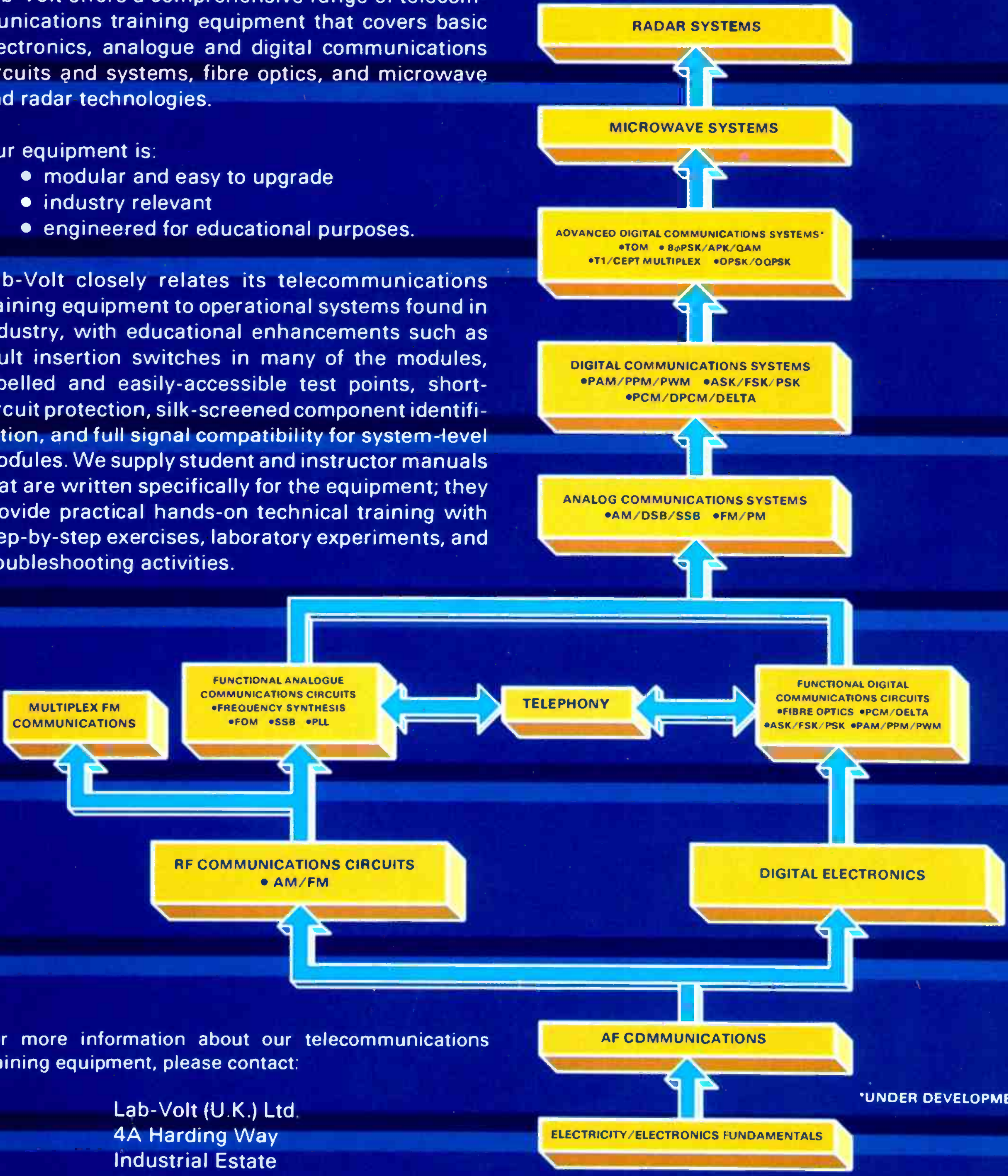

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