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**In next months issue:** In October 1945, Wireless World published an article *Extra Terrestrial Relays* by Arthur C Clarke. It laid the basis for modern satellite communications and, in doing so, charged the world. To mark our 80th anniversary, we will publish Clarke's original paper in its entirety.

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# Visionary stupidity

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After the first of January, 1993, all televisions bigger than 22in will have to be D2MAC compatible if sold within EC countries. This means that every euro-consumer buying a large screen set will pay towards the cost of protecting the French company Thomson and the Dutch giant Philips from external competition. At present mac set prices, you or I would have to cough up an extra £500 although this will fall with time. The same euro-ruling insists that new satellite services use $D^2$mac. Further, when the nation's living rooms are taken over by HDTV, the system in use will be HD-MAC.

The European Commission has chosen to conceal blatant protectionism by selling its directive as "the laying of new foundations for high quality television services in the 21st century".

We take a slightly different view. Why bother to hide the protectionist aspect at all? After all, Europe sells nothing of significance in monetary terms to far-eastern countries and the effects of a hard line pursued against Japan and Korea would do nothing but good for the long-term advantage of the European electronics industry. If Japan were to take retaliatory action, it would amount to the economic equivalent of hara kiri. Far from hiding protectionist euro-policies, we should all be dreaming up new ways to frustrate our far-eastern trading 'partners'.

It goes almost without saying that we must be prepared to behave differently with those countries which value our exports, notably the US. Here co-operation rather than confrontation seems far more fitting.

Yet there remains a disturbing aspect to the EC's imposition of mac-based television. It is not so much the fact that euro-consumers will be denied the choice of low cost Japanese and Korean equipment. It is simply that the mac systems are not flexible enough for the next generation of television broadcasting developments. If Europe adopts mac, the industry will see it to be as limiting as we currently regard pal – and in the space of just a couple of years.

When the old IBA dreamt up the concept of multiplexed analogue components in the early eighties, it looked like a brilliant way over overcoming the shortcomings of the pal terrestrial system using the technology of the day: no cross-colour with check sports jackets, multiple languages/stereo transmission and easy interchange with other broadcasting standards. Best of all, the time domain compression on the video signals allowed broadcasting within normal TV channel bandwidths. There was even room to squeeze in digital sound and text.

Unfortunately, good as it is, the technology of the eighties has now been eclipsed and the analogue compression at the heart of all mac standards, looks stiff and inflexible. Any universally imposed broadcasting system must be based on all-digital encoding to allow for future development. After all, algorithms which can compress a standard colour TV channel into a 1MHz transmission space already exist (GI's Digicypher) and even more astonishing processing convolutions are in the pipeline.

An all digital system matches low cost manufacturing technology yet takes into account future developments in both microelectronics and future transmission technology. It is almost as if we were back in the '30s and were about to choose the Baird mechanical TV system in preference to EMI's electronic scanning method. It is not enough to say that a digital system isn't ready. After all, 99 per cent of viewers are perfectly happy with the technical quality of what appears on their screens.

That the European Commission is prepared to burden its broadcast manufacturing industries and the viewing public with a technological turkey for the short-term benefit of two companies is quite disgraceful.

**Frank Ogden**

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# REGULARS

UPDATE

## Single-atom logic?

IBM scientists here have reported the operation of a new type of electrical switch that relies on the motion of a single atom. They claim to have demonstrated that it is possible for switches to have individual atoms as their critical moving elements.

Writing in *Nature*, researchers Donald Eigler, Christopher Lutz and William Rudge said they had repeatedly moved a single xenon atom back and forth across the gap between two electrodes spaced just several atomic diameters apart. They found that the electrical tunnelling current that flowed between the electrodes changed according to the position of the xenon atom. Such changes could form the basis for a computer logic switch.

The scientists used a special low-temperature scanning tunnelling microscope (STM) to build and operate the atom switch. One of the atom switch's electrodes was the STM tungsten probe held stationary about 5 angstroms (20 billionths of an inch or just a little more than one xenon atom diameter) away from the other electrode – a single crystal of nickel.

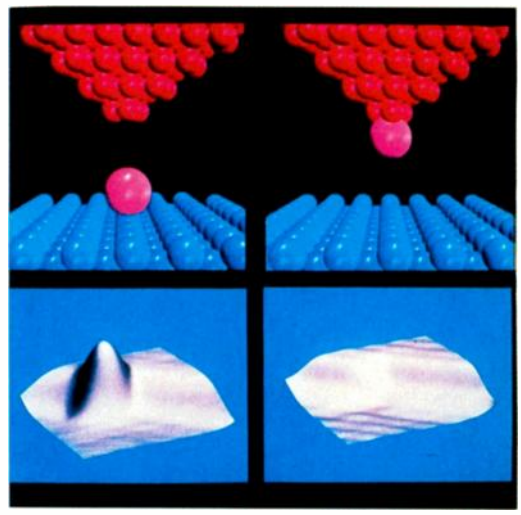
To operate the atom switch, the scientists applied a short voltage pulse to one of the electrodes. The resulting electrical current caused the xenon atom to jump the gap between the electrodes and attach itself to the surface of the opposing electrode. With the xenon atom in its new position, the electrical resistance and tunnelling current measured between the switch's electrodes changed.

By reversing the polarity of the voltage pulse, the scientists found that they could return the xenon atom to its original position and the tunnelling current in the switch to its previous level. Important to the operation of the atom switch is the asymmetric geometry of the flat nickel surface and the relatively sharp STM tip.

The active region of the atom switch is very small, just several atomic diameters. However, to realise any potential size benefits in practical devices, the atom switch's electrodes and electrical leads would have to be greatly miniaturised and arranged very closely together.

The research group is non-committal about the commercial possibilities of atom switches although it hopes to lay the scientific foundation for future generations of very small electronic devices. The initial switch model required high vacuum and low temperatures. However, another IBM research group reported that it had used an STM operating at room temperature to pick up and replace single silicon atoms and clusters of atoms from a silicon surface. This suggests that room temperature atom switches might be possible.

The atom switch is the latest achieve-ment of Eigler and colleagues. In April 1990, they used the STM to move and position individual atoms for the first time and had demonstrated the capability by spelling "I-B-M" in block letters with 35 xenon atoms. Since then, several other types of atoms and molecules have been moved repeatedly back and forth from the surface to the STM tip.



*Computer-generated diagrams (top) and STM images demonstrating operation of the single-atom switch. An electrical pulse attracts the xenon atom to the tip, changing the current flowing between tip-surface. An opposite polarity pulse changes the switch properties.*

The STM was invented in the early 1980s by Gerd K. Binnig and Heinrich Rohrer, Nobel Prize-winning scientists at the IBM Research Division's Zurich Research Laboratory.

It can image individual atoms on a metal or semiconductor surface by scanning the tip of a needle over the surface at a height of only a few atomic diameters.

The instrument can resolve vertical changes in an atom's apparent shape as small as 0.002Å – far smaller than any atom.

## Non ionising waves more serious – NRPB

Low-frequency non-ionising radiation could have more serious medical effects on humans than was previously believed, according to a report by the National Radiological Protection Board.

It has been assumed that the damage caused, increased with frequency and dose level. At microwave frequencies, exposure has well-established adverse biological effects. The new report, *Biological Effects of Exposure to Non-ionising Electromagnetic Fields and Radiation*, suggests that there may be other frequency windows which cause effects out of proportion to the radiation level.

The report does not come to conclusions about medical effects at particular frequencies or dose levels. It was commissioned to find areas of study which need more work.

"In some areas there isn't a lot of information, but what information there is indicates that there might be a problem" commented a spokeswoman for the NRPB.

"But not everyone will definitely be affected by the radiation in a window", she said. "One of the major problems seems to be that people can vary from hypersensitive to completely insensitive."

The effects are fairly esoteric. The report describes some of the results of exposure to low levels of electric and magnetic fields as "the altered mobility of calcium ions in brain tissue, changes in neuronal firing patterns and altered operant behaviour."

It suggests that densities as low as 10mA/sq m have detectable effects on the human nervous system. "It is worth noting that the endogenous current densities generated by the electrical activity of muscles are typically 1mA/sq m and may reach 10mA/sq m in the heart." according to the report.

Although the report made no recommendations, it concluded that people can perceive the effects of oscillating surface charge induced on their bodies, which can be irritating, and that such effects should be avoided.

**Rob Causey**

# Breakers' law breaking

Just over 300 people were successfully prosecuted for breaking various sections of the Wireless Telegraphy Act last year says the Radiocommunications Agency in its annual report.

Of the 309 cases prosecuted, there were 306 convictions resulting in fines and costs totalling £111,386. This averages to £364 per case including costs.

The bulk of prosecutions was for illegal broadcasting (143 cases) with CB related offences accounting for a further 122. Amateur radio activity attracted only five prosecutions.

The Radio Interference Service, which acts as the enforcement arm of the agency, received more than 3000 reports of possible illegal transmitters and other suspect sources of interference from the public. Many of these, it says, were subsequently investigated leading to prosecution.

The RA issued a total of 60,885 amateur radio licences and 69,803 CB licences, a slight decline on last year's figures.

**Prosecution cases concluded in the courts & warning letters issued for financial year April 1990 - March 1991**

| Category | Number of Persons Prosecuted | Number of Persons Convicted | Total of Fines Imposed (£) | Number of Costs Awarded (£) | Number of Forfeiture Orders | Number of Conditional Discharges | Number of Absolute Discharges | Number of Admonishments (Scotland) | Warning Letters Sent |
|---|---|---|---|---|---|---|---|---|---|
| CB AM | 52 | 52 | 6,775 | 3,898 | 37 | 1 | — | 6 | 48 |
| CB FM | 71 | 70[A] | 5,085 | 1,444 | 17 | 5 | — | 4 | 259[B] |
| Unlicensed Broadcasters on Radio | 145 | 143[C] | 37,190 | 33,123 | 122 | 32 | 2 | — | 2 |
| Cordless Telephones | 1 | 1 | 250 | 100 | — | — | — | — | 10 |
| PMR | 20 | 20[D] | 5,625 | 2,673 | 7 | 4 | 1 | 2 | 70 |
| Amateur | 5 | 5 | 1,000 | 1,730 | 2 | 1 | — | — | 2 |
| Marine | 8 | 8 | 1,180 | 1,721 | — | — | — | — | 15 |
| 6.6MHz | 1 | 1 | 250 | 50 | 1 | — | — | — | 1 |
| Others | 6 | 6[E] | 5,630 | 3,662 | 2 | — | — | — | 9 |
| TOTAL | 309 | 306 | 62,985 | 48,401 | 188 | 43 | 3 | 12 | 416 |

A 1 charge of playing music and 1 Section 13 offence (deliberate interference).
B 1 offensive language
C 1 sentenced to three months' imprisonment and 1 sentenced to 4 terms of 60 days imprisonment suspended for one year
D 1 Section 13 offence
E 1 charge of obstruction – CB operator; 2 of using aeronautical frequencies in hot air balloon; 1 bug placed in a taxi office by the proprietor and 2 incitement to commit WT Act offences by sale of illegal devices

# Dishing out double trouble

This winter is crunch time for Société Européenes des Satellites, the Luxembourg owners of the Astra satellites, and Eutelsat, the European telecommunications satellite organisation based in Paris. In late October, Eutelsat launches Eutelsat II F3, following the delay caused by the loss of an Atlas rocket in May. Both Eutelsat and Astra have been allocated the same frequencies.

BSkyB uses Astra to broadcast its programmes to the UK.

So far this has not mattered because Eutelsat's existing satellites are located in orbit well away from Astra's. But Eutelsat's new II F3 satellite will be at 16° East, just three degrees away from Astra at 19° East. The position is too close for some of the four million Astra aerials now installed in Europe to discriminate between satellites.

This follows a fudged report from SES which warned against using any dish smaller than 55cm to receive its satellite services. As a result both Amstrad and Sky dropped their plans for lower cost, more environmentally friendly 45cm dishes.

Simon Orme, of receiver manufacturer NEC, warns that "many viewers with popular, low cost dishes are likely to suffer interference".

NEC says that viewers will not notice any problems with a poorly made or too-small aerial sighted on Astra while there is no other satellite transmitting on the same frequencies from close by in orbit. But Eutelsat will be using some of the same frequencies as Astra, from just three degrees away. With wide beam aerials, some interference is thus inevitable.

*Small may be beautiful but the picture could get spoilt*

Eutelsat's satellites operate in three frequency bands, 10.95 - 11.2GHz, 11.45 - 11.7GHz, and 12.5 - 12.75GHz. Astra 1A uses 11.2 - 11.45 GHz. Astra 1B uses 11.45 - 11.7 GHz and 1C will use 10.95 - 11.2 GHz when it is launched in a couple of years. So far there is no clash between Astra 1A and anything of Eutelsat's. Eutelsat I F5 is already at 21.5° East and thus close to the Astra slot. There are no interference problems because there is no frequency clash with Astra 1A or 1B.

But when Eutelsat II F3 launches into its allocated slot at 16° East it will use the same band as Astra 1B, 11.45 - 11.7 GHz. And when Astra 1C is launched in a couple of years it, too, will share frequencies with Eutelsat II F3.

Eutelsat II F3 is now scheduled for launch in mid October, with eight 50W transponders working in the 11.45 - 11.7GHz band. The frequency clash with Astra 1B is unlikely to affect Eutelsat users, including Spanish broadcasters and British data and news services. They will be using large dishes, which exclude Astra's signals. The people who suffer will be Astra viewers with cheap or too-small dishes. They will see double pictures or herringbone patterns

on screen. The only cure will be to fit a larger or better, dish. This will not be cheap or popular with viewers.

Eutelsat in Paris feels "quietly confident" that it has legal priority. Eutelsat registered its frequency claim with the International Frequency Regulation Board in Geneva (part of the ITU) for 80 or 85cm dishes, ahead of Astra's claim for the same frequencies with 60cm dishes.

Eutelsat could thus, in the unlikely event of it becoming necessary, claim priority rights and force Astra to stop transmitting on the affected frequencies. But Astra's viewers who suffer interference will only be able to complain if they are using 80 or 85cm dishes - which no-one will be because this size exceeds the 70cm maximum now specified by the Department of the Environment.

Astra makes the valid point that its commercial success is largely due to the use of small dishes. It is out of the question to ask the four million people in Europe with small dishes to replace them with larger models.

Astra is very cagey about the channels at risk. "It depends on how Eutelsat deploys its traffic," says Koen van Driel, Astra's Commercial Director. "However British channels will almost certainly not be affected. Technical solutions exist to allow for an interference free environment with 55/60 cm dishes".

Eutelsat agrees that no-one will really know what the problems are until both satellites are in orbit and transmitting on the same frequencies. But Eutelsat says it expects a frequency clash on six of Astra 1B's transponders, with serious problems on only a couple.

But now high end Swiss hi-fi company Revox is selling the £289 ultra-compact Innova antenna. Its aperture is just 34cm and is the first domestic aerial to work on horn principles. The smaller the aperture of a satellite aerial, the wider its beam of acceptance will be. This holds good whether the aerial is a reflector dish, flat plate collector or horn aerial like the Innova.

Peter King of Innova expects interference risks on three transponders. And the subject is closer to Innova's heart than anyone else. The 34cm aperture brings a beam width of over 5° compared to 3° for the 60cm dishes recommended by SES. The wide beam brings a reduction in the strength of the signal reaching the LNB, and a greater risk of interference from Eutelsat II F3.

"The Innova does not meet the Astra specification", says King. "We make no bones about it and have had many discussions with SES at Betzdorf. We cannot change the laws of physics. But neither do a lot of dishes. SES is in a difficult position here. Market research shows that the public wants smaller dishes. For the satellite market to explode we must have smaller dishes. And obviously SES would like to see the market explode.

"Using smaller dishes means there is a risk of interference but it can be avoided if Astra and Eutelsat negotiate and choose their frequencies carefully. And at worst there is a risk of interference on only three of Astra's 48 channels.

"With surplus capacity - and you only have to look at the unused channels on Astra 1B to know that there is surplus capacity - there is no need to use those three channels yet".

King does not know which channels are at risk, either. "Someone inside Astra must know" he says. "But of course they won't say. No-one would ever rent them if they knew, would they?"

SES can delay the crunch because it has not yet rented out all the available Astra channels and can thus steer broadcasters clear of those at risk. But when demand for channels exceeds supply, some of Astra's viewers will start seeing double pictures. This could happen if the European Commission pushes through its plan to force satellite broadcasters, such as BSkyB, to broadcast the same programmes simultaneously in both old pal and new mac systems. There will be no spare transponders on Astra and SES will be forced to allocate those at risk of interference.

**Barry Fox**

## 3-D chips use light, not wires

Researchers in Japan have proposed a means of using light to link multistorey memory cells. Mitsumasa Koyanagi working with a group at the Research Centre for Integrated Systems, Hiroshima University intends to stack memory chips on top of each other rather than putting the circuits alongside on large silicon die.

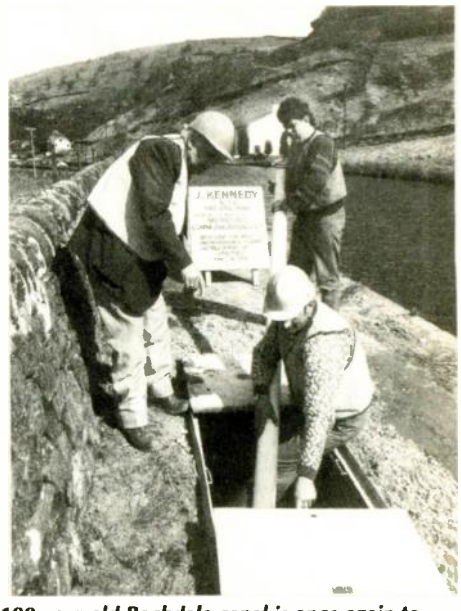
Each layer of the stack is a fully fabricated chip, separated top and bottom from the next device by a layer of quartz glass.

The vertical connections are made by laser diodes and photo detector cells integrated into the die. The backs of the wafers are polished to reduce the depth of the substrate down to 5μm so that the light from the laser can pass through to the next layer.

The polishing also creates a surface underneath the wafer which can be joined to the quartz glass deposited over the active parts of the device. The bottom of the wafer is held by vacuum chuck while the next layer is lined up by microscope.

At the moment, the group has produced test silicon but has not actually built the multilevel device. The final product should allow a block of 512 bits of data to be transferred in 16ns, an equivalent speed of 128Gbit/s.

**Rob Causey**



***190-year-old Rochdale canal is once again to become part of a national communication network. But this time telephone traffic rather than cargo barges will be carried. It was actually the ease of laying the cable under the towpath that attracted Mercury Communications to link Leeds and Manchester in this way. The only hazard was discarded shopping trolleys.***

# Single chip Nicam

Toshiba Semiconductor is now producing a single-chip Nicam system. The TB1204N/F is a bi-cmos device which integrates all the functions of Toshiba's earlier Nicam chip-sets to decode the UK's terrestrial Nicam 728 system.

The device demodulates a quadrant phase shift keyed signal into a 728Kbit/s pulse-code modulated data stream. The resultant signal contains sound information for left and right channels decompressed from 10 to 14-bit resolution. The chip then converts it into an analogue audio signal.

The demodulator features an automatic gain control circuit and uses phase synchronous demodulation by baseband PLL. All necessary filters are included.

The Nicam decoder stage performs frame synchronisation on the 728Kbit/s data stream, and de-interleaves it using 3.5Kbit of on-chip s-ram as temporary storage. The decoder then expands the resultant samples to full 14-bit resolution.

The resultant digital sound information is then processed by a two-times oversampling filter, before passing through a digital de-emphasis network .

This final digital signal is converted to an analogue audio signal by an on-chip sigma-delta D-to-A with a 182 times oversampling characteristic. ■

## Magnetometer cores

Cores for the Fluxgate magnetometer (EW+WW Sept 91) can be obtained directly from the author, Richard Noble. Please phone for details on 0873-890367.

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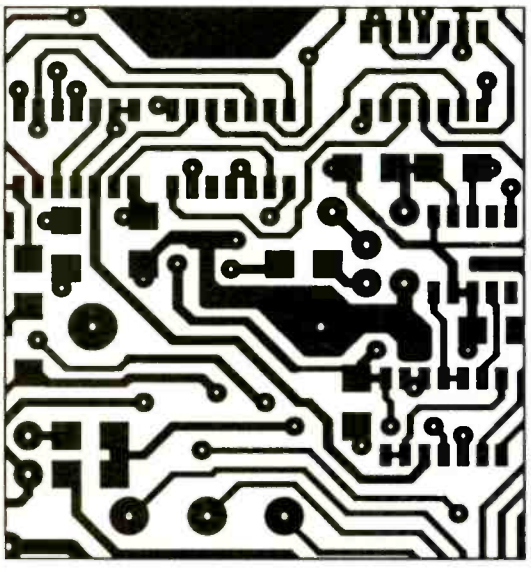

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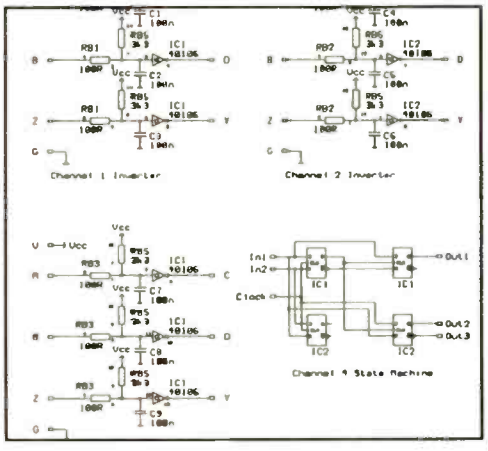

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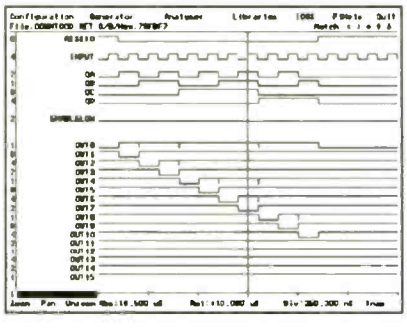

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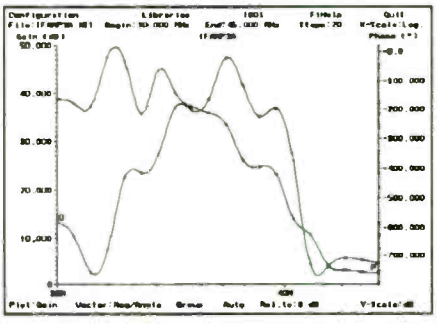

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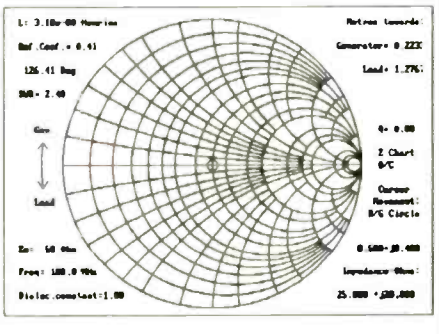

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# REGULARS

RESEARCH NOTES

## Harnessing H-bombs to heat the home?

No sooner has the cold fusion saga passed into history than another fusion prospect has emerged. But this time what is being seriously suggested by two physicists at the Lawrence Livermore National Laboratory is the idea of letting off a series of small H-bombs in an advanced underground cavern and collecting the energy released.

A proposal for (very) hot fusion power is not as crazy as it sounds. Writing in MIT Technology Review (July 1991), Abraham Szoke and Ralph W Moir describe in detail their proposal for PNE (peaceful nuclear explosives), an idea put forward originally in the early 1960s by Albert Latter, then of the Rand Corporation. What is new is that this latest scheme is fully engineered and takes into account the need to reprocess the fusion and fission products.

The reactor vessel is a steel-lined chamber in which small bombs of around one kiloton yield are let off about once every 20 minutes. At the top of the chamber is a sort of elaborate shower head which injects droplets of a molten salt just before each explosion. The liquid traps the energy which then boils water in a heat exchanger and produces steam to drive a turbine in the usual way. According to Szoke and Moir the system could easily produce 1000MW of electricity.

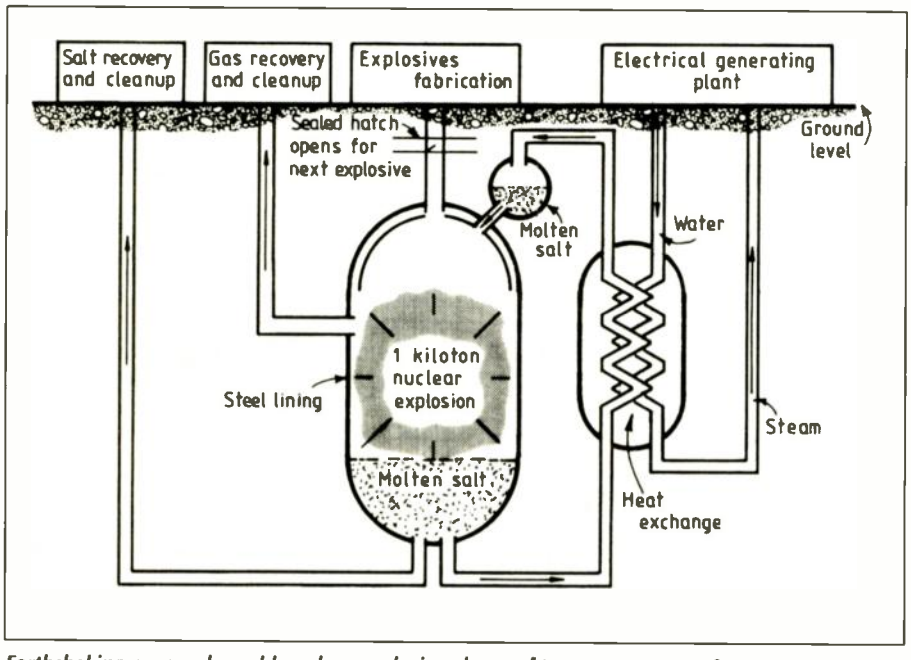
Calculations suggest that controlling the underground explosions would not be nearly as difficult or dangerous as it sounds: most of the explosive energy would be absorbed by the falling droplets. And if the worst did happen and the vessel were to burst, most of the radioactivity would be contained underground. What is more, because each bomblet is injected individually, there could be no thermal runaway of the sort that happened at Chernobyl or Three Mile Island. Szoke and Moir do not make extravagant claims for the safety of this arrangement but reckon that it would compare favourably with today's conventional nuclear power stations.The greatest danger derives from the fact that the reprocessing component of the plant has the inherent capability to manufacture weapons-grade plutonium. But this would be true of any fusion power station.

Szoke and Moir acknowledge that PNE sounds a crazy method of generating electricity. Compared, though, with every other known method it comes out well in the calculations.

Fission power is no safer, fossil fuels produce carbon dioxide while photovoltaic, wind and wave energy are unsuitable for base-load generation. The real question is whether the public would ever accept canned H-bombs.

Technically the idea is simple and requires no additional engineering know-how. All the component systems are well tried and tested; so much so that the writers claim it would be possible to have a prototype up and running within ten years.

Crazy it may be, but is it any crazier than driving to the office propelled by conventional explosions in cans?




*Earthshaking proposal: could nuclear explosions be used to generate power?*

## Planet casts doubt

The first reasonably hard evidence for a planet outside our solar system as widely reported at the end of July. But behind all the hype and the speculation about life in outer space lies a fascinating research project which began back in 1985 at Jodrell Bank.

It all concerns radio pulsars – rapidly rotating neutron stars that emit beams of radiation in the direction of their magnetic poles. Each time the star rotates and the beam crosses the line of sight to Earth, we receive a radio pulse. When the first pulsar was discovered, the regular pulse repetition rate was of course seized upon as evidence of alien intelligence! Some 500 of these pulsars are now known and the main interest lies in measuring the infinitesimally small changes in their periodicity, ie the rate of spin-down. The measurement gives radio-astronomers insight into the stellar dynamics and enables them to refine theories of how pulsars form in the aftermath of supernova explosions.

Of 40 pulsars currently being observed

# Imaging upset for IC

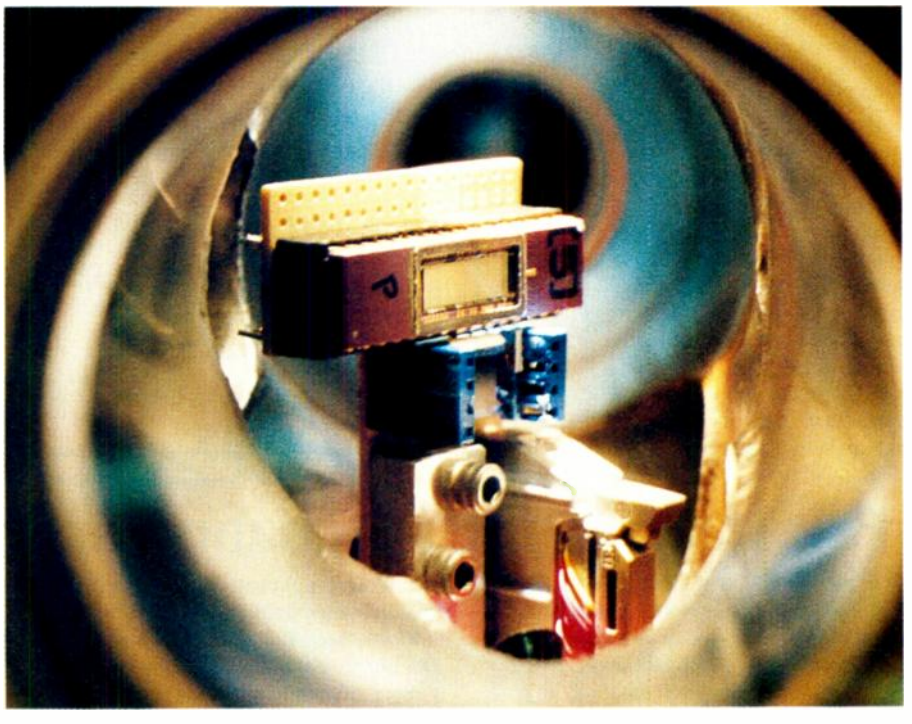
An imaging technique which will pinpoint weaknesses in integrated circuits caused by ionising radiation has been developed by researchers at Sandia National Laboratories. The technique, called single event upset (SEU) imaging, is so precise that it can isolate malfunctions in single transistor components.

Single event upsets are temporary but critical disruptions in an integrated circuit's memory cells; they result from a collision with high-energy cosmic rays. For example, single event upsets occurring in the Hubble space telescope are causing one of the focusing circuits to lose data on a regular basis.

As advances in fabrication technology bring more densely packed ICs and a reduction in size, the problem of radiation-induced failures has become more acute.

Sandia researchers have used ion microbeam techniques to study generation of radiation-induced upsets and have produced micron-resolution "maps" of where upsets occur. The maps are compared with the circuit designer's blueprint of the chip to pinpoint the upset location.

Aim of the technique is to diagnose weaknesses in high-performance integrated circuits so they can be redesigned for greater radiation hardness.



***SEU imaging: ion microbeam enters the target chamber (from right) and focuses on an IC mounted in the chamber to produce a "susceptibility" map.***

Until now, traditional whole-chip radiation testing has been used to identify malfunctioning circuit elements, requiring measured values and complex calculations. But, unlike with SEU-imaging, locations of the upsets cannot be precisely determined or actually imaged.

When an energetic ion strikes and penetrates the silicon of an integrated circuit, it leaves a wake of dislodged, excited electrons as well as the holes that they previously occupied. These electrons can group together and create a collection of charge. If this persists for a sufficient length of time it can induce the memory cell to change its stored logic state.

Only certain circuit components or regions within components are susceptible to upset. But because the microbeam can individually irradiate a single memory cell, transistor or transistor component (such as drains or gates), SEU-imaging can be used to image upset-prone microscopic regions.

The ion beam is scanned across the circuit's surface and can give rise to two signals: emission of electrons from the target (when the ion strikes the surface) and generation of a malfunction, or upset in the target circuit's operation (as the ion penetrates the chip).

One-micron resolution of the technique means it may have application in other radiation-hardness characterisations carried out at chip level.

For example, measurement of total dose effects – the cumulative effect of ionising radiation – to a single memory cell can be achieved using SEU-imaging.

It could also be used to verify software codes used to simulate radiation upset processes.

# on universal theory

at Jodrell Bank between frequencies of 1400 and 1600MHz, one code-named PSR 1829-10 aroused particular interest. Discovered in 1985 its behaviour is markedly different from the others.

Instead of spinning at a steadily changing rate, PSR 1829—10 slows down and speeds up with a period of six months. This regular disturbance, according to the Jodrell team (Nature, Vol 32 no 6333) can only be consequence of the gravitational effect of a planet with about 12 times the mass of the Earth.

This evidence for a planet in orbit around the pulsar is obviously indirect because there is no optical method of detecting it. (Ordinary telescopes can not produce anything more than a point image of even the nearest star). But what is really intriguing is how a pulsar could possibly-ever acquire a planet.

Either the planet somehow survived the cataclysmic heat of the supernova which (on present theory) produced the pulsar, or else PSR 1829-10 evolved in some way as yet unknown.

# Earth free antenna gives good response

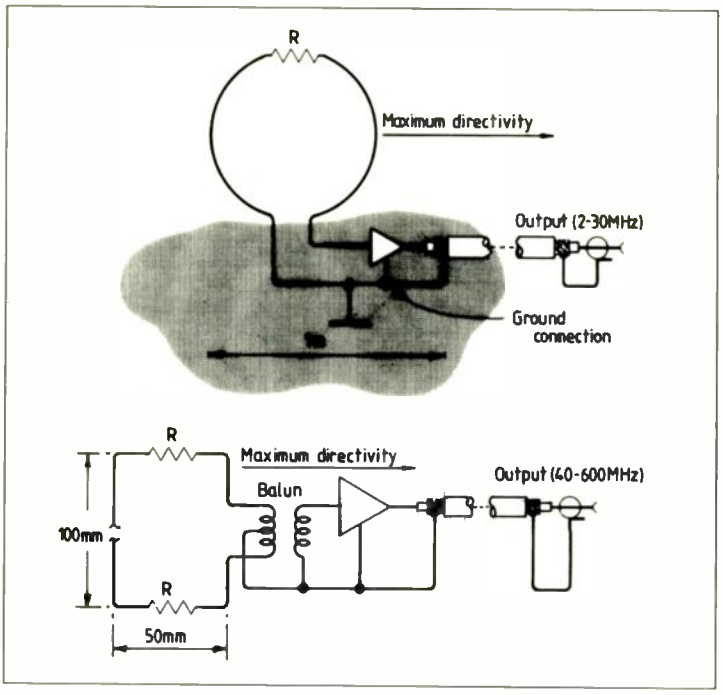
Directional HF loop antennas have been around for a long time and can be configured in omni-directional, bi-directional or cardioid radiation patterns. Adjusting the value of R (see over) gives a good broadband cardioid response, but only if the earth connection is good. Otherwise the antenna tends to have a figure-of-eight response regardless .

But P V Brennan and Y Valverde of the

Department of Electronic and Electrical Engineering at University College London describe (Electronics Letters, Vol 27 no 1) a new balanced version of the antenna which needs no earth at all.

The mirror-imaged design (Fig. 2) was arrived at by reflecting the antenna in the ground-plane and feeding the balanced output via a 180° hybrid into an MMIC amplifier.

As can be judged from the dimensions and components, the experimental model was a scaled down version operating at VHF and UHF frequencies – partly for ease of construction and partly to get the whole test apparatus into a small anechoic chamber.




Over the range 150-600MHz the antenna maintains a good cardioid radiation pattern without any earth, either real or capacitive. Front-to-back ratio is 17dB at 200MHz and the response drops to a perfect theoretical -6dB at 90° to the direction of fire.

Brennan and Valverde say that even without any optimisation, a front-to-back ratio of 10dB is maintained across the whole 4:1 frequency range. They add that if the value of R is trimmed or replaced with a reactive network, it should be possible to achieve a stable pattern, regardless of frequency.

# Fair hearing for six channel ear

**The world s most realistic and effective artificial ear could be the result of collaborative research at a number of institutes in Massachusetts and North Carolina. The cochlear implant, to give it its proper name, has been designed to give a useful degree of hearing to people who are profoundly deaf, usually as a result of damage or disease to those natural transducers, the hair-cells of the cochlea.**

**In practice the ear functions as a compressor, a limiter and a multi-channel filter feeding a nerve bundle comprising 30,000 individual parallel fibres.**

**According to Blake S Wilson, principal author of the latest research (Nature, Vol 352 no 6332), the history of electrical stimulation of auditory nerves goes back to the 18th century when Alessandro Volta (of voltaic pile fame) connected one of his high-voltage batteries to each ear. Volta apparently heard gurgling noises before being knocked to the floor!**

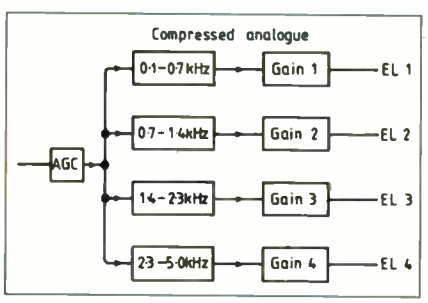



*Fig. 1. Crosstalk is a problem with a compressed analogue approach.*

**More recently the approach has been the more subtle one of taking a signal from a microphone, compressing it, feeding it through four band-pass filters and applying it via surgically-inserted electrodes to the basilar membrane in the cochlea (Fig. 1).**

**Although six channels can only connect to a few of the 30,000 parallel nerve fibres, the results have been surprisingly good in practice. Patients vary markedly in how successfully their brains adapt to this wholly different input, but given help from lip reading, they scan sometimes make good sense of what they hear.**

**One big problem, inherent in the system, that Blake Wilson and his team have had to overcome is crosstalk between channels.**

**Although present systems still use only six channels compared to the 30,000 in nature, there is nevertheless a strong tendency for the electric fields at the electrodes to interact and make the system behave as if there were fewer channels still.**

**What Wilson's team has done is to develop a system in which the processed multi-channel audio is chopped up into trains of fast interleaved pulses, none of which coincide (Fig. 2).**

**This continuous interleaved sampling (CIS) ensures that no two electrodes are simultaneously stimulated. The result is virtual elimination of crosstalk.**

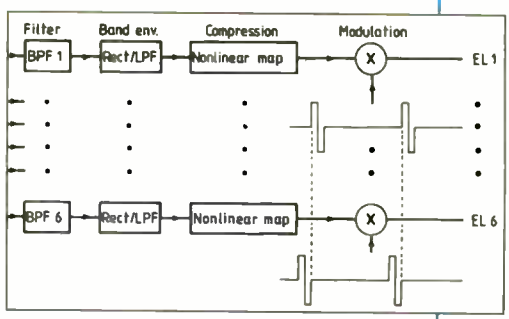
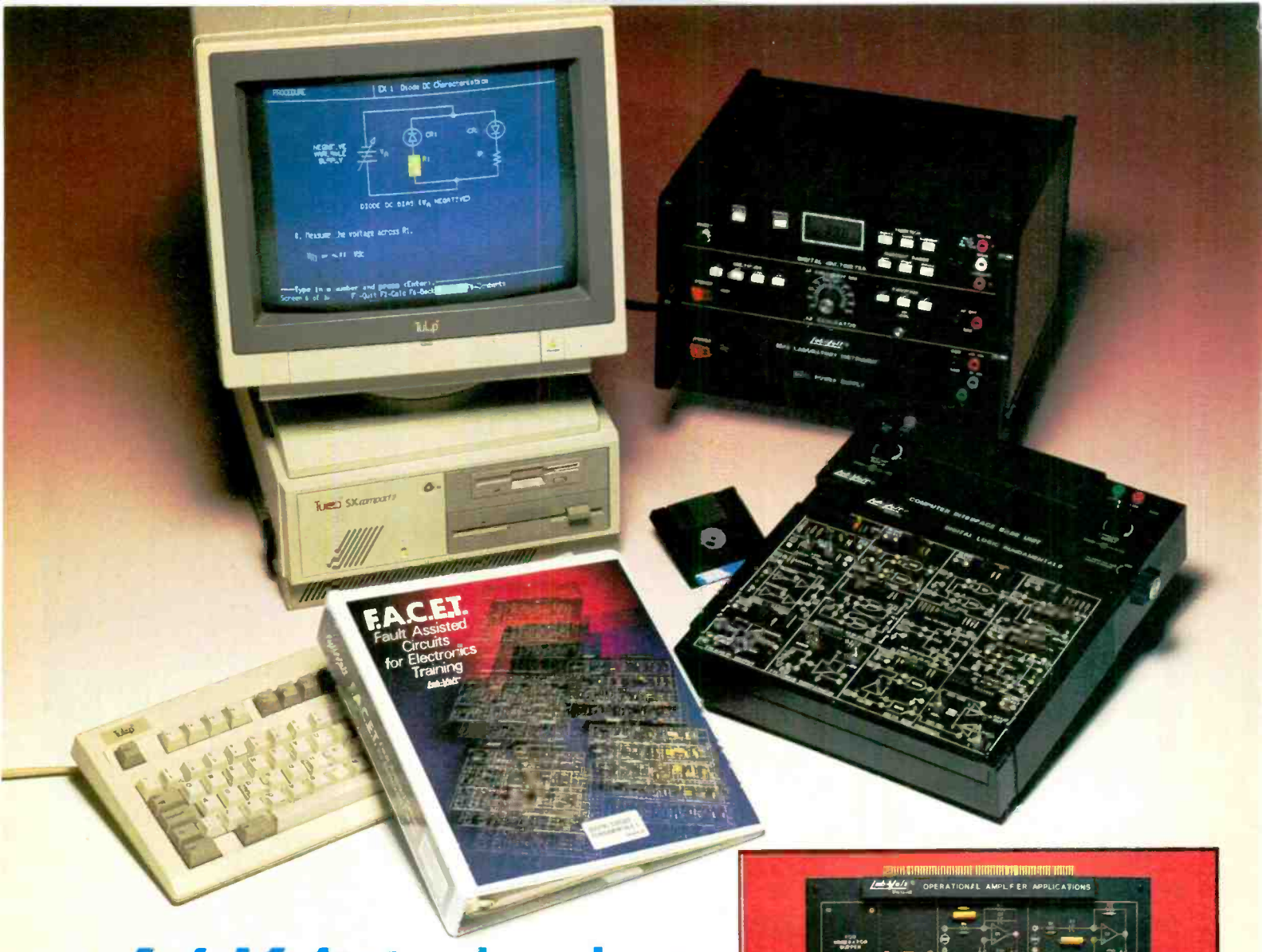



*Fig. 2. Continuous interleaved sampling ensures that no two electrodes are simultaneously stimulated, eliminating crosstalk.*

**As for the patients fitted with the new system, Wilson says: "All the subjects we have studied, lost their hearing relatively late in life, so they have a good recollection of what speech sounded like with normal hearing. However, all of them have told us that the new strategy provides a highly intelligible representation of speech. It is nearly normal, but not completely normal".**

**Some subjects have reported that it sounds a little thin compared with what they remember with normal hearing. Nevertheless they have found speech to be intelligible without the adjunct of lip reading – a remarkable feat in view of the limited number of electrodes and the crudeness of the representation even with the new strategy.**

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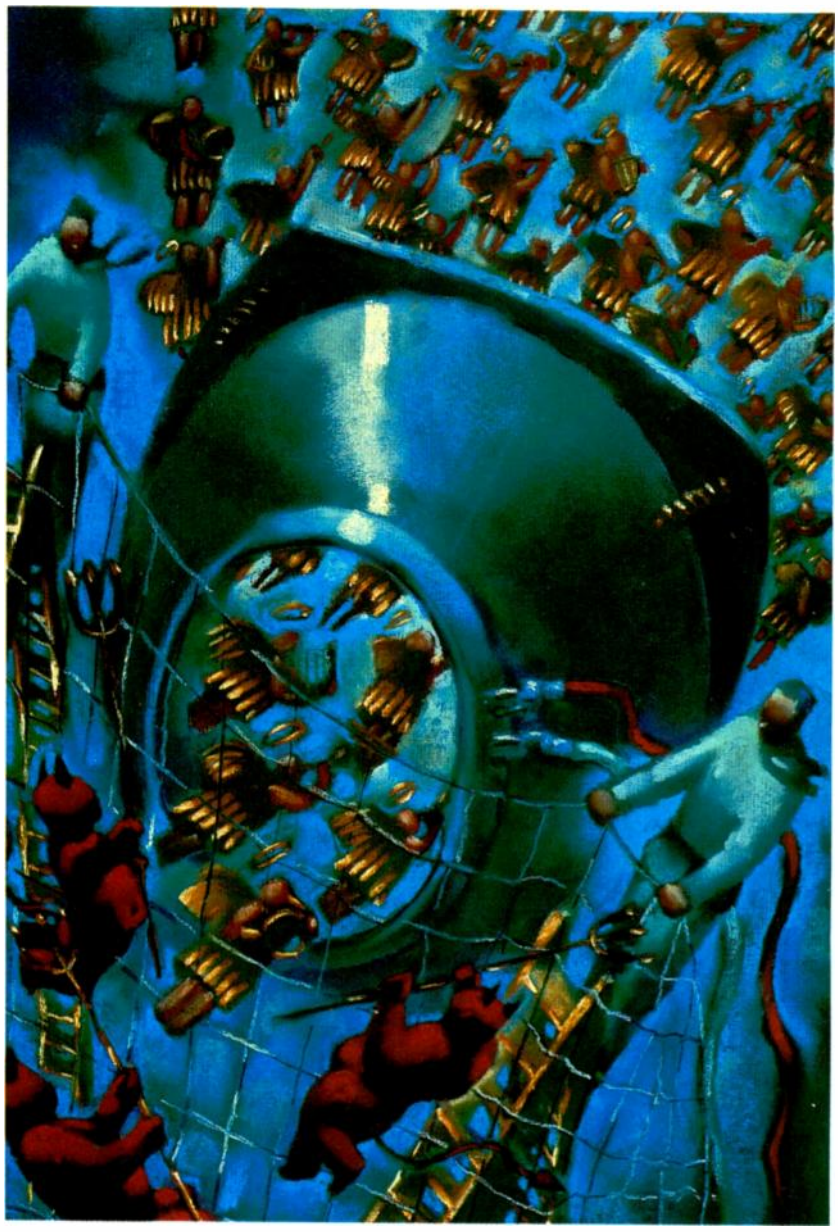

# ACTIVE FILTERS

***A choice of useful active filter systems is available to the linear circuit engineer but circuit details are not easily found, even in comprehensive text books. Here John Linsley Hood surveys the most useful layouts in this field.***

Often in linear electronic circuit design enhancement, or diminution, of one part of the frequency spectrum is required in relation to another. For example, in replay systems for gramophone records, it may be preferable to lessen some of the very low frequency rumble type noises which can occur due to worn turntable bearings, usually on replay but sometimes even when the disc itself was cut.

Or perhaps it becomes desirable to remove the annoying high pitched whistle, so prevalent on the reception of signals in the short-wave bands, due to the 8kHz spacing of adjacent transmitter carrier frequencies. In both cases, other parts of the frequency pass-band should pass through the circuit with little or no attenuation.

Such circuit systems are usually classed as filters, and may carry additional descriptive labels, such as lowpass, highpass, bandpass, notch, or frequency selective, depending on type of function.

A convenient distinction can also be drawn between passive circuits – those built up from resistors, capacitors and inductors, on their own – and active circuits, where some amplifying or impedance converting device is included, usually to improve performance.

The simplest and most primitive form of filter for this kind of application is a simple *RC* or *LR* network (**Fig. 1**) in which the turnover frequency, $f_t$, at which the gain will have fallen by -3dB, will be defined by the equation:

$f_t = 1/(2\pi CR)$ or $f_t = R/(2\pi L)$

This type of passive filter is simple and cheap, but its out-of-band attenuation rate is not very high (**Fig. 2**) so that if, for example, the aim was to reduce an 8kHz whistle to 1/20th of its original level, (-26dB), it would be necessary to start rolling off the HF response of the system some 4.3 octaves below 8kHz, (i.e., 406Hz).

Putting two such *RC* or *LR* filter networks in series (Figs. 1b, 1d) will increase the attenuation slope to -12dB/octave, as shown in the dashed line in Fig. 2, but the output will then be -6dB down at $f_t$.

Taking the same example as before, reducing an 8kHz whistle to 1/20th of its original size will now take some 2.2 octaves, which means that it would be necessary to accept an initial -6dB point at 1.78KHz. Still not very good, but a step in the right direction.

What is needed is a way of contriving a ruler flat frequency response right up to some point at which the system transmission starts to fall. This can not be done with Rs and Cs on their own, but combining an RC and an LR type of circuit allows an improvement to be made.

On its own, the circuit of **Fig. 3a**, - because there are now two "reactive" components, (one L, one C) - will give a -12dB/octave slope, with an $f_t$ of 1kHz. It also shows a small (about 1dB) peak in its response curve just before the transmission begins to fall off, as shown in **Fig. 4a**,

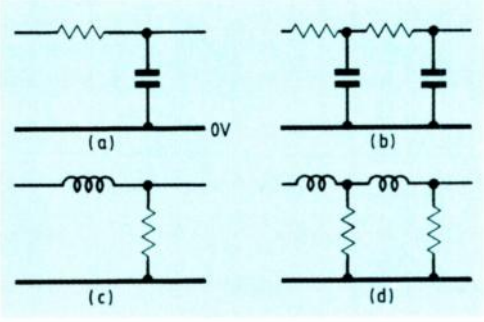


*Fig. 1. Simple first and second order lowpass LR and RC passive filters.*

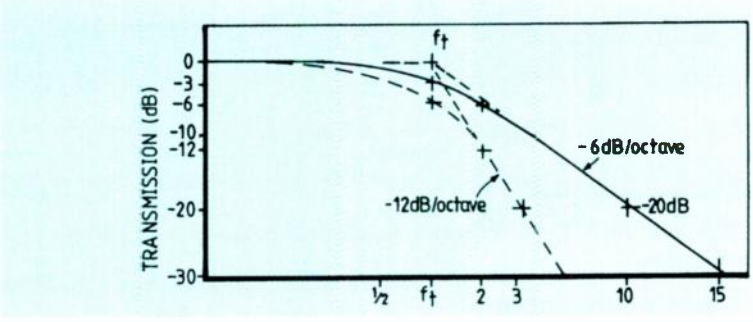


*Fig. 2. Characteristic attenuation slopes of simple RC and LR filters.*

because of the slightly under-damped series resonance of $L_1$ and $C_1$ acting as a tuned circuit.

If this damping is reduced a little more, say by increasing $R_1$ to 14k, (/2x10k), the hump can be increased to +3dB (**Fig. 4b**). Since a straight CR network will give a -3dB point at $f_t$, by putting these two circuits in series (**Fig. 3b**), it is possible to get rid of the hump in the LRC response curve, as well as adding another -6dB/octave to the attenuation rate of the filter.

The approach does work, as shown by the frequency response curve of **Fig. 4c**, which indicates a -18dB/octave, (-60dB/decade), attenuation slope. But the impedance of the second half of the circuit should be made a good bit higher than the first, to make sure that it does not affect performance of the first part of the circuit. shows. This takes us nearer to the ideal type of filter characteristic (**Fig. 4c**), but at the expense of introducing a certain amount of "ripple" in the frequency response, just below the turn-over point.

Returning to the earlier example, such a filter could reduce the amplitude of an 8kHz whistle by a factor of 20x while still retaining a flat response to 2.7KHz, or one which was -6dB down at 3.4KHz.

Still not perhaps the best, but certainly in the right direction.

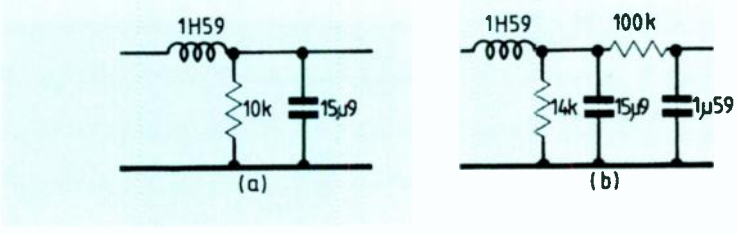


*Fig. 3. Second order and third order LCR filters.*

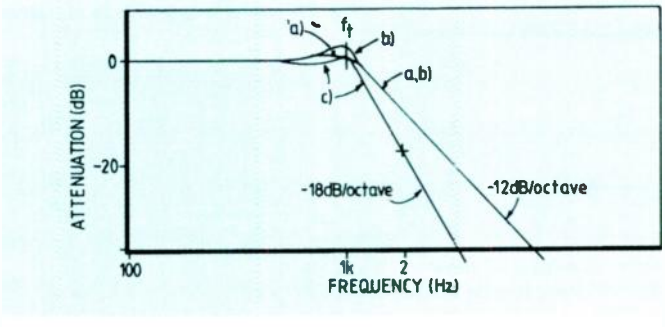


*Fig. 4. Possible frequency response curves from 2nd and 3rd order LCR filters.*

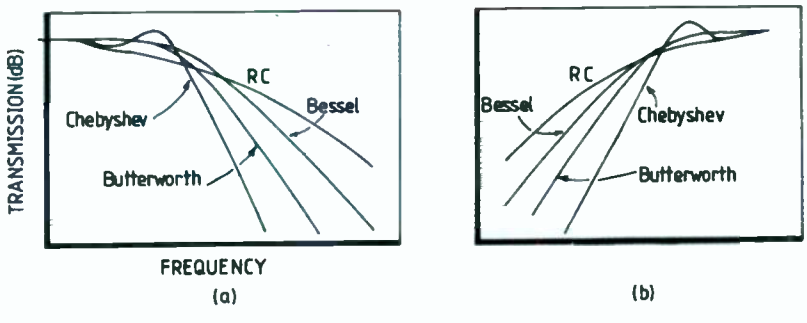


*Fig. 5. General classification of filter types.*

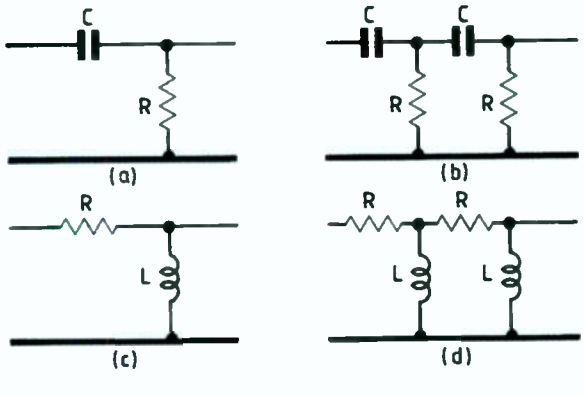


*Fig. 6. Circuit rearrangements to give highpass CR and RL filters.*

### Filter response types

The most widely used classifications of filter characteristics are Chebyshev, Butterworth and Bessel.

Chebyshev covers filter types where design has been chosen to give maximum attenuation rate possible for that circuit, even though this leaves some unevenness in the transmission characteristics at a part of the response; ideally, it should be ruler flat. With this type of filter, it is customary to specify the amount of ripple as "±dB".

The second class of filter is the Butterworth, which broadly refers to those filter types designed to give maximum flatness in the pass-band, even if this means accepting a somewhat lower attenuation rate beyond this point.

The third broad class of filter is the Bessel, where the phase shift alters linearly as a function of frequency, leading to a nearly constant circuit time delay, and minimis-

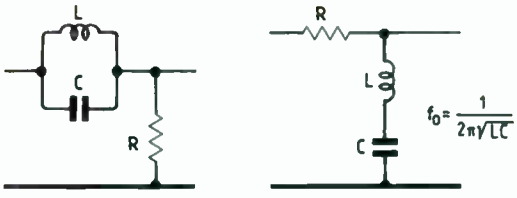


*Fig. 7. LCR type notch filters.*

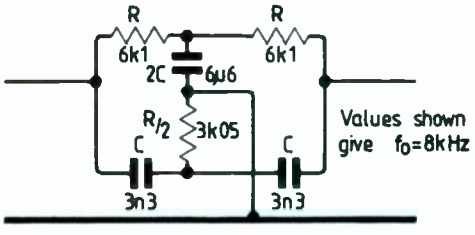


*Fig. 8. The parallel-T notch filter.*

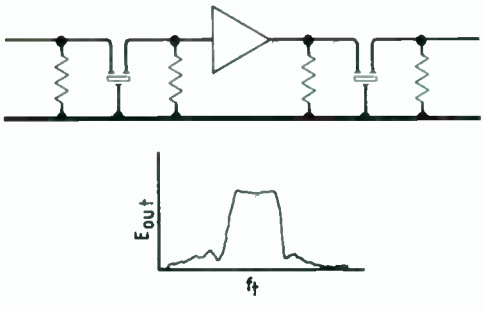


***Fig. 10. Typical modern bandpass RF filter design for VHF FM or TV using IC gain blocks and ceramic ladder filters.***

ing distortion of step-function type waveforms.

I have shown the type of transmission responses for these three filter characteristics, along with that for a simple *RC* arrangement, in **Fig. 5a**. It will be apparent that all of the lowpass filter types which I have, so far, described can be changed into highpass types, giving the kinds of transmission response shown in **Fig. 5b**, simply by interchanging the positions of resistors and capacitors, as I have shown in **Figs. 6a - 6d**.

## Notch filters

Returning again to the problem of the 8kHz whistle in short-wave broadcast reception, another useful possibility is to use a "notch" filter, tuned to cut out the offending signal, on its own.

The *LCR* arrangement shown in **Fig. 7** would work, using either a parallel resonant circuit in series with the signal path, or a series resonant circuit across it. But these would need largish values of inductance, with very good Q characteristics, (low resonant energy losses) – both difficult and expensive. A much more attractive layout is the "Parallel T" (sometimes also called the "Twin T") circuit shown in **Fig. 8**.

Provided that the component values are accurate, this will give a high degree of rejection of an unwanted signal at a frequency given by: $f_0=1/(2\pi RC)$, requiring the component values shown in Fig. 8 for a notch at 8kHz. This would give a -6dB response at 4kHz; but there are ways to sharpen up the notch (see "active systems").

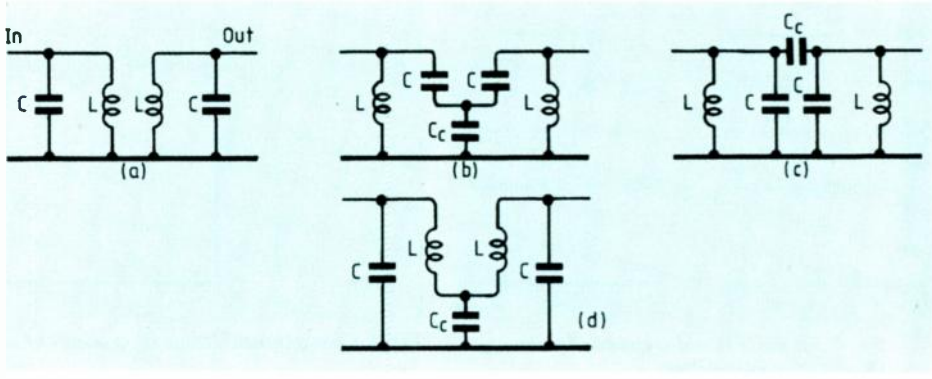


*Fig. 9. Some of the possible forms of RF LC bandpass filters.*

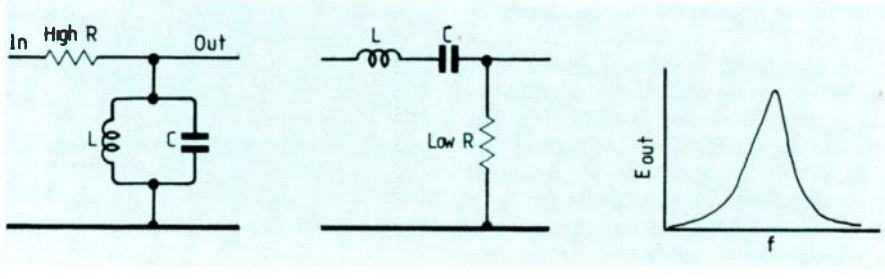


*Fig. 11. Tuned response type LC filters.*

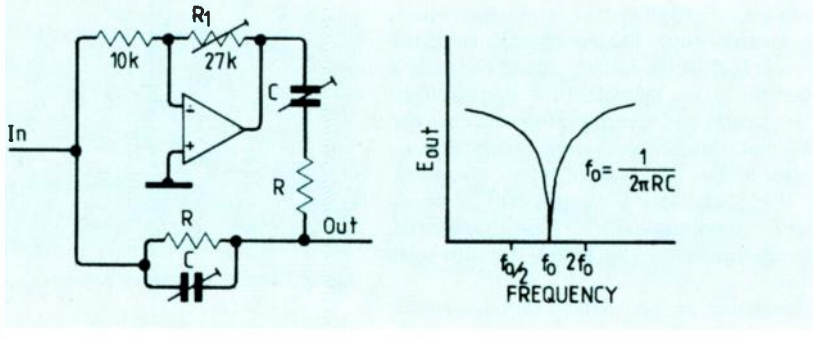


*Fig. 12. Wien bridge notch filter and its frequency response.*

## Bandpass filters and tuned response

Best known of the bandpass filters are those which used to be built up from a pair of coupled tuned circuits, (**Figs. 9a-9d**), and used in the IF stages of old-fashioned radio receivers - nowadays they either don't bother, or use ceramic ladder resonators instead, for example the circuit of **Fig. 10**.

I suppose such a bandpass system could be made with large inductors – for use in lower frequency applications – but I have never seen it done.

Just connecting a pair of RC highpass and lowpass filters in series would work, but not very well, so this kind of filter is mainly made up with active circuit systems.

Tuned response circuits can also be made with Ls and Cs, as in **Fig. 11**, but this type of layout would mainly only be worthwhile at RF.

## Active systems

Putting an amplifier or impedance conversion stage – and, for convenience, I have drawn all of these circuits with op amps – allows an enormous increase in scope in circuit design. For example, a quite useful notch filter can be made with an inverting 2x gain amplifier, coupled to a Wien network (**Fig. 12**.)

With a high impedance op amp output buffer, the variable capacitors can be air-spaced twin-gang capacitors, allowing the notch to be infinitely and delicately tunable. However, since it is unlikely that all other component values will be absolutely spot-on, it is sensible to make the gain of the amplifier somewhat adjustable, by $RV_1$, to allow the notch to be tweaked for maximum depth.

It is in L-P and H-P filters, though, that active systems really come into their own, since it is so easily possible to organise systems which will have a really flat frequency

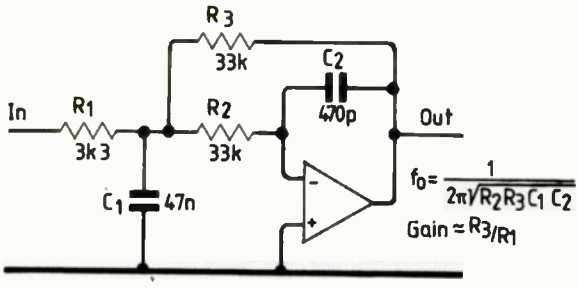


*Fig. 13. Simple lowpass filter based on active integrator and overall loop negative feedback.*

response right up to the point at which the gain starts to fall, and these can then be put in cascade to give as fast a fall-off in response as the designer needs.

The simplest of these is just an active integrator (an op amp with a capacitor between output and inverting input) with negative feedback applied overall, and an additional HF roll-off capacitor, $C_1$, connected to the 0V rail from the junction of $R_1$ and $R_2$ (**Fig. 13**).

This gives a flat, Butterworth style fre-

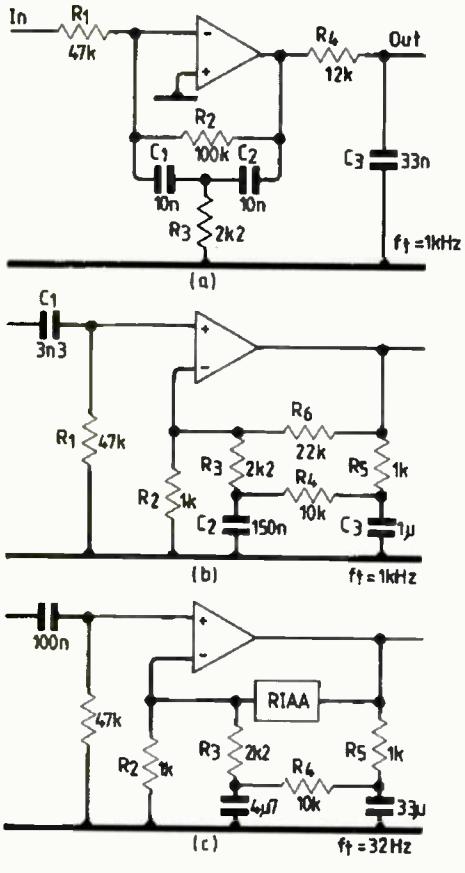


*Fig. 14. Lowpass (a) and highpass (b) arrangements of "bridged T" filter.*

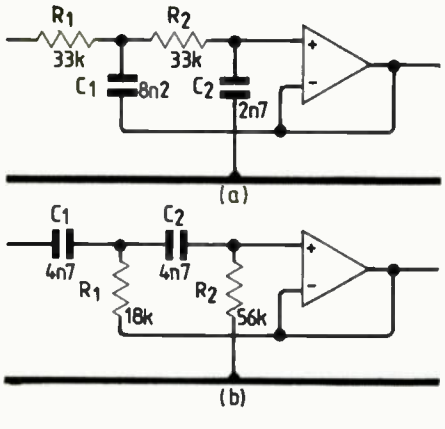


*Fig. 15. Lowpass (a) and highpass (b) Sallen and key filters.*

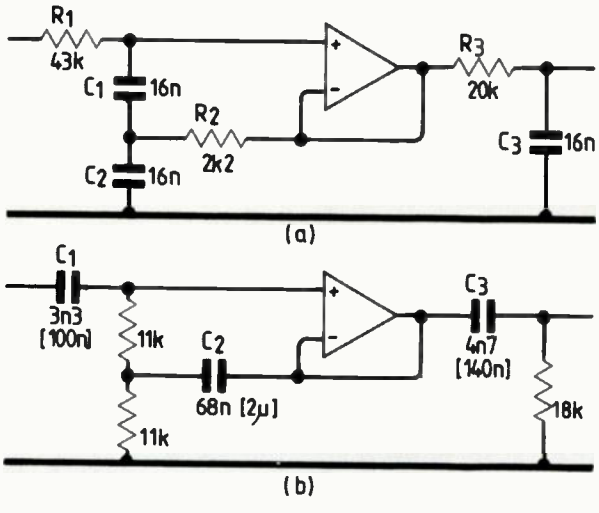


*Fig. 16. Lowpass (a) and highpass (b) Bootstrap filters.*

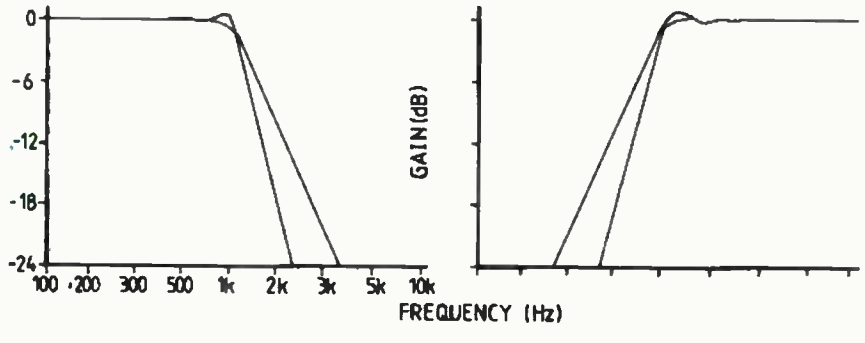


*Fig. 17. Calculated frequency responses of circuits of Figs. 15 and 16.*

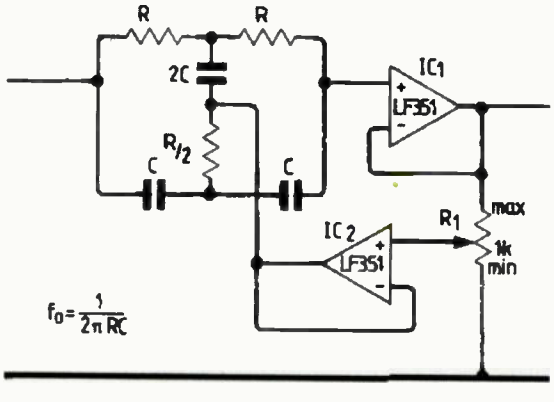


*Fig. 18. Bootstrapped parallel T notch filter.*

quency response up to $f_t$ and a -12dB slope beyond this. It can also give a gain determined by the ratio of $R_2/R_1$.

I have shown this circuit, and all of the others, with component values chosen to give an $f_t$ of 1kHz, and have indicated on the diagrams the formulae by which different values of turn-over frequency, (or notch frequency, etc.) can be calculated.

The lazy option is just to alter frequencies by multiplying or dividing the values of one or other of the effective components - those shown in the formulae - by the amount necessary to shift the frequency from 1kHz to whatever other frequency is required.

Another useful family of filters, also giving some stage gain, is the type generally described as a "bridged T". I have shown circuits for low-pass and high-pass versions in **Fig. 14**. These are usually designed as Chebyshev type third-order filters, where the basic filter gives a hump in the frequency response, at $f_t$, and an RC network is then used to remove this, as well as give an additional -6dB/octave to the attenuation slope.

The high-pass version of **Fig. 14b**, was commonly used as a rumble filter circuit on gramophone record replay pre-amp inputs, because the RIAA frequency response correction network could be connected across it (**Fig. 14c**).

Nowadays designers usually prefer to make all filters capable of being switched out of circuit, so separate unity gain "Sallen and Key", or "Bootstrap" filter layouts would be chosen.

The Sallen and Key layout is widely used, since it can be organised around any convenient unity stage gain block. Even an ordinary emitter- or source-follower will do, and gives highpass and lowpass filters with a Butterworth style -12dB/octave frequency response. I have shown typical H-P and L-P versions in **Figs. 15a** and **15b**.

The Bootstrap layout, (which I invented myself, or, more strictly, explored as a possible circuit transposition of a "bridged T" filter, and then analysed and developed), is similar in its gain-block requirements. But it is basically a third-order design, which can give a Chebyshev type -20dB/octave slope, with a ripple within ±1dB, for a Q value of 2. Altering the chosen Q will change the steepness of the cut-off and the amount of residual ripple. A pair of H-P and L-P designs is shown in **Figs. 16a** and **16b**.

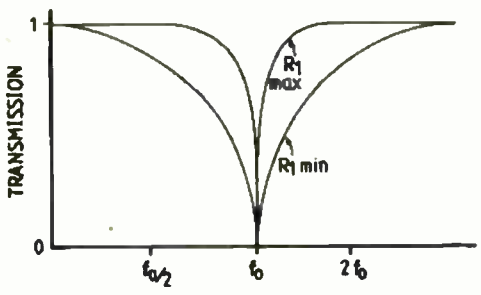


*Fig. 19. Effect of setting of $RV_1$ on frequency response.*

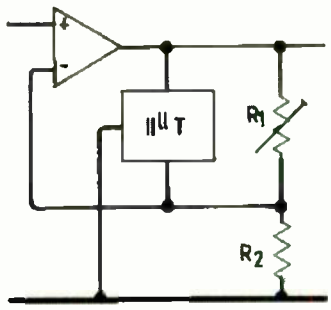


*Fig. 20. Tuned response type filter based on parallel T.*

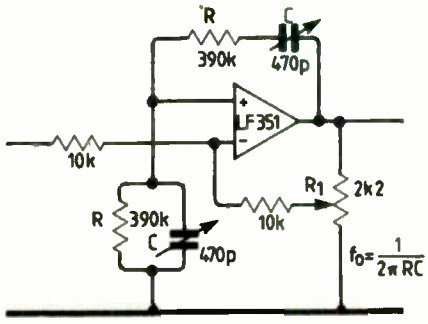


*Fig. 21. Tuned response system based on Wien Bridge.*

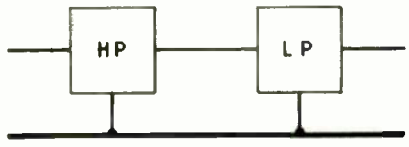


*Fig. 22. Option for a frequency selective filter.*

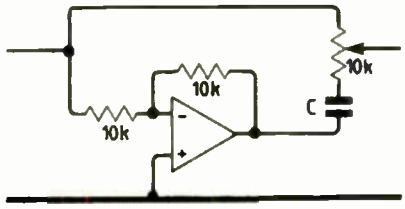


*Fig. 23. The allpass filter*

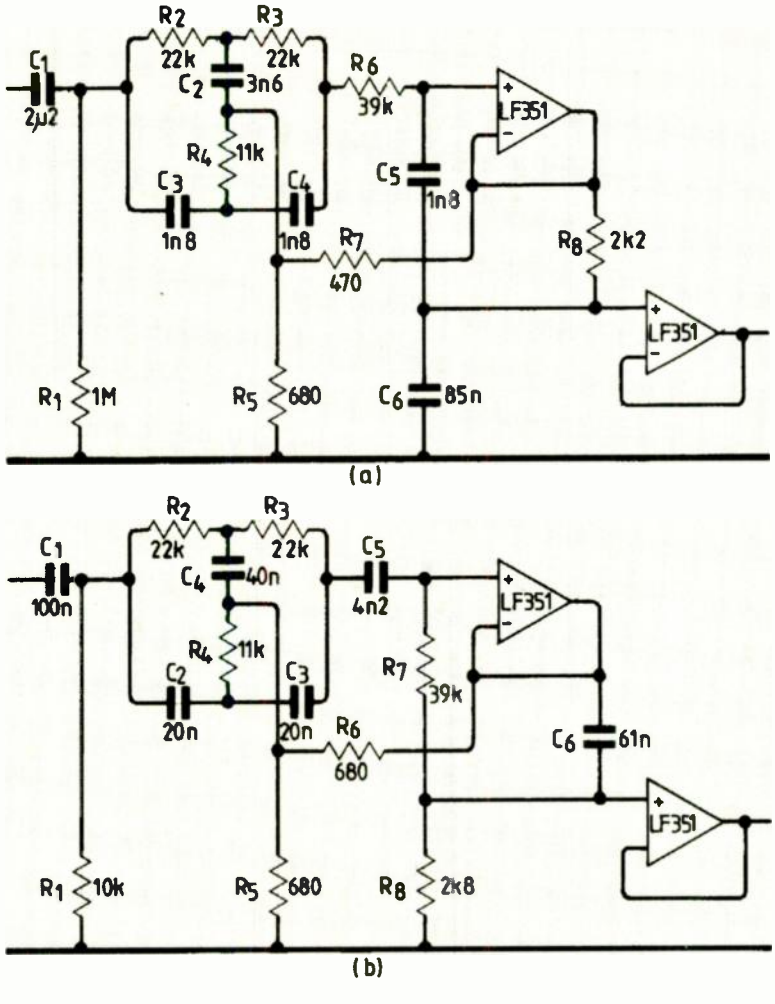


*Fig. 24a. A very steep cut lowpass filter based on the combination of a Bootstrap filter and a paralleled T Fig. 24b Highpass version of Fig. 24a.*

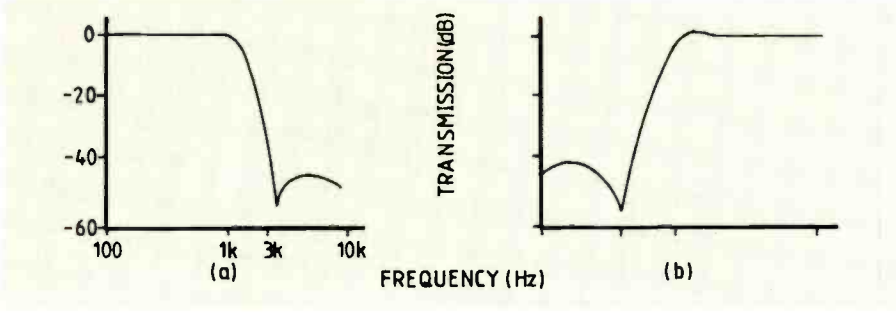


*Fig. 25. Frequency response of filter circuits of Figs. 24a-b*

Component values for a 30Hz H-P type audio amp rumble filter are quoted in the square brackets.

Some calculated frequency response curves for Sallen and Key, and Bootstrap filter designs are shown in **Fig. 17**.

As mentioned above, an impedance conversion block can also be used to sharpen up the notch of a Parallel T filter, by applying "bootstrap" type feedback around the loop. A circuit for this purpose is shown in **Fig. 18**, in which the steepness of the notch is adjustable by the setting of $RV_1$. Types of frequency response available are shown in **Fig. 19**.

Tuned response filters, giving a sharp peak in output at some chosen frequency, can also be made by putting a Parallel T filter in the feedback path of an amplifier (**Fig. 20**). In this case it is necessary to have a bridging resistor to prevent continuous oscillation, and the sharpness of the peak can be controlled by varying this - in this example by adjusting $RV_1$.

The Wien bridge circuit will also give a tuned response circuit (**Fig. 21**) and since its performance will only be limited by performance of the gain block, there isn't any particular reason why this type of circuit could not be used at radio frequencies, to give a "coil-less" radio tuner!

Once again, the sharpness of the peak, up to the point of continuous oscillation, is controlled by the value of *RV1*.

An alternative, and slightly more docile, form of frequency selective filter is given by putting an H-P and an L-P active filter in series (**Fig. 22**) as if to make an active band-pass filter, but with the values of $f_c$ chosen to coincide.

If two high Q Bootstrap designs are cascaded like this, a very decent stable response peak, with steep out-of-band skirts can be obtained.

The "All-pass" design of **Fig. 23** is not really within the class of filters, since it doesn't alter the gain but allows adjustment of the phase of the transmitted signal. Since all filters introduce phase shifts, of one frequency relative to another, this can be a useful tool for subsequent relative phase angle correction.

The final type of circuit is the combination of a standard H-P or L-P filter with a notch design. If the notch is chosen to lie at a suitable point above or below the turn-over frequency, depending on whether it is an L-P or H-P design, some quite impressive attenuation rates are possible.

A pair of Bootstrap + T filter circuits is shown in **Fig. 24**, with frequency responses indicated in **Fig. 25**. This type of frequency response is sometimes called a Cauer characteristic, a term which is used to describe a system in which the extent of attenuation in the stop band has also been exchanged for steepness of cut-off beyond the turn-over point ■

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**MAINS 230V FAN** best make "PAPST" 4½" square, metal blades £8.00.

**SOLAR CHARGER** holds 4 AA nicads and recharges these in 8 hrs., in very neat plastic case £6.00.

**SOLAR CELLS** with terminals for joining in series for higher volts or parallel for extra current. 100mA £1, 400mA £2, 700mA £2.75, 1A £3.50.

**SOLAR MOTORS** 1½-9V precision made to operate from low current off solar cells £1.50, solar generator to drive this £7.00, has provision for battery back up when sun is not shining!

**AIR SPACED TRIMMER CAPS** 2–20 pf ideal for precision tuning uhf circuits 25p each, 10 for £2. 100 for £15.

**1Khz. TONE GENERATOR** this is PP3 battery operated and has a 1Khz output that can be continuous or interrupted at a rate variable by a panel mounted control. Constructed on a pcb and front panel size approx 105× 50mm ex equipment but in as new condition £2 each.

**MAINS ISOLATION TRANSFORMER** stops you getting "to earth" shocks. 230V in and 230V out. 150 watt upright mounting £7.50.

**MINI MONO AMP** on pcb size 4" × 2" with front panel holding volume control and with spare hole for switch or tone control, output is 4 watt into 4 ohm speaker using 12V or 1 watt into 8 ohm using 9V. Brand new and perfect only £1 each or 12 for £10.

**5 RPM 60W MAINS DRIVEN MOTOR AND GEARBOX** this has a 3in square mounting plate and is 4in deep. It is a shaded pole motor. Price £5.

**POWER SUPPLY UNITS** mains in, dc out, based 4.5v 100mA regulated £1, 6v 200mA regulated £1, 6v 700mA £1, 9v 500mA £2, 12v 500mA £2, 12v 2A£5, 24v 200mA £2.

**TORROIDAL MAINS TRANSFORMER** with twin outputs, 6.3v 2 amps and 12v 1 amp, one use would be power supply, price £5.

**AMSTRAD POWER UNIT** 13.5v at 1.9A encased and with leads and output plug, normal mains input £5 each, 10 for £45.

**AMSTRAD 3.5 FLOPPY DRIVE** Reference FD9 brand new and perfect, £45.

**ATARI 64XE COMPUTER** at 65K this is quite powerful so suitable for home or business, unused and in perfect order but less PSU, only £19.50, Handbook £5 extra.

**9" CATHODE RAY TUBE** Philips M24/306W, which is not only high resolution but is also X Ray and implosion protected, regular price over £30, you can have them at £12 each and you will receive the deflection coils as well tubes are guaranteed unused.

**80 Watt MAINS TRANSFORMERS** two available in good quality, both with normal primaries and upright mounting, one is 20V 4A the other 40V 2A only £3 each or 10 for £27 carriage paid.

**PROJECT BOX** size approx 8" × 4" × 4½" metal, sprayed grey, louvred ends for ventilation otherwise undrilled made for GPO so best quality, only £3 each or £10 for £27.

**12V SOLENOID** has good ½" pull or could push if modified, size approx 1½" long by 1" square, £1 each or 10 for £9.

**WATER VALVE** 230V operated with hose connections, ideal for auto plant spray or would control air or gas into tanks etc, £1 each or 10 for £9.

**HANG UP PHONE** won't clutter up your desk or workbench, current model, has push button dialling, last number recall, internal alarm etc., Ex B.T. in good condition and fully working ready to plug in. £5

**HIGH VOLTAGE CAPS** if you use these ask for our 1-30 Kv Capacitor list, we have over ¼ million in stock and might save you a lot of money.

**ELECTRONIC BUMP & GO SPACESHIP** sound and impact controlled responds to claps and shouts and reverses or diverts should it hit anything! Kit with really detailed instructions, will make ideal present for budding young electrician. Should be able to assemble but you may have to help with the soldering of the components on the PCB. Complete kit £8.95.

**500V BRIDGE MEGGER** developed for G.P.O. technicians the Ohmeter 18B is the modern equivalent of the bridge meggar. 9V battery operated it incorporates a 500V generation for insulation testing and a null balance bridge for very accurate resistance measurement. Ex B.T. in quite good condition with data & tested. Yours for a fraction of original cost £45+ £5 insured delivery.

**EXPERIMENTING WITH VALVES** don't spend a fortune on a mains transformer we can supply one with standard mains input and secs. of 250-0-250V at 75 mA and 6.3V at 3 A. price £5.

**15Watt 8ohm 8" SPEAKER & 3" TWEETER** made for a discontinued high quality music centre, give real hi-fi, and for only £4 pair.

**TIMES TEN IONISER** using transformers and novel circuitry, our ioniser emits at least ten times as many ions as does any other kit on offer, nor do we know of a ready built model that is as good, you don't need a tester to see if it is working just bring your hand close to it and feel the stream of neg ions. It's a kit complete with case, nothing else to buy yours for £14.50.

**ULTRASONIC TRANSMITTER/RECEIVER** with Piezo alarm, built into preformed case, is triggered by movement disturbing reflected signal, intended for burglar alarm, car alarm etc. has many extras, time delay, auto reset, secret off device etc. A £40 instrument yours for £10.

**MOVEMENT ALARM** goes off with slightest touch, ideal to protect car, cycle, doorway, window, stairway, etc. etc. Complete with piezo shrieker ready to use. Only £2 (PP3 battery not supplied).

**STEREO HEADPHONE** extra lightweight with plug £2 each or 10 pairs for £18.

**B.T. TELEPHONE LEAD** 3m long and with B.T. flat plug ideal to make extension for phone, Fax, etc. 50p each, £40 per 100, £300 per 1000.

**WATER PUMP** very powerful and with twin outlets, mains operated, £10.00.

**STUDIO 100** by Amstrad, the ultimate disco control panel, has four separately controlled and metered channels, twin cassettes, AM/FM radio, stereo audio amplifier, phono & C.D. inputs, etc, etc, etc, regular price over £400 we have a few still in maker's packing, brand new and guaranteed, yours for £99.

**ROTARY POSITION CONTROLLER** for aerials, ventilators, dampers, rheostats, dampers or applications requiring 180 degrees clockwise and anti-clockwise movement. We have the Sauter MVE4 154 servo motor drive ref AR30W3S regular price over £70 brand new, £15 each.

**12 VOLT 8 AMP MAINS TRANSFORMER** £4, waterproof metal box for same, £4.

**110 WATT SWITCHMODE POWER SUPPLY** 230v mains operated, outputs of 38v 2½A and 5v 3A, we have a lot of these and need the space so you can have these at a fraction of their cost if you order before Oct 31 price is £6.

**10 VA MAINS TRANSFORMERS** all p.c.b. mounting, all £1 each, 10 for £9, 100 for £75, for output 12-0-12v order ref WA1, 15-0-15v order ref WA2, 20/0/20v order ref WA3, 18-0-18v not p.c.b. mounting but fully shrouded same price order ref WA4.

**0–1 mA FULL VISION PANEL METER** 2¾" square, scaled 0–100 but scale easily removed for re-writing £1 each, 10 for £9, 100 for £75.

**PANEL AMP-METERS** 80 × 70mm beautiful instruments £5 each 30 amp order ref WA5, 10 amp order ref WA6, 5 amp order ref WA7.

**Vu METER** illuminate this from behind becomes on/off indicator as well, 1½" square 75p each, 10 for £6, 100 for £50.

**EDGE-WISE PANEL METER** ideal when short of panel space only 40 × 14mm, also have built-in led, 500 uA f.sdd, scaled 0-5, £1 each, 10 for £9, 100 for £75.

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**P.C.B. DRILLS** 12 assorted sizes between .75 and 1.5mm £1 the lot.

**LOW PRICED FIELD TELEPHONES.** You will know from current advertising that we are selling ex-B.T. field telephones at **£12.50** each. We have acquired some earlier ex-GPO models, not quite so nice-looking but quite efficient, and have the big advantage that the ringing is done by means of a hand operated internal generator. This saves a lot of batteries – the only battery required is something like a PP3 for the speech. These 'phones have the normal type of rotary dial built in and can still be connected into a normal B.T. system. Tested, guaranteed in good order, price only £9.50 each. Order Ref 9P5.

**HAND GENERATORS** as fitted in the above field telephones, this hand generator is a permanent magnet type and has an AC output of approximately 50v depending on how quickly you wind it. If you want a higher voltage then simply connect the output to a transformer. We have lit a 60 watt bulb quite successfully. The hand generator, complete with handle, £4.00. Order Ref 4P51.

**AMSTRAD 3" FLOPPY DRIVE** cased and with built-in power supply so a self contained extra drive for you if you use 3" discs, real bargain **£35.00.** Order Ref 35P38.

**DRY BATTERIES CAN BE RECHARGED** but not with a normal dc charger, it must be a periodic current reversal type. We can supply the kit, with data, £6.50. Order Ref 6P9B.

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*CIRCLE NO. 128 ON REPLY CARD*

# Impedance transformation with standard 50Ω coaxial feeder

***RF equipment, transmission lines or feeders usually have input/output impedances matched to 50Ω. Occasionally matching problems arise. Dick Manton suggests using a quarter-wave transformer and shows how simple networks of 50Ω lines can be used to perform this task.***

Propagation of waves along a transmission line is very similar to the propagation of water waves in a long, narrow channel. If the channel is uniformly wide and deep, and fitted with a perfect wave absorber at the far end then, assuming there is no attenuation as the waves proceed, the wave pattern will consist solely of forward travelling waves which have a constant amplitude or wave height along the channel.

If, however, the channel changes width abruptly at some point, then waves having a fraction of the amplitude of the forward waves will be reflected back from the discontinuity towards the wave generator. Stationary or standing waves will be produced between the generator and the discontinuity as the forward and backward waves slide in and out of phase. These conditions are shown in **Fig. 1**.

With radio frequencies the characteristic impedance of the transmission line corresponds to the width of the channel and a matched load or matched antenna corresponds to a perfect wave absorber. A change in line impedance, or the presence of an unmatched load impedance, will result in reflected waves of voltage and hence voltage standing waves. The voltage standing wave is quantified by the voltage standing wave ratio (VSWR), which is the ratio of the maximum amplitude of voltage along the line to the minimum amplitude of voltage a quarter-wavelength away.

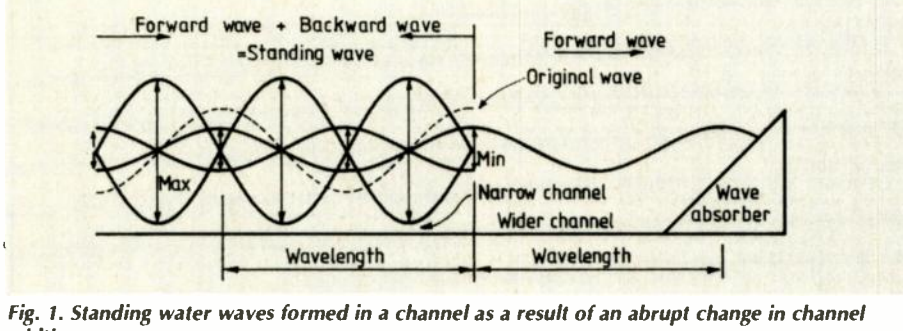



*Fig. 1. Standing water waves formed in a channel as a result of an abrupt change in channel width.*

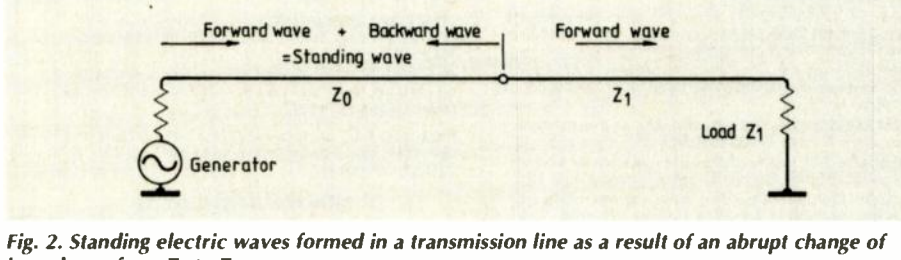



*Fig. 2. Standing electric waves formed in a transmission line as a result of an abrupt change of impedance from $Z_0$ to $Z_1$.*

By convention, the ratio is always greater than or equal to 1. In **Fig. 2** a transmission line of impedance $Z_0$ changes to impedance $Z_1$ which is then terminated by a resistive load impedance $Z_1$. The resulting VSWR between the generator and the discontinuity is $Z_1/Z_0$ if $Z_1>Z_0$, or $Z_0/Z_1$ if $Z_0>Z_1$. The relationship between the VSWR and the reflection coefficient $P_v$, which is usually expressed as a percentage, is

$$p_v = \frac{(VSWR-1)}{(VSWR+1)} \times 100\%$$

or

$$VSWR = \frac{1+\frac{P_v}{100}}{1-\frac{P_v}{100}}$$

Provided that the minimum amplitude of voltage on the line is greater than zero, one fraction of the forward power remains, which will travel on past the discontinuity to be absorbed by the load. This is more easily visualised by considering the voltage reflection coefficient $P_v$. If the forward power is W, the power reflected back is equal to $P_vW$. The remaining forward power is therefore:

$$\left(1-\left(\frac{P_v}{100}\right)^2\right)W$$

Disadvantages of having reflected waves in a transmission system include loss of available power in the load or antenna, increased voltages at half-wave intervals along the line and correspondingly increased currents at half-wave intervals between them, and distortion in FM, TV and pulse modulated systems if the transmission line is sufficiently long, typically when it is longer than 50m. The reflection coefficient of a TV broadcasting antenna has to be kept below 2% (VSWR<1.04 ) to avoid transmitting an appreciable level of ghost image.

### Quarter-wave transformers

If quarter-wavelength of transmission line of characteristic impedance $Z_2=\sqrt{(Z_0Z_1)}$ is interposed at the junction of two unequal line impedances $Z_0$ and $Z_1$, then the system will become matched at the design frequency. This is because $Z_0/Z_2 = Z_2/Z_1$ resulting in equal-amplitude reflections from Junction

points *A* and *B* (**Fig. 3**). Because of the time delay for waves getting from *A* to *B* and back and the relative phases of the reflected waves at their points of generation, the reflected waves will completely cancel at *A* and no reflected waves will proceed back beyond that point. In Fig. 3 and elsewhere $\lambda$ equals the wavelength in the feeder, is $300v/f$ metre where $v$ is the velocity factor of the feeder and $f$ is frequency in MHz.

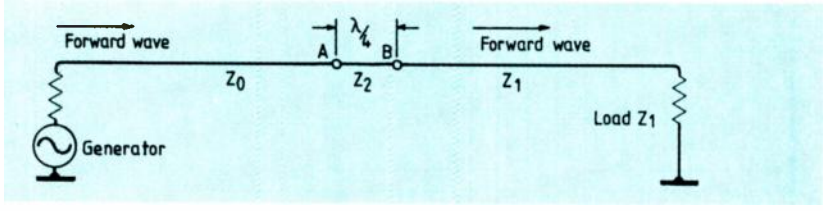



*Fig. 3 Standing waves eliminated by the use of a quarter-wave transformer. $Z_2 = \sqrt{(Z_0 Z_1)}$*

### Equivalent quarter-wave transformers

In general, the characteristic impedance $Z_2$ will turn out to be a non-standard value. In strip-lines or microstrip-lines a wide range of impedance can easily be fabricated but non-standard-impedance coaxial lines are likely to be inconvenient to construct and are unlikely to be obtainable commercially. Fortunately, however, "equivalent" quarter-wave transformers of any characteristic impedance $Z_E$ can be formed by three sections of 50Ω feeder in the form of a T, with two equal arms of (length $l_1$) for the input and output line. The third arm of length $l_2$ forms a stub line at the junction of the other two. If the required equivalent characteristic impedance $Z_E$ is less than 50Ω, then the stub has an open-circuited end; if $Z_E$ is greater than 50Ω, the stub has a short circuited end. The lengths $l_1$ and $l_2$, which are indicated and plotted in **Fig. 4**, are given by

$$l_1 = \frac{\tan^{-1}\dfrac{Z_E}{50}}{360}$$

and if $Z_E < 50$

$$l_2 = \frac{\tan^{-1}\left(\dfrac{50}{Z_E} - \dfrac{Z_E}{50}\right)}{360} \quad \text{open-circuited end}$$

or if $Z_E > 50$

$$l_2 = 0.25 + \frac{\tan^{-1}\left(\dfrac{50}{Z_E} - \dfrac{Z_E}{50}\right)}{360} \quad \text{short-circuited end}$$

At frequencies close to the design frequency, the equivalent quarter-wave lines have all the attributes of real quarter-wave lines. That is, they delay phase by 90° and transform impedances in the same way, even to the extent of transforming open-circuits to short-circuits and vice versa.

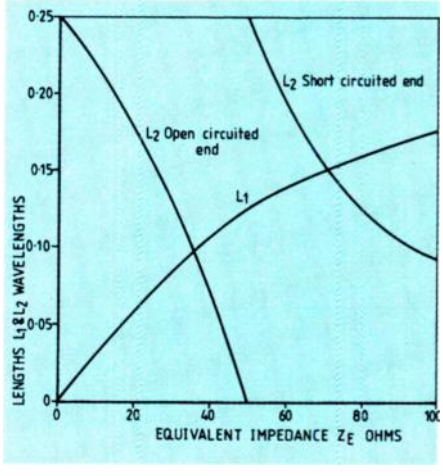



*Fig. 4 Dimensions of the 'equivalent' quarter-wave transformer*

### Performance conflicts

As one might expect, the penalty for using a substitute product is a decrease in operational bandwidth when compared with a real quarter-wave transformer. This is best illustrated by comparing the variation of reflection coefficients with frequency for transformers which are designed to transfer from 25Ω to 50Ω and to transfer from 100Ω to 50Ω. Either of these transformers can be used to feed two 50Ω loads in parallel, as illustrated in **Figs 5(a)** and **(b)**.

If an equivalent transformer circuit is being used to transform a load impedance to or from 50Ω, regardless of phase delay, the arm of the T that adjoins the 50Ω can, of course, be omitted.

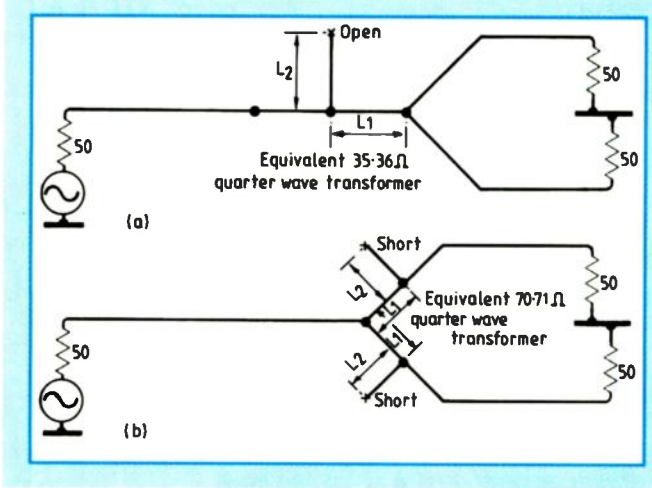
Resulting variations of reflection co-efficients with frequency are shown and compared with reflection coefficients of real quarter-wave transformers. It is immediately apparent that the equivalent quarter-wave line with an impedance lower than 50Ω has two advantages; its bandwidth is greater and the number of connections that are required is less.

### Increased bandwidth transformers

The transformers that are illustrated in Fig. 4 and 5 are specifically designed to be matched at the design frequency. If, however, the transformer arms are slightly modified a matching stub is added, a good compromise in reflection coefficient can be achieved over a much wider frequency band. **Figs 6(a)** and **(b)** show 25Ω to 50Ω transformers and 100Ω to 50Ω transformers that have been optimised for frequency bands of ±10% (Band II 88-108 MHz) and ±20% (B and V 614-854 MHz).

Some further improvement might have been possible if multiple stubs had been used but this possibility has not been explored here. If four 50-ohm loads have to be fed in parallel from a single generator, an improved bandwidth can be obtained by first transforming pairs of 50-ohm loads in parallel to produce single 50-ohm impedances and then transforming these to produce a final single 50-ohm input.

Specific length of feeder has to be used between the two sets of transformers to ensure that the residual reflection in the first



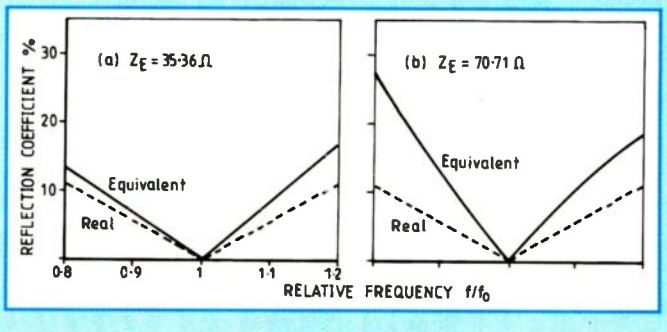




*Fig. 5. Alternative transmission line circuits for feeding two 50Ω loads in parallel using equivalent quarter-wave transformers. Dimensions: (a) $l_1 = 0.098\lambda$, $l_2 = 0.098\lambda$ oc; (b) $l_1 = 0.152\lambda$, $l_2 = 0.152\lambda$ sc. Resulting reflection coefficients are compared with those of "real" quarter-wave transformers.*

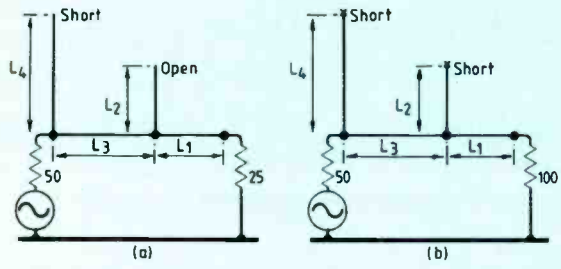



*Fig. 6. Wideband circuits for transforming (a) from 25Ω to 50Ω and (b) from 100Ω to 50Ω.*

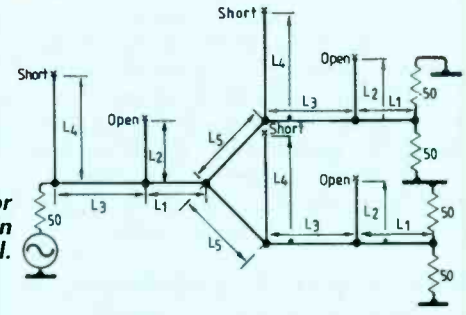
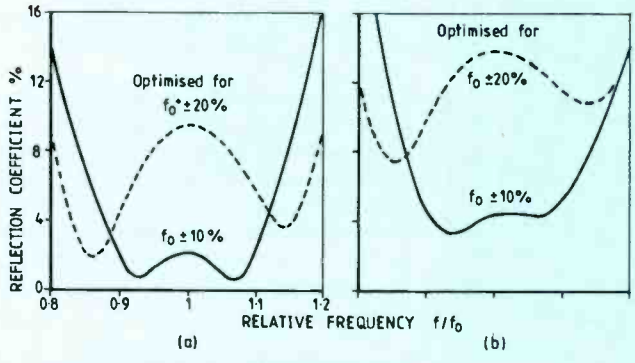
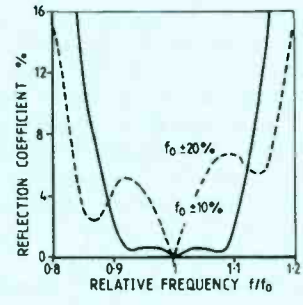



*Fig. 7. Wideband circuits for connecting four 50Ω loads in parallel.*




| | $f_0 \pm 10\%$ | $f_0 \pm 20\%$ |
|---|---|---|
| $l_1$ | .102λ | .117λ |
| $l_2$ | .094λoc | .079λoc |
| $l_3$ | .297λ | .297λ |
| $l_4$ | .252λsc | .250λsc |
| $l_5$ | .297λ | .292λ |




| | 25Ω – 50Ω | | 100Ω – 50Ω | |
|---|---|---|---|---|
| | $f_0 \pm 10\%$ | $f_0 \pm 20\%$ | $f_0 \pm 10\%$ | $f_0 \pm 20\%$ |
| $l_1$ | .102λ | .117λ | .143λ | .127λ |
| $l_2$ | .094λoc | .079λoc | .159λsc | .184λsc |
| $l_3$ | .297λ | .297λ | .212λ | .212λ |
| $l_4$ | .252λsc | .250λsc | .245λsc | .250λsc |

pair of transformers are optimally compensated by the residual reflections in the second transformer. **Fig. 7** shows the dimensions and performances of four-way splitters using transformers designed for ±10% and ±20% bandwidth.

Small modification can be made to improve the bandwidth. All reflection coefficients, that are illustrated above, were calculated by means of a network analysis computer program which was written by the author. ■

engineering

# Sound models for MicroCap

***Ben Duncan illustrates the modelling of some real passive components for greater realism in simulation of audio components.***

Passive components (resistors, capacitors, inductors and their derivatives) used in both pen and paper design and computer simulation, as well as in circuit schematics, are pure or "primitive" parts. But the map is not the territory and nothing quite like them ever pertains in nature or exists as a manufactured part. Instead, real components contain, in addition to their explicit behaviour as R or L or C, the other two terms.

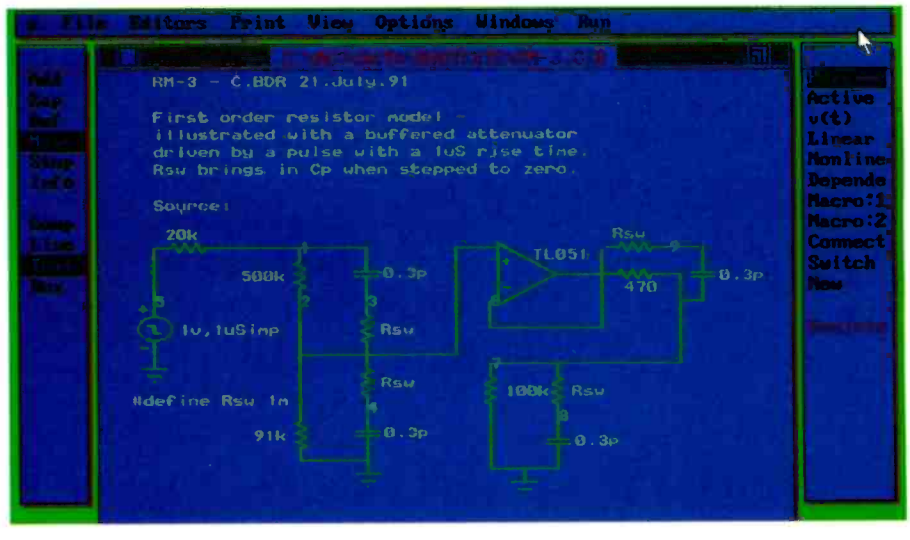
For example, all capacitors exhibit inductance and resistance, albeit small in good specimens. Additional, second order phenomena include dielectric absorption, transmission line effects, mechanical losses, and non-linearities in magnetic cores – where applicable. Parasitic elements are well heeded by RF designers (they have to be), but are commonly ignored or only hazily appreciated by practitioners in other areas. In analogue audio and instrumentation, passive component parasitics become important when developing and analysing circuits to high precision (eg to <0.5dB, <1°). Even with purely nominal circuitry, component imperfections become increasingly significant when operating above 100kHz and in some cases below 10Hz, or wherever extreme part values, power, voltage, current ratings and network impedances are involved. Awareness of passive component parasitics is no less important in digital design, for the optimising of power supply decoupling and suppression networks. References[1,2,3,4] provide introductory reading on the attributes of real components.

This article introduces some passive component models and describes how they have been created and evaluated, using Spectrum Software's MicroCap-III premium simulator software[5]. Known as MC3 for short, it's friendlier and more versatile than most if not all of the Spice-based programs, but nonetheless, it has much in common, and Spice users will have no difficulty translating the model information into their local dialect.

### Resistors and pots

Real resistors feature a shunt capacitance of about 0.3pF, for modern, 1/4 watt metal film types. The value depends on physical size, core geometry – hence type and wattage –

*Fig. 1. Using MC3 as a first order resistor model*



and is fairly independent of ohmic value. So whether operating frequencies and/or network impedances are high enough for it to matter in particular instances will generally be intuitively obvious to the designer. If uncertain, **Fig. 1** shows how you can use MC3 as an A/B demonstrator. The parasitic capacitors ($C_p$) are connected via resistors ($R_{sw}$) which can be used to switch them in and out by stepping from zero to a very high resistance. The resulting time domain or transient graph **Fig. 2** shows the ±1V stimulus (input) at the top, and the two output plots, with and without $C_p$. Note the peaking and timing advance when $C_p$ is included.

Potentiometers are modelled in MC3 by causing two resistors to step in opposite directions, maintaining a constant value. The value of each resistor is equal to the pot's nominal value. In **Fig. 3**, which models a log pot used as an audio volume control, it is done with the aid of the sub-circuit artifice at the bottom right. The voltage of battery called "set" is stepped during analysis, and drives the adjacent polysource "Logstep". The polysource acts as the multiplier in the #DEFINE statements which comprise equations governing upper and lower arm resistances (UAR and LAR). A log term linearises step increments on the dB scale.

The stepping equations include the parasitic capacitance ($C_p$) across the element, which can be quite substantial in some dual carbon models with close tracking, eg. ALPS. Their values, in the order of 5pF, are arrived at by multiplying the pot's value ($10^4$) by a huge 0.005p ($5^{-15}$)! Real pots also have endstop resistance ($R_e$), a wiper resistance ($R_w$), and capacitance between their pins (5pF). These values have been written as #DEFINE statements to keep the page tidy.

Real loads have finite resistances and with shielded cable, capacitance may be tens or hundreds of pF too. The load model contains typical values. The source generator (it's not visible but appears across the $10^8$ input tie-down resistor during an AC run) has the default $R_s$ of 1mΩ. This is an allowable simplification as the direct source impedance of any halfway decent driving op-amp will be within the tolerance of the upper $R_e$.

**Figure 4** shows the pot's frequency response versus attenuation setting, demonstrating the way in which the capacitive portion of the divider turns the HF response from a roll-off to a roll-up as attenuation increases, with a nearly flat response occurring at around -20dB. By altering the stepping range, the maximum attenuation will be found to be around -66dB, and by appending tolerances to all the resistive values, and performing a worst case Monte-Carlo run, you can predict the maximum and minimum of full audio band attenuation in production.

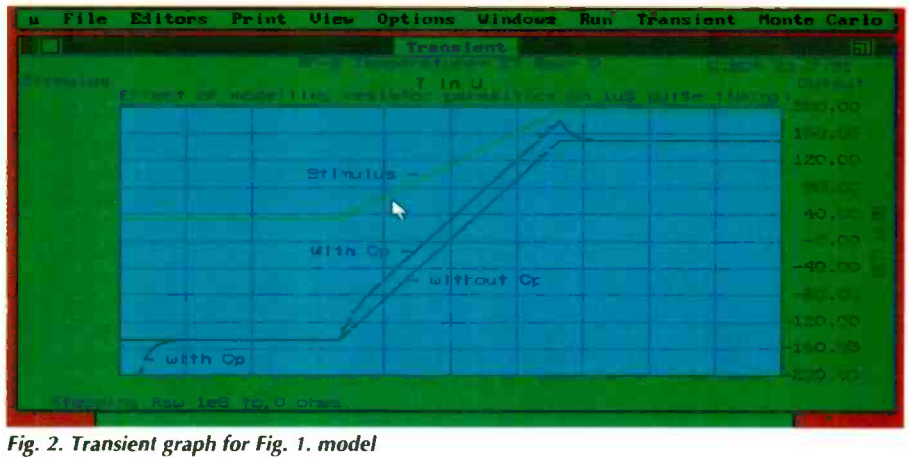



*Fig. 2. Transient graph for Fig. 1. model*

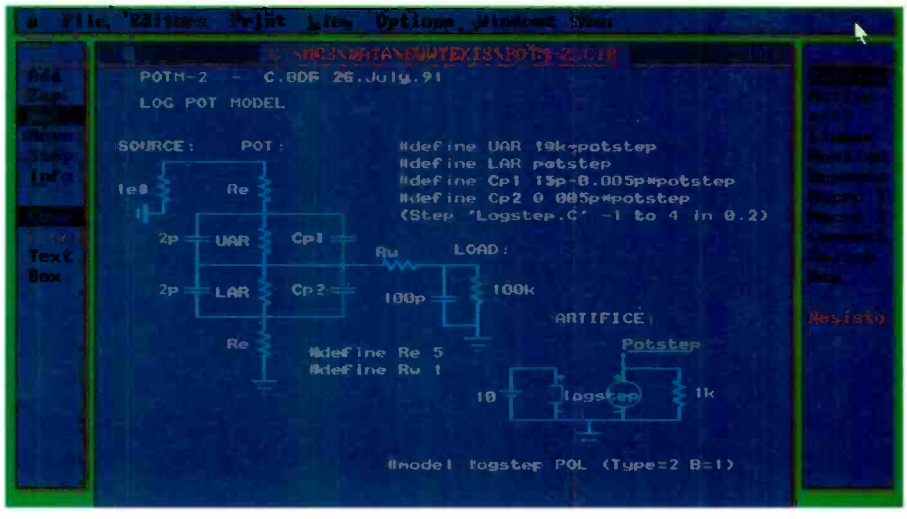



*Fig. 3. Model of a log pot used as an audio volume control*

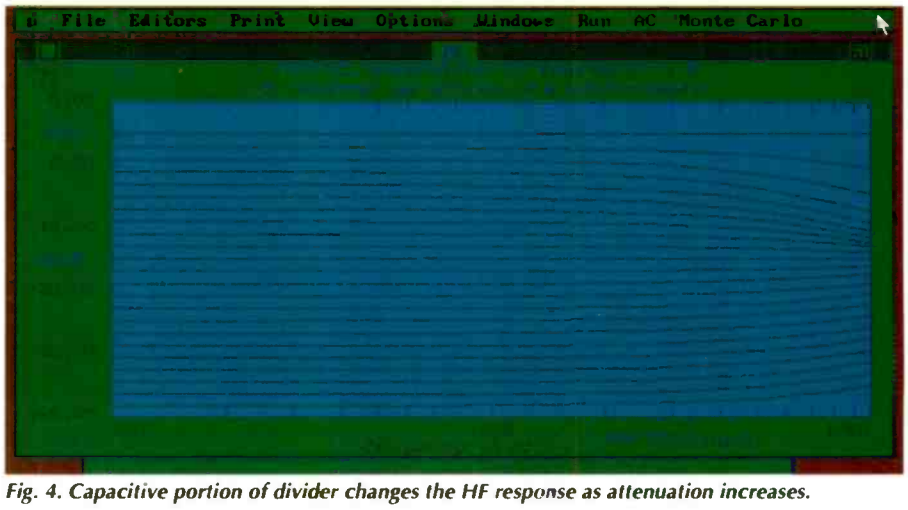
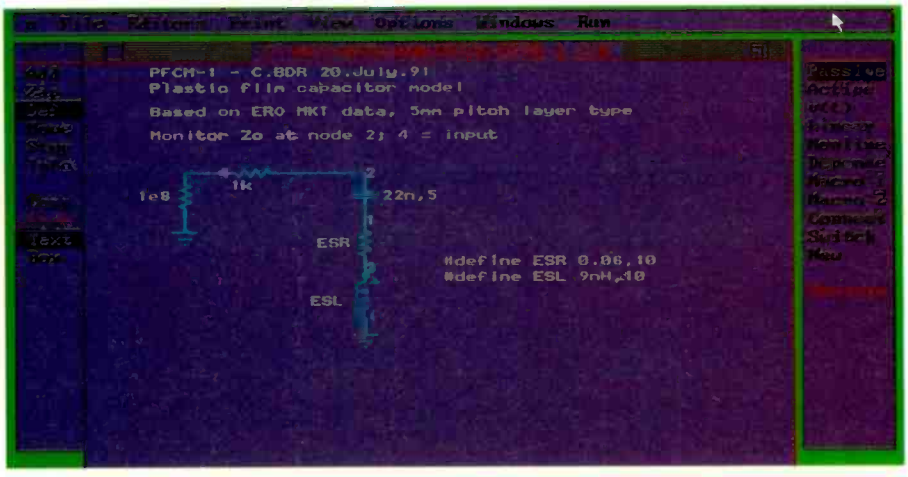


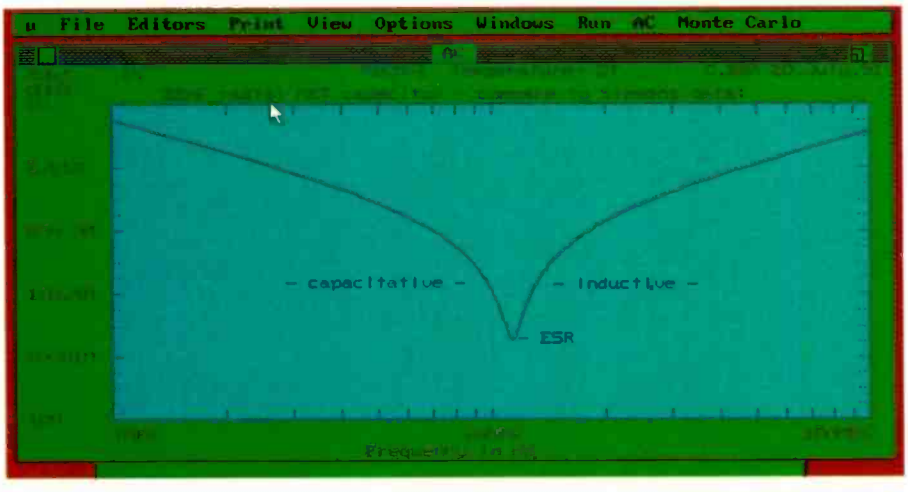

*Fig. 4. Capacitive portion of divider changes the HF response as attenuation increases.*

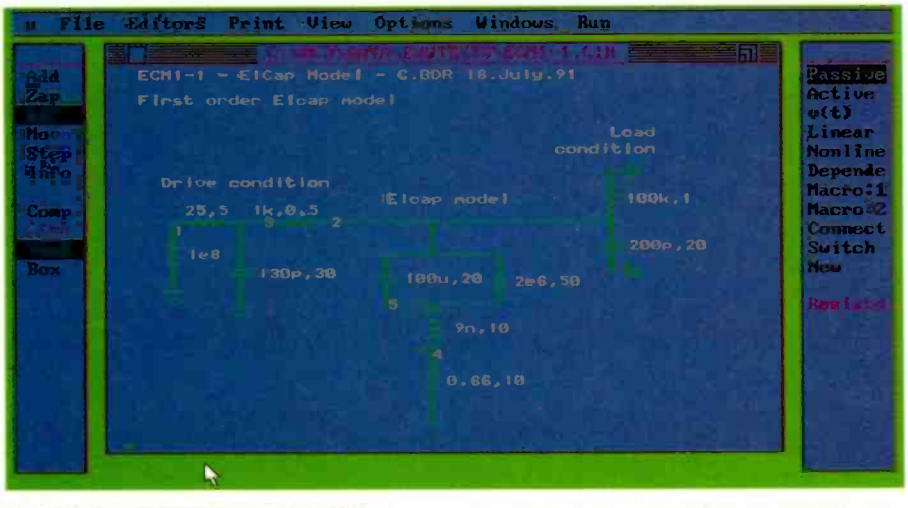
## Capacitors

The first order model of a real, capacitor comprises equivalent series resistance (ESR), equivalent series inductance (ESL) and leakage resistance (RL). Despite their title, the "equivalent' parts are real, physical quantities. MC3 readily plots input and output impedance (or conductance if you prefer) in AC analysis mode. A suitably large series resistance is needed to separate input from output, else the 1mΩ AC analysis source would dominate.

The parasitic values for the 22nF capacitor in **Fig. 5** have been arrived at by inspecting spot values on the maker's impedance against frequency graph, then entering reasonable initial values. The ESR is the resistance at the impedance minima. ESL will be in the order of a few nH for most physically small components. The values can then be adjusted by stepping them until the capacitor's impedance versus frequency plot (**Fig. 6**) closely corroborates with the maker's data. An uncertainty, hence tolerance of 10% has been included in the ESR and ESL "#define' statements. The leakage term has been excluded, as with the plastic film



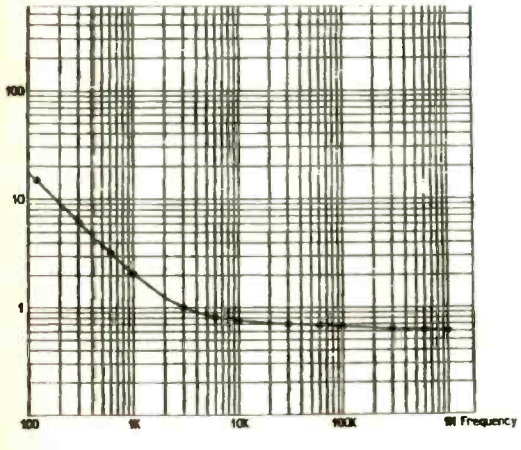




*Fig. 5. (top). Parasitic values are arrived at by taking "reasonable" initial values then stepping until the impedance vs frequency plot, Fig. 6 (middle) matches the maker's data.*

*Fig. 7. (above) Model of a modern 100µF electrolytic and maker's data, Fig. 8 (left).*

capacitor modelled here, it is at least 100MΩ, so only significant in very high impedance networks and at VLF.

**Figure 7** presents a model for a modern 100µF electrolytic, made by Elna. The model closely follows the maker's impedance data (**Fig. 8**) as shown in **Fig. 9**

## MODEL IN CONFIDENCE

Analysis with MicroCap-III or MC3 for short involves entering the circuit as a schematic in a windows type of environment. Simple circuits are speedily tested and then developed into bigger ones by copying blocks and merging. Nodes are numbered automatically.

In the latest V3.08 used here, numbering is fairly cumulative so the addition of new parts rarely alters existing node numbers. The latest version is also thoroughly gamekeepered by factual error messages which leap out to prevent you entering a hang or making a fool of yourself. Component values can be stepped and may be optionally defined by statements (which may include formulae) on the screen. Notation is a mixture of engineering shorthand and floating point numbers, as convenient. MC3 already allows you to model two kinds of real-world passive component errors neglected in the main text, namely value tolerances, and temperature coefficients.

Confidence in the results have been gained by rigorous comparisons between simulations and measurements of the resulting physical circuits using Audio Precision *System One* and Techron TDS "TEF" test sets. In the majority of cases of disparity, an error in the physical circuit was revealed – rather than a modelling oversight. Thus simulation, so easily casually vilified as "inaccurate", actually has a role to play in verifying that the expensive PTH PCB you're about to make is the circuit you think it is.

but not an Audio Precision (AP) test-set's plot of magnitude, **Fig. 10**. The 1kΩ series input resistor is the same value as that used in the physical measurements and the latter test set's source and load conditions have been included in the modelling circuit. Looking at the AP plot, note the change of slope towards -3dB/octave above 1kHz. This phenomenon is common in wound capacitors (not just electrolytics) and arises because of the transmission line quality of the plates, owing to their sheer length.[6]

The second-order circuit in **Fig. 11** replaces and upgrades the basic model, and retains a similar total capacitance, but spreads it along a line of distributed ESRs (DESR) having much higher values (330mΩ), with the leadouts' resistance (10mΩ) and lumped inductance (4.5nH) expressed separately. Leakage resistance ($10^8$) with a fair uncertainty (60 means 60% to 160%) has been included for completeness. The network is then connected across the existing source and load conditions in the previous circuit (using the tie marked ec+), and yields the curve in **Fig. 12**. The change of slope above 1kHz now closely follows the AP plot in Fig. 10, although the different aspect ratios make this hard to see at first.

In case there are any doubts, **Fig. 13** shows 15 worst case Monte Carlo tolerance

runs, homing in on the bottom portion of the original graph. The variation is the sum of the two tolerances expressed, ie. DESR varies ±5% and C varies ±20%. ESL variation has been expressly excluded by not appending a tolerance to its value. Note how the difference is a linear offset below 1kHz, with a change of slope at higher frequencies – where the plots cross each other. Thus it can be seen that any lack of corroboration in the slope and the corner are within the tolerance band of the distributed elements alone. If desired, the model can be refined by further sub-division and dispersion of the R, C and even L components.

### Dielectric absorption

Dielectric absorption (DA) or soakage is the ability of high permittivity dielectrics – notably electrolytic, medium and hi-k ceramic, and the polar plastic films – to release charge more slowly than predicted by first order equations.

The ideal equivalent circuit for DA is a series of nested RC networks, across the main capacitance. For a first order approach to this third order problem, the series can be simplified to a single, nested RC network. It may not be good enough to give definite answers to audio mysteries, but it may come in handy with problems in sample and hold, and integrator circuits. The values needed to replicate DA in a 4.7µF polyester capacitor were established by building the standard US Mil Spec DA test-set in MC3.

It comprises an electrometer looking across the capacitor under test, which is charged for five minutes, then shorted. MC3's time switches vastly simplify the accurate and automatic timing of the charge/dump/read cycle. A virtual electrometer built in MC3 (or other simulators) has perfect leakage and noise specifications and, unlike real instruments, it doesn't need cleaning and a bake in the oven after a period of disuse!

The DA term values were stepped in transient analysis until the recovery voltage 5s after discharge followed the results for the 4.7µF MKT capacitor in Jung & Marsh's classic report[7].

Looking at **Fig. 14**, the op-amp gain stage has three high pass poles built around it, all using the 4.7µF polyester capacitor. $10^8\Omega$ models leakage resistance, and 0.1Ω the ESR. ESL isn't modelled as we're only looking at low to sub-audio frequencies. The DA term is the 158nF, in conjunction with $R_{sw}$, when the latter is 10MΩ. When stepped to a much higher value ($10^{11}\Omega$) DA can be safely assumed to be out of the picture. The op-amp is a Jung-Boyle macro of LT1037, based on recent work by Walt Jung while working as staff scientist at Linear Technology.

It has the advantage of more closely modelling the op-amp's second order performance aspects, such as CMR and $I_{out}$. As a Jung macro, it's easier to enter than Spice based macros released by other op-amp

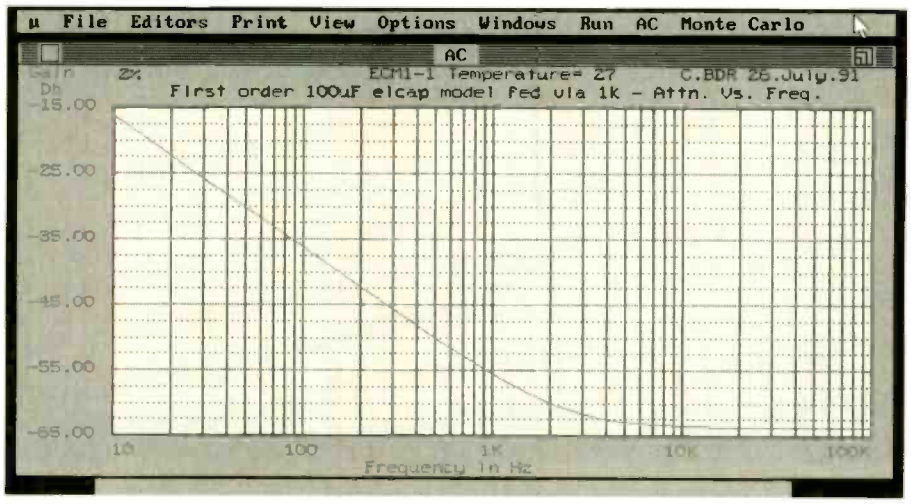



*Fig. 9. The model closely follows maker's data (Fig. 8) but not an Audio Precision test-set plot, Fig. 10. (right).*

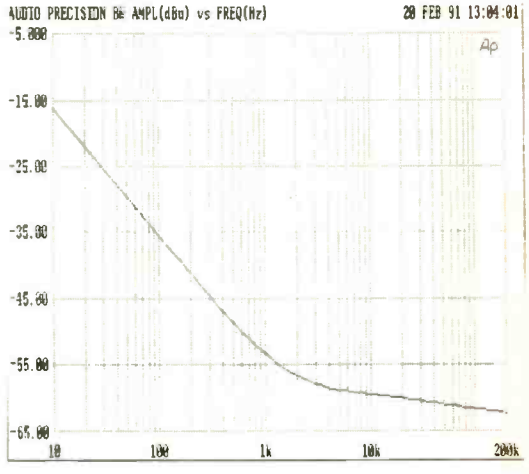
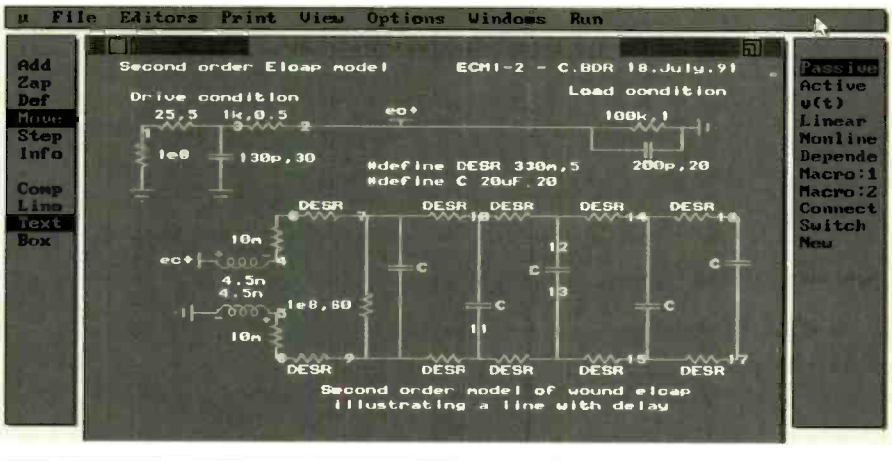
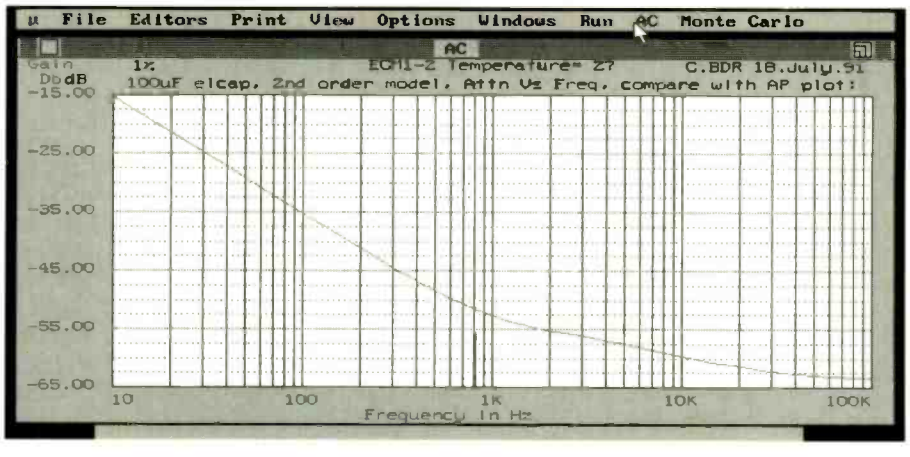



*Fig. 11. (below) An upgrade of the basic model with total capacitance retained. Connecting the network across the existing source yields Fig. 12 (bottom).*



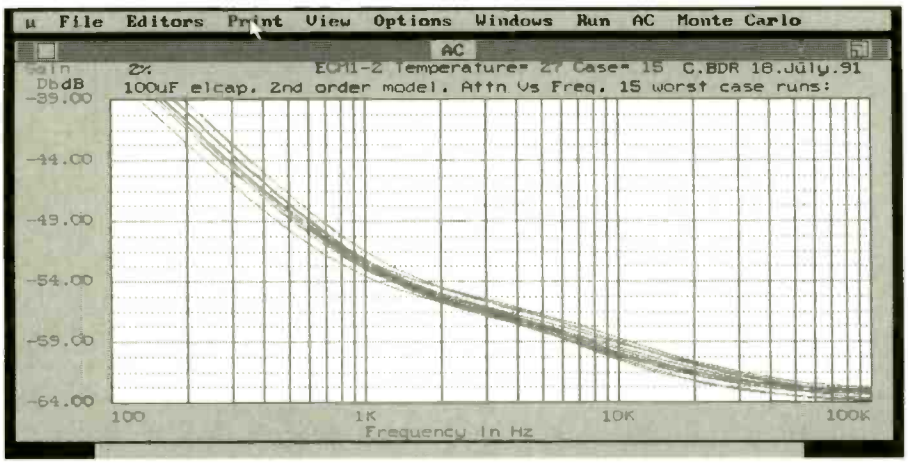



*Fig. 13. Checking "worst case" matches.*

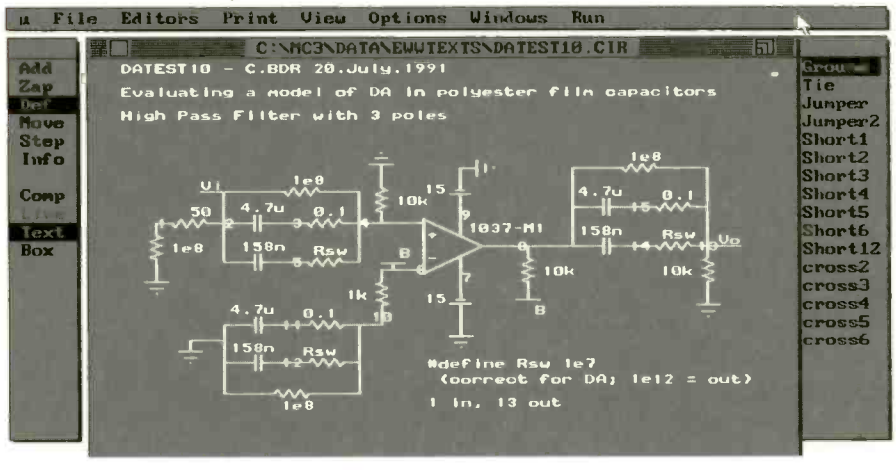



*Fig. 14. Evaluating a model of DA in polyester film capacitors.*

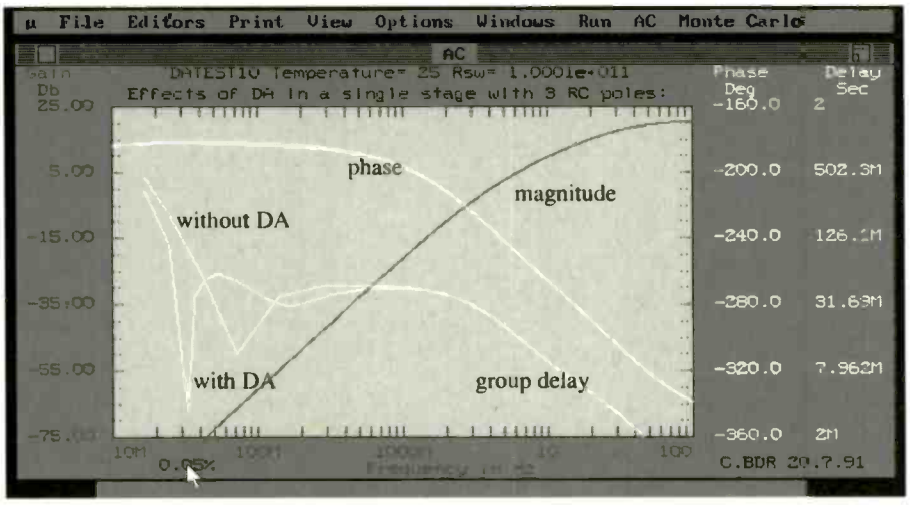



*Fig. 15. AC response with and without DA term.*

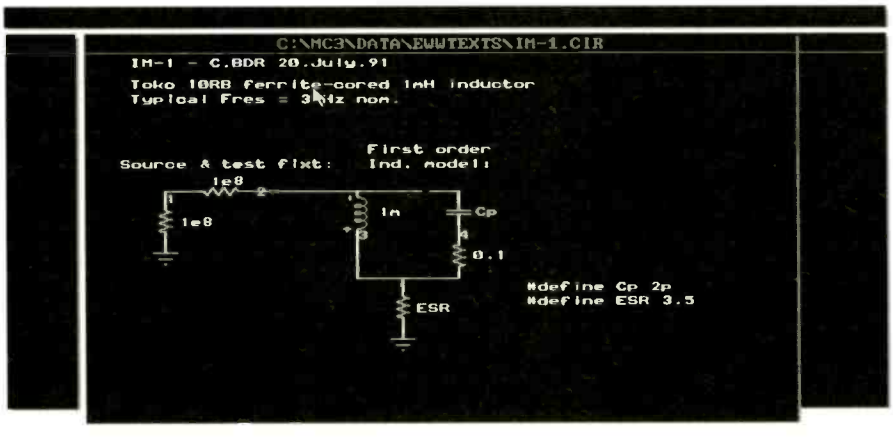



*Fig. 16. First order model for an inductor*

manufacturers, by avoiding the more esoteric types of sources. A recent issue of Spectrum Software's MC3 newsletter has covered the conversion and entry of Spice macros into MC3.

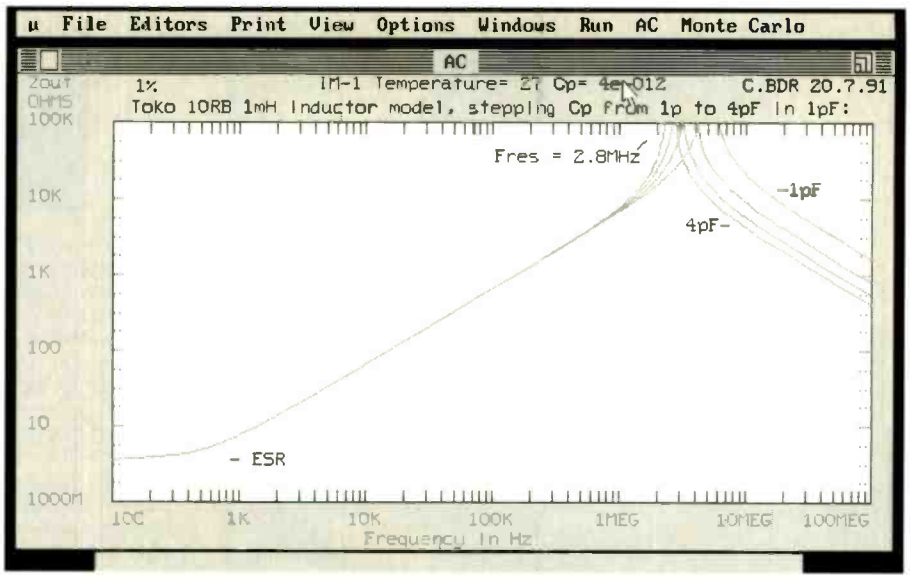
Some years ago, the correspondence columns of *EW + WW* and *Hi-Fi News* echoed with exchanges about whether or not capacitor DA (amongst other things) could give rise to audible differences and/or loss of sonic quality. The debate locked-up with both sides disputing the relevance of each other's evidence and viewpoint but, as it came to a close, the mathematician Stanley Lipshitz issued a challenge: If there were any effects, they should be demonstrable in the AC domain.

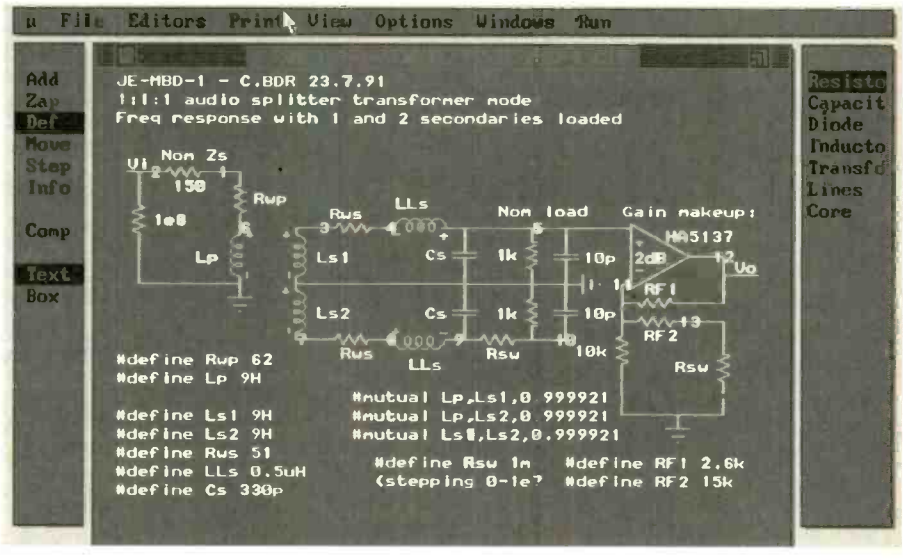
**Figure 15** replies by plotting the AC response of the circuit with and without the DA term. The plot shows an abrupt change in group delay and a smaller change in phase response, albeit at subsonic frequencies. There must also be some accompanying change in amplitude response. So yes, DA has effects in the frequency domain, albeit very small (<0.1dB), and in realms where signal magnitude is extremely small, as well as occurring over seconds. Still, the way is now open to model DA with more nested terms integrated with Hawksford's transmission line model. Across a complete studio chain, and considering the much higher DA at large in electrolytic coupling capacitors, and how broadband amplitude variations of well below 0.1dB are now rated as psychoacoustically significant to experienced listeners, who knows what may transpire ?

## Inductors and transformers

**Figure 16** illustrates the first order model for an inductor. Note that as the resonant impedance for an inductor is a maximum, the driving resistance (test fixture) has been made very high, so it doesn't appreciably shunt the impedance around resonance. A value as high as 100MΩ wouldn't be very feasible in a physical setup, due to the effects of parasitic impedances and stray field pick-up, but simulation just doesn't have this problem. The inductor's nominal self-resonant frequency, $F_{res}$ is 2.8MHz; the impedance versus frequency plot in **Fig. 17**, $C_p$ has been stepped (from 1pF to 4pF in 1pF steps) to find the value which fits the spec. MC3's ruler scale has been selected so the grid lines don't obscure the near vertical resonant portions.

For problems where a ferrite or iron cored inductor is operating at very low current lev-



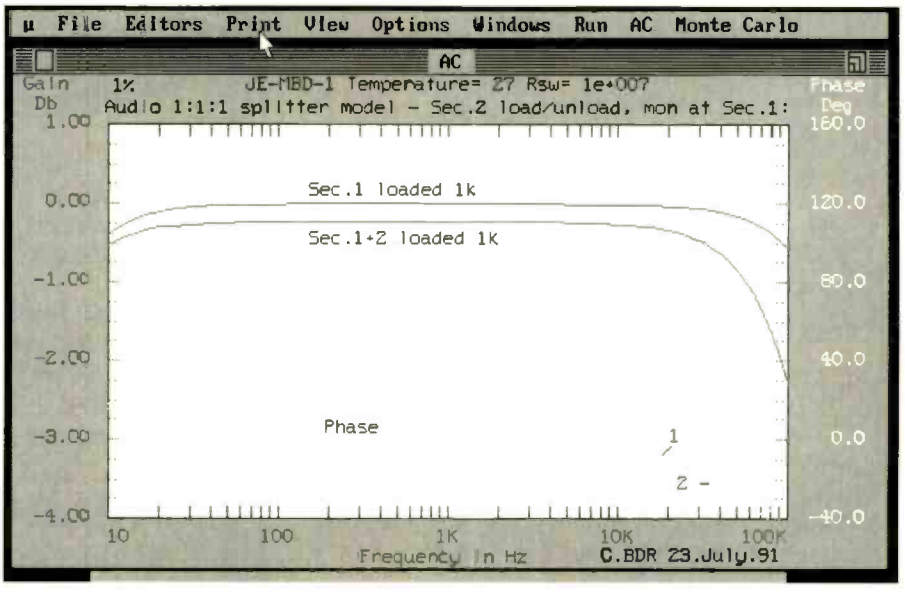




***Fig. 17. Stepping $C_p$ to find the value which fits the spec.***

***Fig. 18 modelling an audio splitter transformer and frequency.***

***Fig. 19. Transformer and frequency responses under load.***

els or close to saturation, one can use MC3's Jiles-Atherton magnetics model to simulate core saturation and hysteresis. Inductors can also be given values which are a function of the current they're passing.

Finally, the circuit in **Fig. 18** uses MC3's mutual inductance capability to model an audio splitter transformer. The model has enabled a leading UK pro-audio manufacturer to evaluate the interactions between different microphones, multicore cables and buffering techniques without the great cost and fraught logistics of borrowing, hiring and physically assembling the £20,000+ worth of equipment in one place for a measurement session.

On the left, 150Ω is the source resistance used in the maker's data. $R_{wp}$ is the primary DC resistance. The #MUTUAL statements define coupling between the primary (p) and secondary (s) windings, whose inductance (L) is given in the adjacent #DEFINE statements.

The transformer's frequency response is governed by the winding inductance and coupling factors. $R_{ws}$ is the secondary DC resistance, while LLs and Cs are reasonable values for leadout and lead inductance and capacitance to the test set used by the maker. The nominal load's parasitic capacitance is cited separately.

Finally, an op-amp normalises the amplitude to 0dB at 1kHz, for ease of reading. The second secondary ($L_{s2}$) is loaded when $R_{sw}$ is stepped to zero ohms. When this happens, the op-amp's gain is also increased to place the second plot exactly one division under the first to make comparison easy. **Figure 19** then shows the frequency and phase responses under the two load conditions. This closely follows the maker's data except for a linear slope below 120Hz. Refinements to incorporate this will involve distributed L-R sections, the invert of the wound capacitor.

In closing, I'd like to acknowledge Walt Jung in the USA, for making helpful suggestions about DA modelling, Rita Drew at Calona for securing elusive Elna data, and BSS Audio, for their support of the transformer modelling project. ■

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6. Malcolm Hawksford, The Essex Echo: Unification, Track four, *Hi-Fi News*, P.43, Feb '87.
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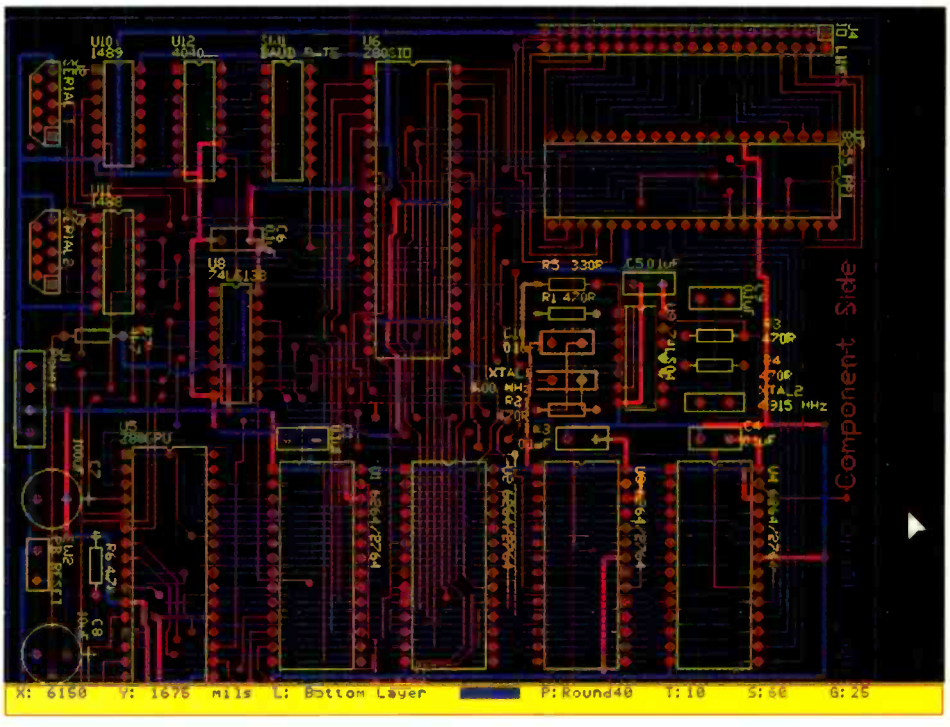



*Easytrax devotes most of the screen to layout.*

# Layout PCBs without ladling out cash

***Should you jump at Easytrax 2's low cost entry to computer PCB layout? Martin Cummings looks for the compromises.***

At £95 Easytrax is part of a family of cad software which includes an elaborate autorouter costing ten times more. But though it is the baby, it certainly appears to have gained from being part of the family.

In keeping with its low cost approach, the package will run on quite modest hardware and a 640K machine with twin floppy drives will suffice though a hard disk will speed things up. Even a mouse is not essential (but money has to be very short to take that route). Most current PCB layout packages require EGA graphics or above so no doubt some will be pleased to know that it will run with CGA and Hercules cards, but at the other end of the scale it supports some 1024 x 768 modes.

Six signal layers can be routed together with a power and ground plane and a single silk screen overlay. A further layer is provided for board outline, alignment marks and text such as drawing numbers. I have yet to see a printed circuit board 32in square, but if needed, Easytrax could lay it out. Calculations are performed to one thou resolution (0.001in) so in practice, layout accuracy will be limited by what happens after Easytrax, not the programme itself.

No problems are experienced in getting the package up and running and it soon becomes enticing to experiment without reading the manual.

A fully completed layout file is provided as an example and this together with the very easy-to-use menus mean that within minutes you can be drawing and moving tracks and components.

The manual takes the form of a small paperback, well produced with plenty of diagrams and handy hints, and the fact that most important items are covered in a paragraph or two is a tribute to the package's ease of operation. My only criticism is that it will not stay open on the desk at the right page, but some people are never satisfied.

## Screen design

Almost all the screen is devoted to the artwork, two lines at the bottom being reserved for useful things such as XY coordinates, the current layer, track size and pad type. A single drop down menu with 16 items appears at the press of a key or mouse button and selecting one of these items usually leads to further sub-menus.

Sensible names have been given to menu items and operation quickly becomes second nature. As an alternative to mouse control, pressing the first letter of the menu items can help navigate with considerable speed through the command sequences. The user/machine interface would do credit to many more expensive packages.

All the usual screen manipulation commands are here. Panning around the drawing can be automatic or at the press of a button and zooming can be with any of seven magnification factors or, as is more usual, by defining a window of interest. Screen colours for each item can be reconfigured.

There are two grids, one visible the other hidden, and both are fully adjustable in pitch and if required the cursor will snap onto the hidden grid. Easytrax performs all its operations in thou, but it can be set to metric units, so that everything is converted to millimetres. The calculations to perform the conversions noticeably slow down screen refresh so there is a distinct advantage in staying imperial and for the moment component manufacturers seem to concur.

## Full library

A full library of pre-defined components is included with the software, containing just over 100 items – not a great deal but probably providing 99% of components because it covers all the common component and IC layout arrangements including pin grid arrays.

The library does not however include surface mount components and Easytrax does not support them.

I toyed with the idea of creating some surface mount parts by using short stub tracks instead of pads for pins and this would probably work with the exception of the solder resist layer which would cover the pads. So if you are prepared to live without the solder resist and have a silk screen on just one side you can probably deal with surface mount though this could not be recommended for professional use.

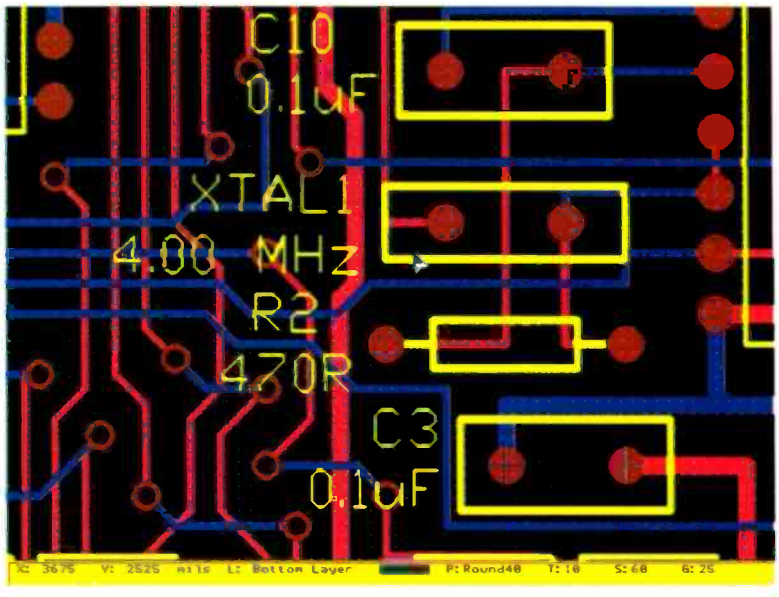
It is also possible to browse sequentially

through at the click of a mouse – a convenient way to explore the library – but in practice the method is far to slow for selecting the components; names are reasonably meaningful and are a much quicker way of choosing.

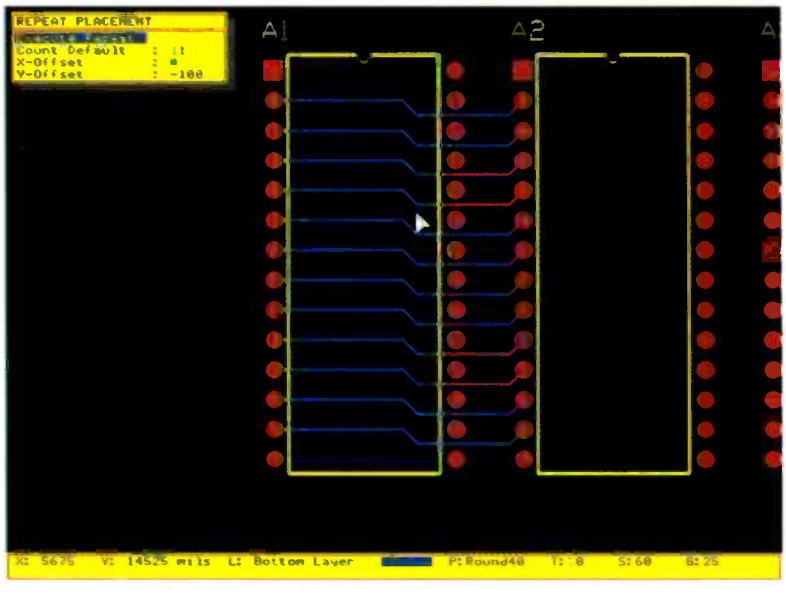
Rectangular sections of the layout including tracks and devices can be saved as blocks and imported into fresh layouts at some future date. In this simple but rather elegant way fresh devices can be added to libraries.

At the start of a layout, positioning components follows the usual sequence of choose, rotate, then place in position. As each component is placed it can be automatically numbered in sequence or the program can be overwritten with an own identifier. Alongside the component identity, another piece of text can be placed to define, for example, the resistor value.

Placing tracks is just a matter of deciding position and dragging the cursor around. Tracks can be forced into 90 or 45° angles or, by switching this feature off, giving free range to adopt any angle. Track widths range in discrete steps from 10 thou up to 100 thou and spacing is defined by the grid which can go down to 1 thou if needed. At any time whilst drawing tracks, a single key press will change layers and a via hole is automatically created at that spot.




*Visible and snap grids are fully adjustable.*




*The repeat feature is ideal for memory arrays.*

## Automation

"Repeat" is particularly useful feature allowing duplication of an operation an infinite number of times (or 5000 times anyway), but each time with a user-defined XY offset. Hence laying a bus, memory grids, edge connectors and anything repetitive can be automated in this curious way.

Easytrax includes a "pad to pad autorouter" and once the pads to be linked have been clicked on this will automatically place the tracks to make a connection. The operation is quite interesting to watch as the programme temporarily draws lines on the screen as it tries various routes. Its approach should not be compared with a full autorouter that creates the board from a netlist. But it is probably the best that can be managed in the absence of a netlist file and is quicker than placing the track step by step using the mouse, particularly on low-density boards where it could halve or more the design time compared to a similar package without such a tool.

Once all tracks have been placed, the electrical connectivity has been defined and Easytrax will generate a netlist file. It is unusual to have a netlist appear this late in the design sequence; netlists are generally prepared prior to laying out and serve little purpose afterwards. Probably the only use of such a netlist print out, as suggested in the manual, is to check the layout against the original circuit. A list of parts used on the board can also be generated. Again it is more common to see this earlier in the process but both these features are probably quite easy to include in the package and may be of use to some users.

True aficionados of design automation can further increase the power of Easytrax by creating their own macros. As in many other programmes, these are merely combinations of keystrokes that can be called up together at the press of a single key. They can be created by a special keystroke editor or learnt in action. Easytrax predefined macros are in most cases mere duplicates of single menu selections. They have been assigned to function keys to simulate the user interface of previous Protel products hence providing compatibility.

### SYSTEM REQUIREMENTS

IBM-PC/XT/AT or compatible
640K ram
Dos version 2.0 or later
Two floppy drives or hard disk
Hercules, CGA, EGA, VGA etc.

### SUPPLIER DETAILS

JAV Electronics Limited
Unit 12A Heaton Street
Denton
Manchester
M34 3RG
£95
Tel: 061 320 7210

## Easy options for hard copy

There are several ways of obtaining a hard copy of artwork. Supplied with Easytrax is Easyplot, a separate programme allowing output on dot matrix printers, laser printers, plotters and photoplotters.

Range of printers and plotters is limited, but all the old favourites are there such as Epsons, HP and postscript lasers and Roland plotters. Being a separate programme Easyplot can be run simultaneously on a different machine or even on another site if required.

Printing the layout on a dot matrix printer is a cheap, easy and effective way to get a check print. It can be scaled up or down if required and can be completed with filled or skeleton tracks.

Skeleton tracks are quicker and wear the ribbon less, and are quite adequate for checking.

Results on a simple dot matrix printer are impressive to the point where it is tempting to use for artwork though in reality definition will not suffice. Any combination of layers can be combined onto a print and a mirror image selected for each layer.

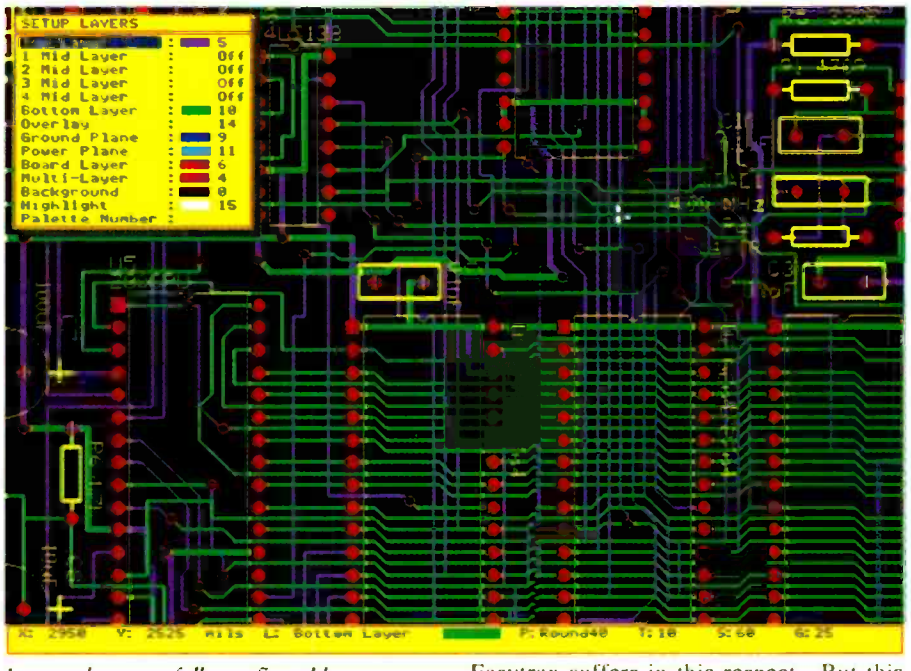
The manual devotes considerable space to advice on using laser printers to generate artwork – an increasingly popular means of producing artwork. The major consideration is that of dimensional accuracy and Easyplot provides independent X and Y axis fine tune scaling factors to compensate for variations in the laser printer.

A whole chapter in the manual is devoted to Gerber plots (RS-274) and NC drill files, explaining not only how to generate them but some useful background information. It covers things like apertures, flash or stroke exposures and helps match settings to machines.

## Professional feel

The look and feel of this package is that of a well tried and tested professional piece of software. Used on its own, it cannot be faulted. Organisations involved with surface mount components will not choose Easytrax. But they are likely to have a lot more than £100 to spend and Easytrax is aimed at a different market.

Anyone serious about computer aided design must question whether PCB layout




*Layer colours are fully configurable.*

enough or whether this together with a compatible schematic capture programme is needed.

Even the most accomplished layout software will require a lot of manual input if not fed data automatically from a schematic and Easytrax suffers in this respect. But this must be seen in the context of the price which puts it into the reach of people who may be prepared to spend time to achieve a very high quality computer generated artwork. For these people Easytrax will prove to be a skilled and dedicated friend with features to satisfy any reasonable requirement and an easy to work with personality. ■

# MATHCAD ENGINEERING

**Allen Brown finds the new addition to MathCad is a valuable tool for electrical engineers**

Mathsoft, the creator of MathCad, has issued an Electrical Engineering Application Pack for use with the package. Not only does it serve as a useful set of programs in its own right, but it also provides many welcome tips on applying MathCad to other problems.

As we have seen in a previous review (Modelling with MathCad, *EW + WW* March, pp. 230-233) MathCad has several features of interest to the electronics engineer. It is a page oriented-environment where mathematical expressions can be entered directly and evaluated, and has a good facility for graphing results and also displaying data in tabular form.

Many built-in functions are included such as ROOT and SOLVE which are quite powerful tools for solving iterative equations. Data can be imported from disk files and subjected to a range of text processing options. From an engineering prospective, there are several interesting features including a fix on the units which are used during the course of the calculations.

In the EEA pack some of the programs ) are of limited use but others are applicable to every-day engineering problems. The pack comes as a booklet with listings of each program and a generous description of application. The booklet is also accompanied by a floppy disk with the programs which can be imported directly into the MathCad environment.

A typical example from the selection is the Smith chart, used to map impedance as a function of reflection coefficient (**Fig. 1**). Data for creating the Smith chart is provided on the disc as a data file. As the changes are made to the load impedance Z, the contours change accordingly.

Engineers already using MathCad will find the EEA-pack helpful as it will most certainly suggest unrealised techniques which are available within the MathCad environment. ■

### EEA PACK CONTENTS

Field patterns of a uniform linear array; waveguide, striplines, coaxial lines; two-port parameter conversions; network analysis using an admittance matrix; American wire gauge table transmission line impedance as function of frequency; Smith chart; transmission line calculations; FIR filter design by windowing design of a IIR filter; elliptical IIR filter design; Chebyshev polynomials; transfer function calculations; polar plots and Nyquist plots; Convolution and deconvolution; algebraic codes; quantising a signal; delta modulation; Z-transform applications, and unit definitions.

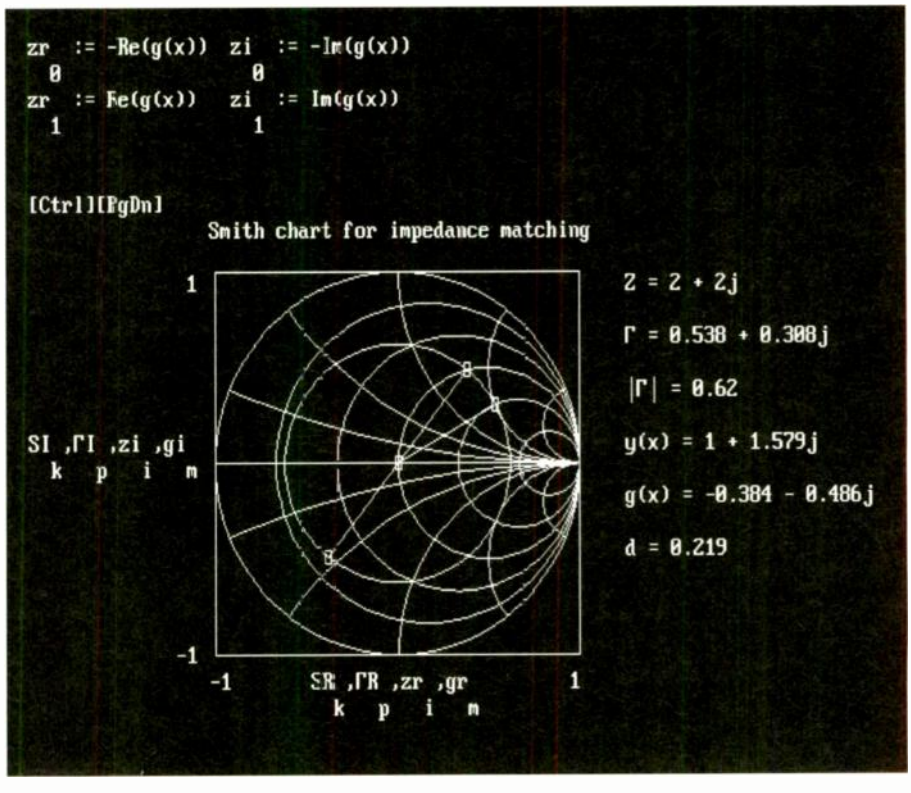



*Fig. 1. Using the Smith chart from the MathCad EEA pack*

# Take the Sensible Route!

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

## NEW VERSION

In the new version V2.40, full consideration has been given to allow designers to continue using their existing schematic capture package as a front end to BoardMaker. Even powerful facilities such as Top Down Modification, Component renumber and Back Annotation have been accomodated to provide overall design integrity between your schematic package and BoardMaker. Equally, powerful features are included to ensure that users who do not have schematic capture software can still take full advantage of BoardMaker's net capabilities.

***BoardMaker V2.40 is a remarkable £295.00 (ex. carriage & VAT) and includes 3 months FREE software updates and full telephone technical support.***

## AUTOROUTER

BoardRouter is a new integrated gridless autoroute module which overcomes the limitations normally associated with autorouting. **YOU** specify the track width, via size and design rules for individual nets, BoardRouter then routes the board based on these settings in the same way you would route it yourself manually.

This ability allows you to autoroute mixed technology designs (SMD, analogue, digital, power switching etc)in **ONE PASS** while respecting **ALL** design rules.

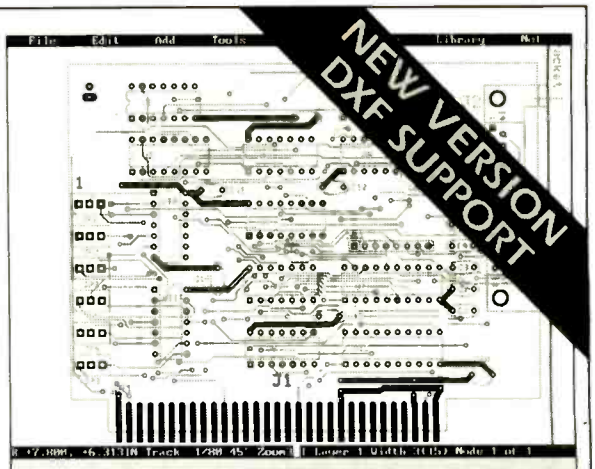
## GRIDLESS ROUTING

No worrying about whether tracks will fit between pins. If the track widths and clearances allow, BoardRouter will automatically place 1, 2 or even 3 tracks between pins.

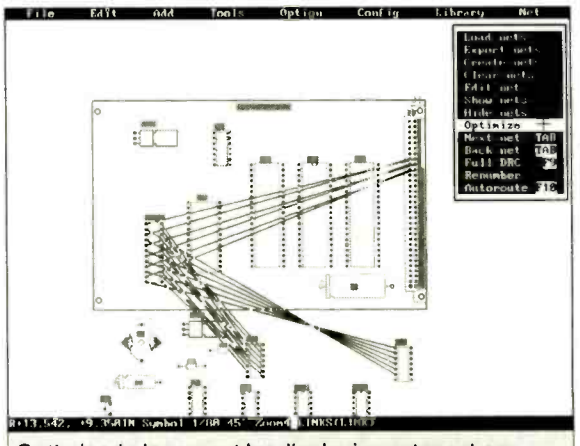
## FULLY RE-ENTRANT

You can freely pre-route any tracks manually using BoardMaker prior to autorouting. Whilst autorouting you can pan and zoom to inspect the routes placed, interrupt it, manually modify the layout and resume autorouting.

***BoardRouter is priced at £295.00, which includes 3 months FREE software updates and full telephone technical support. BoardMaker and BoardRouter can be bought together for only £495.00. (ex. carriage & VAT)***




Full analogue, digital and SM support - ground and power planes - 45 degree, arced and any angle tracks with full net-based Design Rule Checking.



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

## HIGHLIGHTS

- Net list import from OrCAD, Schema etc.
- Graphical and manual netlist entry
- Top down modification for ECOs
- Forward and back annotation
- Component renumber
- Effortless manual routing
- Fully re-entrant gridless autorouting
- Simultaneously routes up to eight layers
- Powerful component placement tools
- Copper fill
- Curved tracks
- Extensive Design Rule Checking
- Full complement of CAM outputs
- Support and update service
- Reports generator
- Gerber, PostScript & DXF output
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Access VISA

# Circuits, Systems & Standards

*First published in the US magazine EDN and edited here by Ian Hickman.*

## Innovative design techniques yield optimum counter oscillator

### Need a noisy oscillator?

How to ruin the coherence of a frequency standard! RF engineers are used to designing or procuring frequency standards, for example a 10MHz reference for a synthesizer, where the requirement is not only for long-term frequency accuracy but also short-term stability and low sideband noise. This article describes an application where long-term frequency accuracy is just as important, but short-term stability is deliberately degraded in the interests of measurement accuracy. In addition, it also describes a novel application of that good old stand-by, the 1496 double balanced modulator. **IH**

Starting with a 10-MHz oscillator and a handful of readily available commercial ICs, you can use the techniques described in this article to configure a 100-MHz counter oscillator that incorporates the random phase modulation needed to break coherence in time-interval-averaging systems.

### The quest for incoherence

To eliminate any possibility of harmonic relationships between the oscillator's frequency and that of the input signal, you must randomly modulate the 10-MHz oscillator's phase before multiplying its frequency by ten. The phase-modulator section (**Fig 1a.**) comprises a 10-MHz tank, a varactor diode and a digital noise source applied to an RC timing circuit.

The noise source used in the 1965A counter is an 8-pin IC widely used in electronic organs. The part – National Semiconductor's Model MM5837 – is a mos/MSI pseudo-random sequence

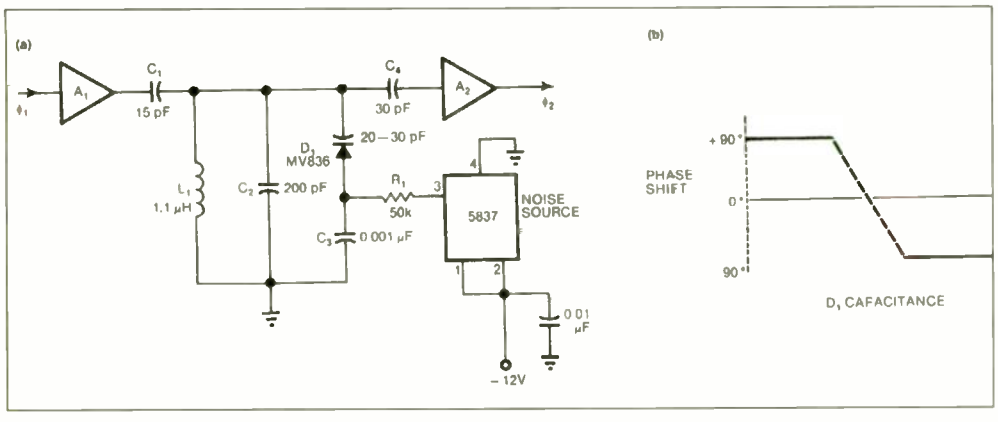
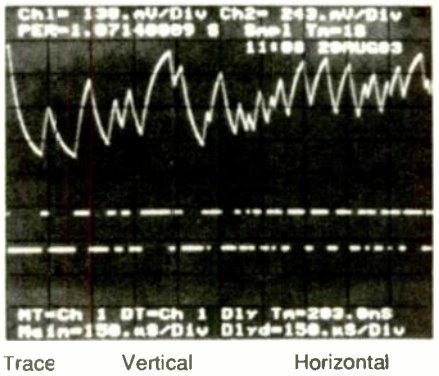
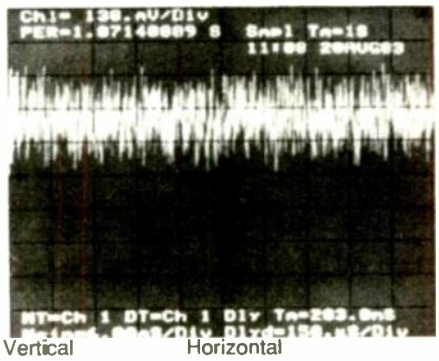



*Fig .1. Using an electronic organ IC, the circuit in (a) yields random phase modulation of the l0-MHz reference-oscillator signal. The digital white noise from the IC varies $D_1$'s capacitance to detune the LC tank circuit. (b) shows the phase variation as a function of the varactor's capacitance.*

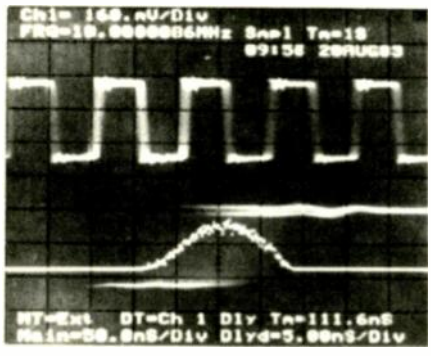


| Trace | Vertical | Horizontal |
|---|---|---|
| A | 138mV/div | 150μs/div |
| B | 243mV/div | 150μs/div |



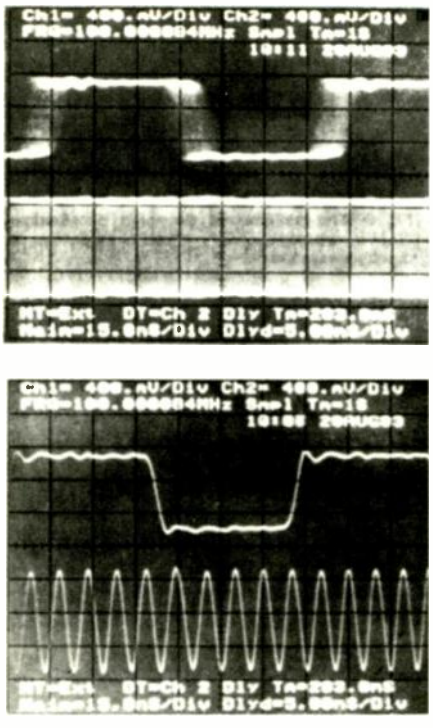
| Vertical | Horizontal |
|---|---|
| 138 mV/div | 6ms/div |

*Fig. 2. Random ramping of the varactor's anode voltage is evident in (a)'s upper trace. The ramping is caused by the digital noise seen In the lower trace. (b) shows the anode voltage with a slower time scale.*




| Trace | vertical | horizontal |
|---|---|---|
| A | 160mV/div | 50ns/div |
| B | 160mV/div | 5ns/div |
| C | 160mV/div | 5ns/div |

***Fig. 3. The bell-shaped Gaussian distribution of the 10-MHz reference signal's phase is evident in trace C's digitised waveform.***




| Vertical | Horizontal |
|---|---|
| 400mV/div | 15ns/div |

***Fig. 4. Modulated and unmodulated 10- and 100MHz signals are seen in (a) and (b), respectively. The modulation shows up, naturally, as jitter in the scope traces.***

generator designed to produce a broadband white-noise signal for audio applications. A built-in oscillator provides an output that switches between ground and the -12V rail. $L_1$, $C_2$, $C_3$ and $D_1$ constitute a tank circuit tuned close to 10MHz. $D_1$ is an MV836 varactor diode whose capacitance is a function of the reverse-bias voltage; it varies from approximately 20 to 30pF. $C_3$ and $D_1$ form a series capacitance in parallel with the $L_1/C_2$ parallel combination. $C_2$'s 200pF value in parallel with the diode's 20 to 30pF results in a 220 to 230pF tank capacitance, depending on the diode's reverse bias. With the tank tuned close to 10MHz, any change in tuning (arising from $D_1$'s variations) results in a phase shift of $\phi_2$ relative to $\phi_1$. The change in phase is a function of the non-ideal properties of the tank's components and the amplifier circuitry's input and output impedances. **Figure 1b** shows the phase shift as a function of $D_1$'s capacitance variations.

$R_1$, connected to the digital noise source output forms an RC time constant with $C_3$. Because the noise source pulse widths are always less than one time constant, the potential at $D_1$ anode is a virtually random ramping of the reverse-bias voltage. In **Fig. 2a**, trace B shows the digital noise applied to the RC integrator; trace A, the virtually random ramping of $D_1$ anode voltage. **Figure 2b** shows the same ramping signal on a different time scale.

The instantaneous voltage has an approximately Gaussian distribution, because the voltage applied to $R_1$ is a broadband white-noise signal that itself has a Gaussian pulse-width distribution. The change in $D_1$'s capacitance has a nearly one-to-one relationship with the change in its reverse-bias voltage, resulting in an approximately Gaussian $\phi_2/\phi_1$ phase distribution. **Figure 3** trace A shows the phase-modulated, 10-MHz reference signal – trace B waveform is an expansion of a leading edge; trace C digitised waveform shows the relative phase distribution at the leading edge's 50% point.

Although the 10 x frequency multiplier multiplies the relative phase shift, the absolute time shift remains constant. For example, if the $\phi_2/\phi_1$ shift changes randomly by 10° p-p, the output shifts by 100° p-p – however, the 10MHz, 10° and 100MHz, 100° shifts result in a 2.78ns time shift.

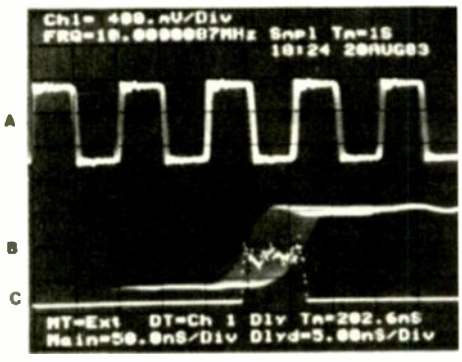
How much total phase modulation is needed? This is a critical design parameter, but the answer is not intuitively obvious. The final 100MHz output needs to have an even distribution of phase shift relative to the unmodulated 10MHz ($\phi_1$) reference. With an even phase distribution, a rising edge of the 100MHz clock occurs on the average only once in every 10ns window. The exact time occurrence of each edge of the oscillator waveform, however, is totally random.

This situation apparently creates a problem. With a Gaussianly modulated 10MHz reference clock, the 100MHz clock also exhibits Gaussian phase-shift distribution rather than the desired even distribution.

If the amount of modulation exceeds one full period (>10ns, or >360°), the distribution is effectively even for any 10ns window. When the output phase shift exceeds 360° p-p, the clock occurrences overlap into preceding and succeeding windows, resulting in overlapping distributions.

### Why use Gaussian modulation?

Summing these overlapping distributions results in an almost even distribution. **Figures 4a** and **4b** show photos of unmodulated and Gaussian-modulated 10- and 100MHz signals. But, because this




| Trace | Vertical | Horizontal |
|---|---|---|
| A | 400mV/div | 50ns/div |
| B | 400mV/div | 5ns/div |
| C | 400mV/div | 5ns/div |

***Fig. 5. A triangular waveform applied to the varactor's anode results in trace C's even distribution of phase shifts. This method, however, is difficult to control.***

technique only allows you to approach an even distribution, why use Gaussian modulation at all? It would seem the ideal solution is to modulate evenly, and you could do this fairly easily.

First, remove the digital noise source and $R_1$ from the phase-modulator circuit and apply a triangular waveform to $D_1$'s anode. Apply negative offset to the source and tune the frequency for a non-harmonic of 10MHz in the audio band. Monitor $\phi_2$ relative to $\phi_1$ and adjust the triangular waveform peak-to-peak amplitude until exactly 36° phase shift results. With triangular-waveform reverse bias applied to $D_1$'s anode, the anode's instantaneous voltage is always evenly distributed, resulting in a correspondingly even $\phi_2/\phi_1$ phase-shift distribution, as shown in **Fig. 5**.

This technique is not without problems, however – you must obtain exactly 36° phase shift; no more, no less. If you obtain only 35° p-p shift, for example, the output will shift by 350° p-p. This scenario produces "voids" in the 100MHz signal (**Fig. 6a**). If, on the other hand, you overmodulate by 1°, the output displays 370° p-p shift. This situation results in the shift's overlapping into preceding and succeeding windows, destroying the evenness of the distribution (**Fig 6b**).

Undermodulation and overmodulation conditions create undesirable bias, which occurs when clock edges are no longer totally random; the counter is biased to trigger in some areas of any 10ns window, in preference to other areas in the same window. The result is biased (ie, wrong) answers. For the two described undesirable conditions, each 10ns window has two distinct levels of even distribution, as shown in Figs 6a and 6b.

The exact amount of peak-to-peak phase shift depends on component values in the phase modulator's tank circuit. Because it's not practical to control tightly the components' variances, the best technique for attaining almost-even phase modulation is to overmodulate the 10MHz signal (in Gaussian fashion) in the range of 50° to 80°. This action results in 500° to 800° p-p modulation of the 100MHz output. With this Gaussian technique, the exact amount of peak-to-peak modulation is not critical.

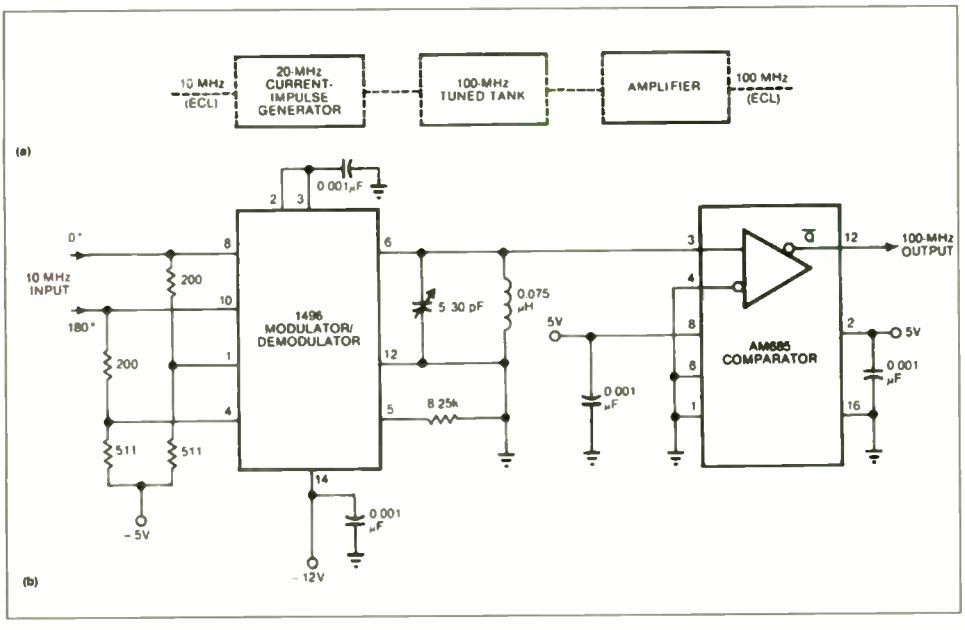
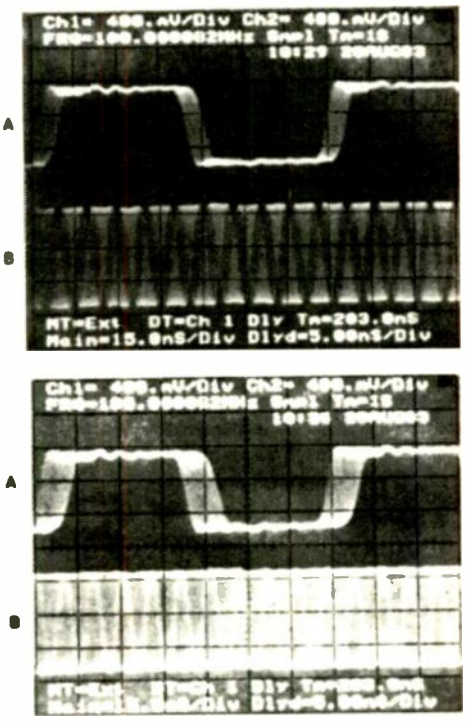



***Fig. 7. Multiplying the 10MHz reference signal by ten is easy with widely available modulator/demodulator and comparator ICs. Current impulses from the first IC cause 100MHz ringing in the tank circuit; the comparator evens up the waveform.***




| Vertical | Horizontal |
|---|---|
| 400mV/div | 15ns/div |

***Fig. 6. Undermodulation and overmodulation create problems in the even-distribution method, evident in these photos. Undermodulation creates voids in the 100MHz signal (a); overmodulation, an uneven distribution (b).***

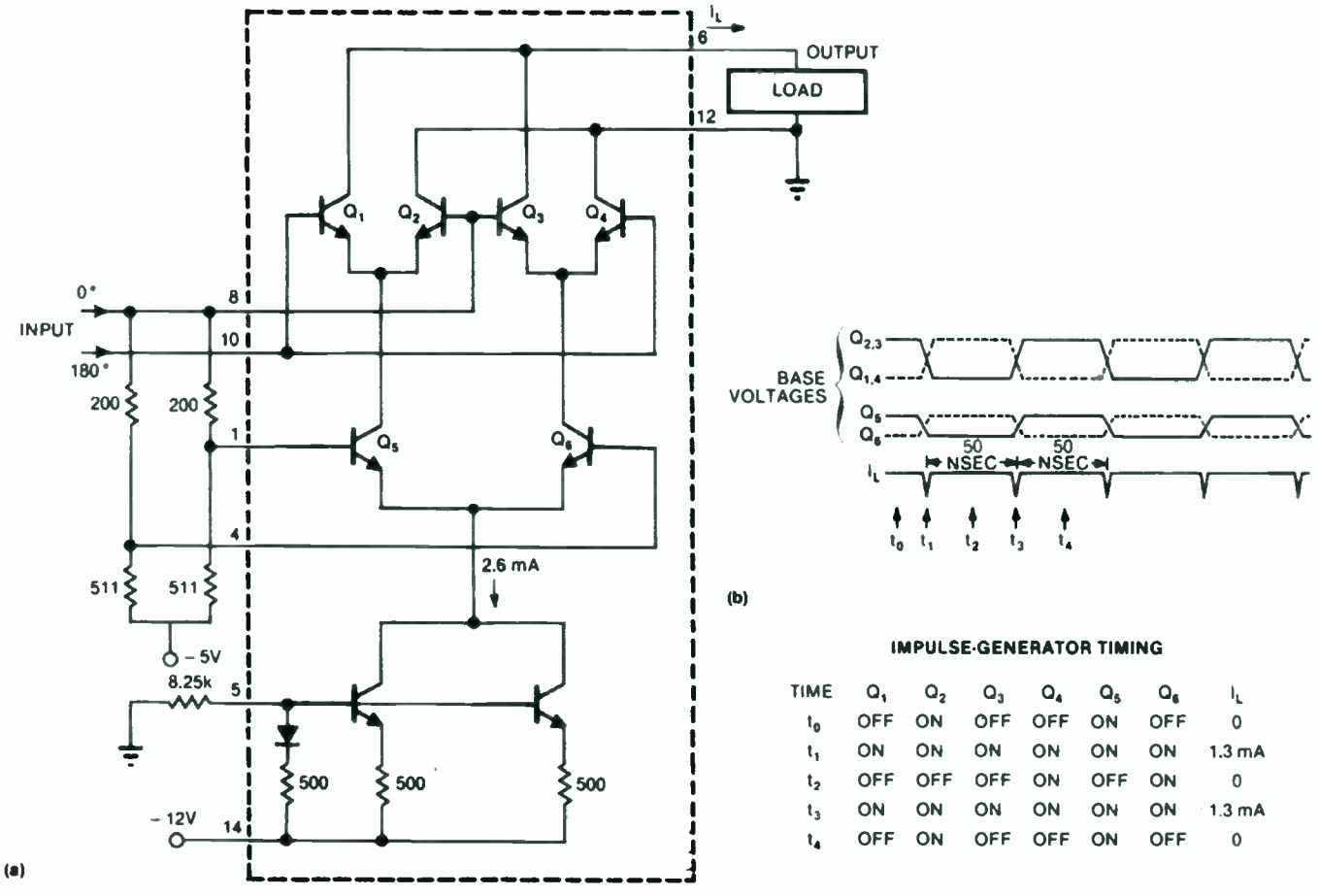
### Multiplier steps up the reference

The frequency multiplier steps up the reference oscillator's frequencyfrom 10 to 100MHz, resulting in a 10ns reference-clock interval. As **Fig. 7a** shows, the multiplier circuit comprises three blocks: a current impulse generator, a 100MHz tank and a comparator amplifier. **Figure 7b** gives a detailed schematic of the multiplier chain.

The 20MHz current-impulse generator uses a modulator/demodulator IC to create current spikes for each transition of the 10MHz input signal.

The IC used is the industry-standard 1496, produced by Motorola, National Semiconductor, Signetics and Silicon General. **Figure 8a** shows the IC's internal configuration and associated input/output circuitry.

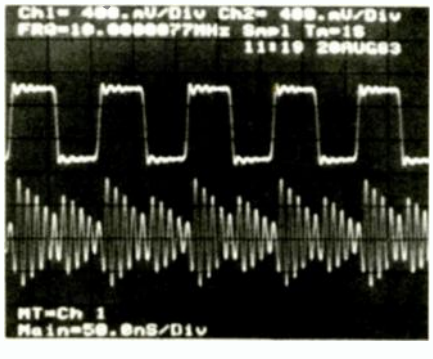
In this application, the unit is always




**IMPULSE-GENERATOR TIMING**

| TIME | $Q_1$ | $Q_2$ | $Q_3$ | $Q_4$ | $Q_5$ | $Q_6$ | $I_L$ |
|---|---|---|---|---|---|---|---|
| $t_0$ | OFF | ON | OFF | OFF | ON | OFF | 0 |
| $t_1$ | ON | ON | ON | ON | ON | ON | 1.3 mA |
| $t_2$ | OFF | OFF | OFF | ON | OFF | ON | 0 |
| $t_3$ | ON | ON | ON | ON | ON | ON | 1.3 mA |
| $t_4$ | OFF | ON | OFF | OFF | ON | OFF | 0 |

*Fig. 8. The modulator/demodulator IC emits a current pulse for each transition of the 10MHz signal's waveform, resulting in a 20MHz chain of pulses.*




Vertical 400mV/div
Horizontal 15ns/div

*Fig. 9. Excited once every 50ns by a jolt of current, the tank circuit creates a series of exponentially decaying 100MHz waveforms. The comparator then does its limiting and amplifying job to produce a uniform 100MHz output.*

operated in a saturated mode, resulting in digital current switching.

The 1496 has two differential-input pairs. The 10MHz oscillator connects to the upper inputs (pins 8 and 10), driving a quad differential pair ($Q_{1,2,3,4}$). The same signal, slightly attenuated and shifted toward the negative, connects to the lower inputs (pins 1 and 4), driving a differential current switch ($Q_{5,6}$). In steady state conditions, all current supplied by the constant current source (-2.6mA) is dumped from pin 12 to ground. When the input at pins 10 and 4 is high relative to that at pins 8 and 1, the current is channelled through $Q_5$ and $Q_2$.

When the input's polarity reverses, all current is channelled through $Q_6$ and $Q_4$. The only time the load receives any excitation is during the input's high-to-low or low-to-high transition. At one point during each transition, all transistors are equally biased in their active range, resulting in the dumping of approximately half the current (-1.3mA) from pin 6 to the load. **Figure 8b** shows a functional timing diagram of the relative transistor base voltages and output current.

With the output of 20MHz current pulses, it's relatively easy to pick off the fifth harmonic (100MHz) with a highly tuned, high-Q tank circuit. **Figure 9** shows the tank's output – an exponentially decaying sinusoid excited once every 50ns. Finally, the AM685 high speed comparator (made by Advanced Micro Devices) yields the amplified 100-MHz output.

**Johnnie Hancock, Hewlett-Packard Corp.**

# Hazarding a guess at EMR effects

***We are starting to understand cellular mechanisms. So will we look back on current EM limits with incredulity? Roger Coghill reports from bio-hazard conference BEMS 1991.***

A record 170 papers from 13 countries drew over 400 delegates to Salt Lake City to hear the latest research results from the world's major bio-effects laboratories – and there was plenty to interest electronics engineers wondering whether their daily exposure to electromagnetic fields could be a long-term health hazard.

Most of the presented papers concerned ELF effects, but there were also insights into RF and microwave interaction with human and animal tissues.

Arguably the highlight of these was a further sneak preview of a new Electric Power Research Institute-funded study measuring EM fields in the homes of 232 leukaemic children in six counties round Los Angeles.

The EPRI study has already received much media attention, but has still not been accepted for publication. The research team, headed by Dr. John Peters of Southern California University and Joe Bowman had clearly hit difficulties with their dosimetry. Bowman admitted that instrument battery failure and related problems had necessitated substitution by another make after the study was underway. So data-sets were not comparable, and that (perhaps in consequence) no correlation was likely to be reported between electric field strength and leukaemia incidence.

A correlation was found, however, with external wiring configurations, and with certain appliance use (eg hair-dryers, monochrome TVs) – seen by cynics as a move which neatly shifts product responsibility from EPRI members to appliance manufacturers.

Further question marks hang over the Peters' protocol. Spot measurements of ambient EM fields were taken in the middle of children's bedrooms, rather than at the bed itself, and thus were well away from domestic electric circuits, which are usually routed round the walls. Mid-room fields thus measured are likely to be minimal: other research has shown that within one room alone ambient EM fields can vary up to ten-fold.

Another somewhat disappointing paper came from Bob Mcgaughy of EPA, who last year caused an international storm by proposing in his 400-page draft review of the published research that EM fields shouldbe viewed as a "probable human carcinogen". Publication of the final version of the EPA report has been delayed ever since, and his BEMS presentation did not build on last year's conclusions. Some were saying that the final EPA document may never actually see publication.

### New initiatives

Several new initiatives were announced at the conference, and the Health Effects Research Laboratory (previously connected with auto exhaust emission research) announced a $2.5 million annual research effort. The initiative will commence in June 1992 consisting mainly of US research project applications and 60Hz. studies.

In Canada a 600 case-control study of childhood cancer was just beginning, expected to report in four years time, while the National Academy of Sciences and the FDA are also beginning major projects in a research field previously dominated by EPRI funding.

### UK BEHIND THE TIMES?

Shamefully only one (minor) paper presented at BEMS came from the UK, demonstrating how far behind we are in this field. It was from the NRPB and looked at what happens to fetal development of mice in a 20mT field – a level somewhat removed from the real world.

The researchers found no adverse effects.

The paucity of UK bio-electromagnetics research effort contrasted with the appointment of Brian Maddock from the UK National Grid to the chair of the mysterious "Research Coordinators' Group", which met during the two days prior to the main meeting behind tightly closed doors.

Despite all the media publicity voicing concerns about power-lines, computer screens, electric blankets and microwave ovens, the Grid has not researched the measured effects of power-lines on adult members of the public (though one promised study is overdue), and its current modest £600,000 research programme is largely confined to peripheral cell studies.

Enertech Consultants and The National Cancer Institute are also investigating childhood lymphocytic leukaemia and low frequency EM fields, a happy combination of public and private enterprise. They reported in a pilot study that geometric mean magnetic field exposure in 29 test cases (between four months and 8 years) ranged between 0.8-1.4mG with a standard deviation of 2.4. This suggests maxima in excess of 3.36 mG, which is above the "carcinogen threshold" found by Savitz and others. Final results from these studies will not report for some years.

### Limits announced on VDU exposure

High on the list at Salt Lake were VDU bio-effects papers. The Swedish Government agency Swedac has announced permitted exposure guidelines for ELF fields emitted from computer screens (effective from January 1991) at only 25V/m electric and 2.5 mG magnetic, and the US is likely to follow soon with similar if slightly higher E-field guidelines, possibly 50V/m.

The problem - ultimately likely to cause an even bigger stir than the EPA report- is that several of the BEMS papers were reporting consistently that such levels are by no means uncommon in the bedrooms of sleeping adults or children. The Peters-Bowman report for example found outlier fields averaging 27mG, with a maximum of 67mG.

Houses under power-lines and utility- or related occupations could exhibit even higher levels.

Clearly it is illogical that NRPB guidelines should permit chronic exposure to field levels in the home, or factory, which are likely to be banned for computer screen operators. By January 1993 the European Commission will have to set its own standards, probably following the Swedish model. LCD or gas plasma screens (which emit little if any EM radiation) are not likely to become common-place before the mid 1990s, there are some 8 million aging VDUs being used right now in the UK alone, many of which are probably illegal by the new Swedish standard. These can be tested by cheap Gauss and E-field meters now becoming available at under £50 both here and in the US.

Against this controversial background all eyes were on the latest VDU research findings. Monica Sandstrom from Sweden's National Institute of Occupational Health at Umea reported a 3.0 odds ratio of likely skin symptoms from VDU use, and another Swedish paper (Hamnerius and Galt from Goteburg) revealed a means of reducing magnetic VDU fields by superimposing equal and opposite fields round the deflection coils. (Incidentally Howard Bassen from the FDA's Center for Devices and Radiological Health coyly announced a similar reduction technique for electric blankets, which the FDA has patented.

But if the FDA is already recognising EM bio-hazards it must be asked why the epidemiology results are so controversial? Could it be because of a delicate dance of avoidance by vested interests, resulting in contrived or dubiously flawed studies like that of Peters- and indeed Fulton before him?).

Other studies on eggs and rats fuelled the VDU controversy, and from Serduk and Polka in the USSR one significant, but overlooked paper, reported the bio-effects on 1386 children living in 13 cities near radar sites.

The children showed psychoneurological impairment 2-3 times more often than that of controls, including delay in puberty by up to one year, and also haemodynamic lability, increasing in proportion to exposure. These effects were confirmed by clinical examination of their CNS physiology. Exposure levels were stated as being in the order of 50$\mu W/cm^2$, which is of course wildly below current Western exposure limits.

### Dramatic confrontation

The most dramatic moments in the meeting happened during a set-piece confrontation between Professor Robert Park of the American Physical Society and former Nobel laureate Eberhardt Neumann. They debated the existence of any bio-effects from non-ionising EM fields.

Park's brave opening argument was that thermal noise is some 2000 times the levels supposed to cause bio-effects, and that experimental "evidence" is far from robust.

He cited the difficulties confronting exponents of the ion cyclotron resonance hypothesis of EM-cell interaction (eg the resonating radius of the ion's path is over a metre across, during which orbit it will inevitably collide with other particles). He also recalled the famous calcium efflux experiments of Ross Adey and Carl Blackman, where quite differing results (both inhibition and enhancement) were found in very similar protocols, and suggested it all simply boiled down to temperature differences. He even cited the new Peters study as being atypically equivocal and confusing result.

In fact Park's information on ion cyclotron resonance is out of date – Lednev's precession hypothesis has probably now superseded it – and one paper by Bob Fitzsimmons from Loma Linda reported good experimental confirmation of his notion, (though another from Goteburg using patch clamped techniques found no effect).

Neumann replied that organic cells were clearly capable of selective signal recognition and amplification. He cited the acetylcholine receptor as an example of information storage, and alluded to the late Professor Frohlich's examples of retinal signal amplifying systems. Because of electrochemistry there is always an E-field effect in biological systems, he concluded, just as there is always kt thermal noise.

But just as radio technology allows us to select radio signals and amplify them coherently, cells can also distinguish signals against a high noise background. Moreover they are capable of co-operative action, and this alone can be viewed as an amplification system.

Ross Adey had his own view on the exchanges and accused professor Parks of "an appalling ignorance of the way biology works" and questioned whether he should have been allowed to address the meeting at all.

But controversy apart, BEMS this year gave the distinct impression that real progress has been made in understanding cellular processes and mechanisms, and that epidemiology is not far behind. Within a few years the current NRPB guidelines will surely be looked back on with almost incredulity, just as we look back today with horror at the early days of X-radiation limits. ■

**PIONEER WORK**

This year's D'arsonval Award went to Andy Bassett for his pioneer work in non-union fracture repair using specially structured EM waveforms applied to the locus of the fracture.

Thousands of people would have now been amputees if it had not been for his techniques.

But Bassett's influence stretches far beyond that. Reba Goodman went first to him before commencing her decades-long programme of investigation into EM-induced RNA transcription, which has gained us so much knowledge about how weak EM fields cause important geneticchanges. The emergence of electromagnetic medicine of this sort preludes a new paradigm in therapeutic practice, and once more there were a scattering of papers this year on such research.

**HOME EXPERIMENTS**

New light is emerging on why some homes have high fields and others do not. Creation and elimination of unbalanced ground return or "vagabonding" currents was the subject of at least three papers, mainly from Europe. These imbalances occur when the current from a transformer returns not via the neutral cable offered for the purpose, but directly through the ground, usually because this is a quicker route. Such unbalanced currents can cause magnetic fields as high as 12mG in some homes, and since mere distance from a sub-station is not crucial to the field strength (as we have shown), they may provide a clue to childhood leukaemias and to certain kinds of adult ill health.

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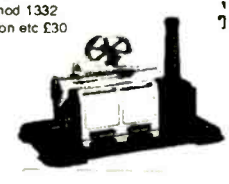

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# Design brief: voltage references

## *Ian Hickman looks at voltage reference circuit designs.*

Voltage references have made great strides in the last quarter of a century, since solid state types replaced gas tubes. First on the scene was the zener diode, used with a simple series current-limiting resistor, **Fig. 1a**. Popular ranges were the BZY88- series (Mullard/Philips) and the American 1N821 - 827 series.

Slope (incremental) resistance and the temperature coefficient of a zener diode each affect both the stabilisation (change of output voltage with change of supply voltage) and the regulation (change of output voltage with output current drawn) of the circuit.

Operating mechanism is true zener breakdown for low voltage diodes and avalanche breakdown for higher voltage types. The former has a negative "tempco" and the latter a positive, accordingly at the changeover point – somewhere between 4.7 and 5.6V where both mechanisms occur – the tempco is near zero, varying with the device process used and also with operating current.

Thus it was tempting to use a nominal 5.1V diode where high stability was required, but unfortunately the lowest slope resistance is found in diodes of about 7.5V nominal; these were therefore often preferred where good regulation and particularly stabilisation were important. But, the quoted slope resistance of a zener is always measured adiabatically, by superimposing a small AC ripple component on the DC current and observing the ripple voltage.

The temperature of the diode does not vary in sympathy with the instantaneous current as the frequency of the AC is too high, so the tempco does not influence the result. Many an unwary circuit designer has chosen a zener with the lowest slope resistance only to find the apparent stabilisation of a circuit much worse than expected: when the supply voltage is suddenly increased, the increased dissipation in the diode raises its temperature and the positive tempco then contributes a rise in output voltage above and beyond that due to the extra current flowing through the slope resistance.

In **Fig. 1b** and **1c** the high slope resistance of a depletion mode fet greatly reduces any current variations through the diode due to change of supply voltage. But a fet is comparatively expensive, and anyway has an embarrassingly high variation, up to 5:1, in drain saturation current $I_{dss}$, controlled to some extent by the self-bias resistor in Fig. 1c.

The circuit of **Fig. 1d** seems to be comparatively little known but is very economical: any increase in current through the zener diode due to increased supply voltage would tend to increase the base emitter voltage across $R_2$, shunting most of any increase in current through $R_1$ to ground via the collector circuit.

Straightforward zeners had a long run for their money, with many ingenious circuit variations to improve regulation and stabilisation.

One I developed many years ago, published in Wireless World under the title "Two for the Price of One", provided two stabilised supply rails using a single zener diode. However my favourite augmented zener circuit is shown in **Fig. 2a**. Here, the zener is incorporated in a bridge circuit which is driven by an op-amp whose input signal is the bridge output. The circuit is thus a little incestuous and usually needs a resistor (shown dotted) to ensure reliable start-up.

However its value can be as high a 10MΩ, so that although it feeds some current into the zener from the unregulated input voltage, its effect on stabilisation is negligible. The op-amp buffers the load current, resulting in excellent regulation, whilst the bridge is fed from a constant voltage, resulting in constant current through the zener and hence excellent stabilisation.

This circuit is available in IC form, for example the Burr-Brown REF10, which is shown in **Fig. 2b** and provides 1ppm/°C max tempco, 10ppm/1000h stability, 6μV p/p noise, 0.001%/V stabilisation and 0.001%/mA regulation.

These are two-terminal devices, needing an external current limiting resistor just like a zener diode. However the "knee current", that is, the current at which the slope resistance has fallen to a low value, is very low for these devices – less than 100μA, making them ideal for battery-powered applications. They are also available in trimmable three-terminal styles and in SMD – surface mount – packages.

### Variations and applications

Voltage references are available in a wide range of output voltages such as 2.5V, 5.0V and 10.0V while others cater for binary-oriented instrumentation, with 2.56V, 10.24V outputs etc. Two-terminal types are subject to a selection tolerance but many three or more terminal devices offer the facility to adjust the output voltage exactly to the nominal. Where an output voltage is required which is not available as standard, the circuit of Fig. 2a is ideal; by choosingappropriate values for the bridge resistors, any desired output voltage can be obtained. Where several different voltages are required simultaneously, the highest can be produced with a Fig. 2a type circuit and the others obtained from it with a potential divider string of precision (or adjustable) resistors, the tappings being buffered with non-inverting op amps.

Very often however, only one voltage is required at a time, but it must be adjustable

***Fig. 1. Voltage references built around the zener diode*** *(From Analog Electronics, Ian Hickman, 1990. By permission of Heinemann Newnes).*

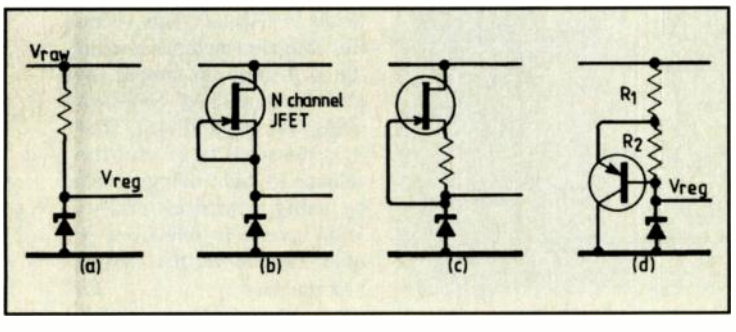
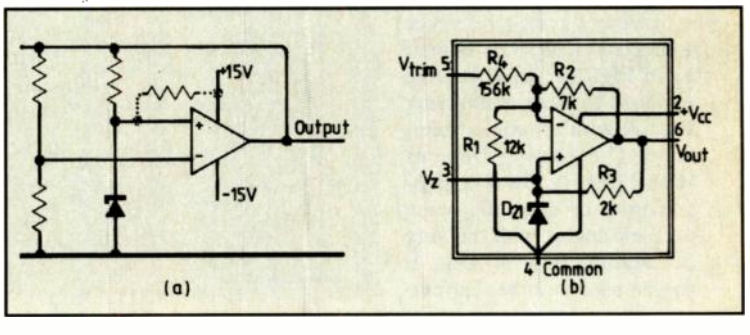



***Fig. 2. Two of the many augmented zener circuits developed.***



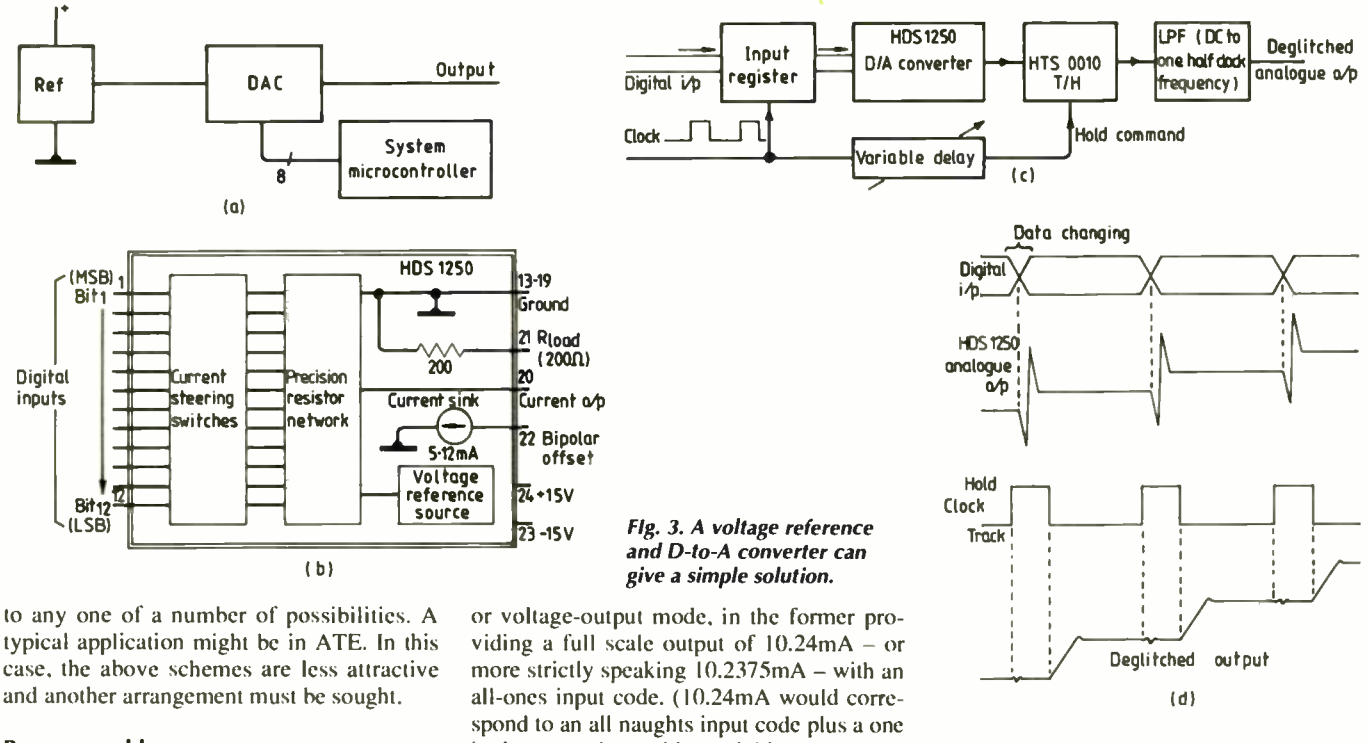



*Fig. 3. A voltage reference and D-to-A converter can give a simple solution.*

to any one of a number of possibilities. A typical application might be in ATE. In this case, the above schemes are less attractive and another arrangement must be sought.

### Programmable sources

A simple solution, particularly attractive in ATE where a microcontroller is incorporated to organise the operation of the system, is to use a voltage reference and a multiplying D-to-A converter, as indicated in **Fig. 3a**. The D-to-A chosen will determine the resolution to which the voltage can be set. For instance, with an 8-bit D-to-A and a 10.24V reference such as National Semiconductor's LH0071-OH, the resolution will be 40mV, ie. 0.39% of full scale, which in many cases would be inadequate.

Using a 10-bit unit, such as Philips' MC3410F, would improve the resolution to 10mV or better than 0.1% FS, while a 12, 14 or 16-bit multiplying D-to-A would clearly provide much greater resolution. The accuracy of the output would also improve generally in line with the resolution, but the designer must decide just what is needed and can be afforded: many D-to-As are available in various selection grades offering an accuracy which may be as high as 1/4 of an LSB (least significant bit) inbetter devices, to as poor as one and a half LSBs in more economical sorts.

Instead of using a reference source and a separate D-to-A as in **Fig. 3a**, an attractive option is to use a multiplying D-to-A with a built-in reference. The Analog Devices HDS-1250 **Fig. 3b** is a high-performance example, being a 12-bit device with the very fast settling time of 35ns. It can be used in either current- or voltage-output mode, in the former providing a full scale output of 10.24mA – or more strictly speaking 10.2375mA – with an all-ones input code. (10.24mA would correspond to an all naughts input code plus a one in the non-existent thirteenth bit).

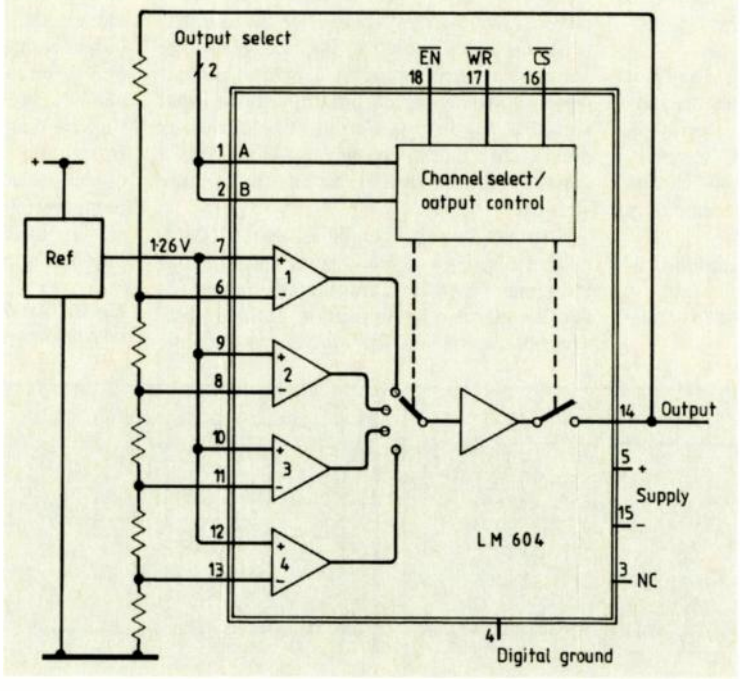
Glitches commonly occur when the output of a D-to-A changes, and these can be pronounced if there is any skew between the various bits of the control word. In some circuit applications, this can be most embarrassing. One way to reduce these is to include input buffer registers in the D-to-A, as in the AD7224 cmos monolithic 8-bit double buffered voltage output unit from Maxim. In addition to de-skewing the input data word, double buffering permits simultaneous updating in systems where several D-to-A channels are successively written to by a single controller. **Figure 3c** shows alternatively how a T/H (track-and-hold circuit) can be used in conjunction with an unbuffered device such as the HDS-1250 mentioned earlier. The minor residual switching transients introduced by the action of the T/H are very fast and contain little energy, **Fig. 3d**: they are easily eliminated by a little light lowpass filtering.

In electronics there are usually many ways of achieving the desired result; and that is true here, especially where only a few output levels are required.

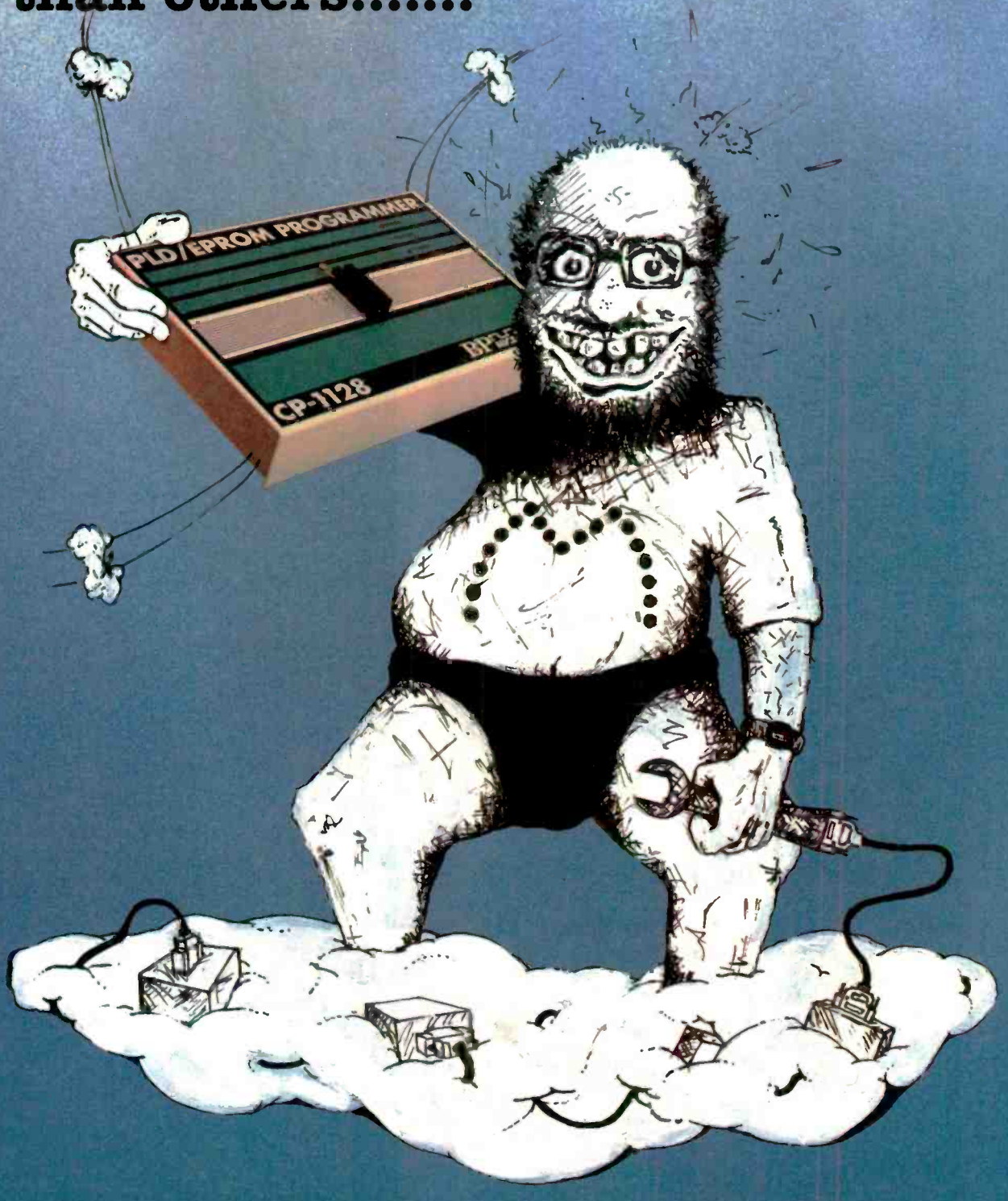
In this case an economical solution is to use a voltage reference plus a mux-amp. The latter is an op-amp with two or more input stages, only one of which is activated at a time. The gain is thus determined by the feedback components associated with the selected stage.

A good example is the National Semiconductors LM604, with four input stages, and a typical application is shown in **Fig. 4**, where two data bits determine, under control of the CHIP SELECT BAR and WRITE BAR pins, which of the four output levels is selected. This versatile chip also includes a facility to disable the output, so that the outputs of two such chips may be paralleled. Thus it is possible to extend the scheme to eight output levels by using a third bit and its logic inverse to select one or other LM604 via the ENABLE BAR inputs. ■

*Fig. 4. Circuit providing one of four different outputs of 1.26V or more.*



# Some programmers are more powerful than others.....

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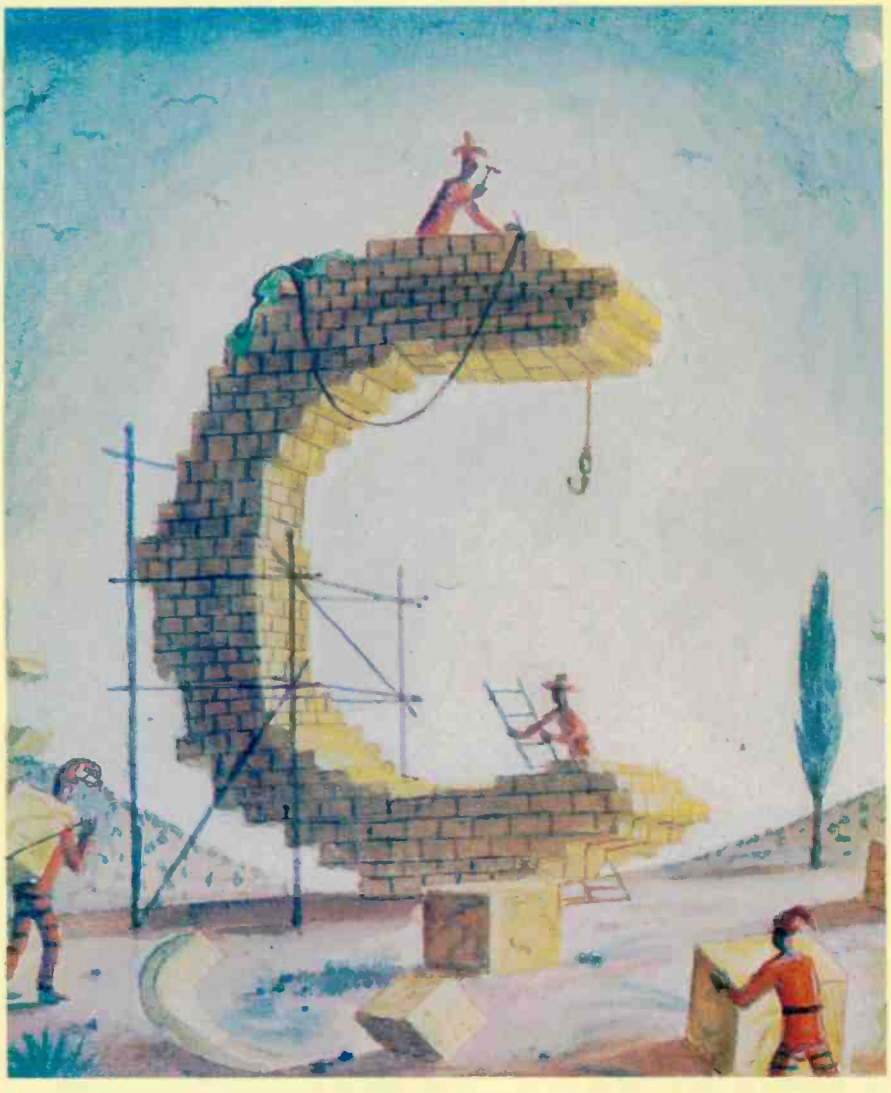


# INTERFACING WITH C

by

HOWARD HUTCHINGS

Interfacing with C can be obtained from Lindsey Gardner, Room L333, Quadrant House, The Quadrant, Sutton, Surrey SM5 2AS. Please make cheques for £14.95 (which includes postage and packing) payable to Reed Business Publishing Group. Alternatively, you can telephone your order, quoting a credit card number. Telephone 081-661 3614 (mornings only, please). A disk containing all the example listings used in the book is available at £25.50 + VAT. Please specify size required.

# C HERE!

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

But, rather than turning up old issues of the journal to check your design for a digital filter, why not have all the articles collected together in one book, Interfacing with C?

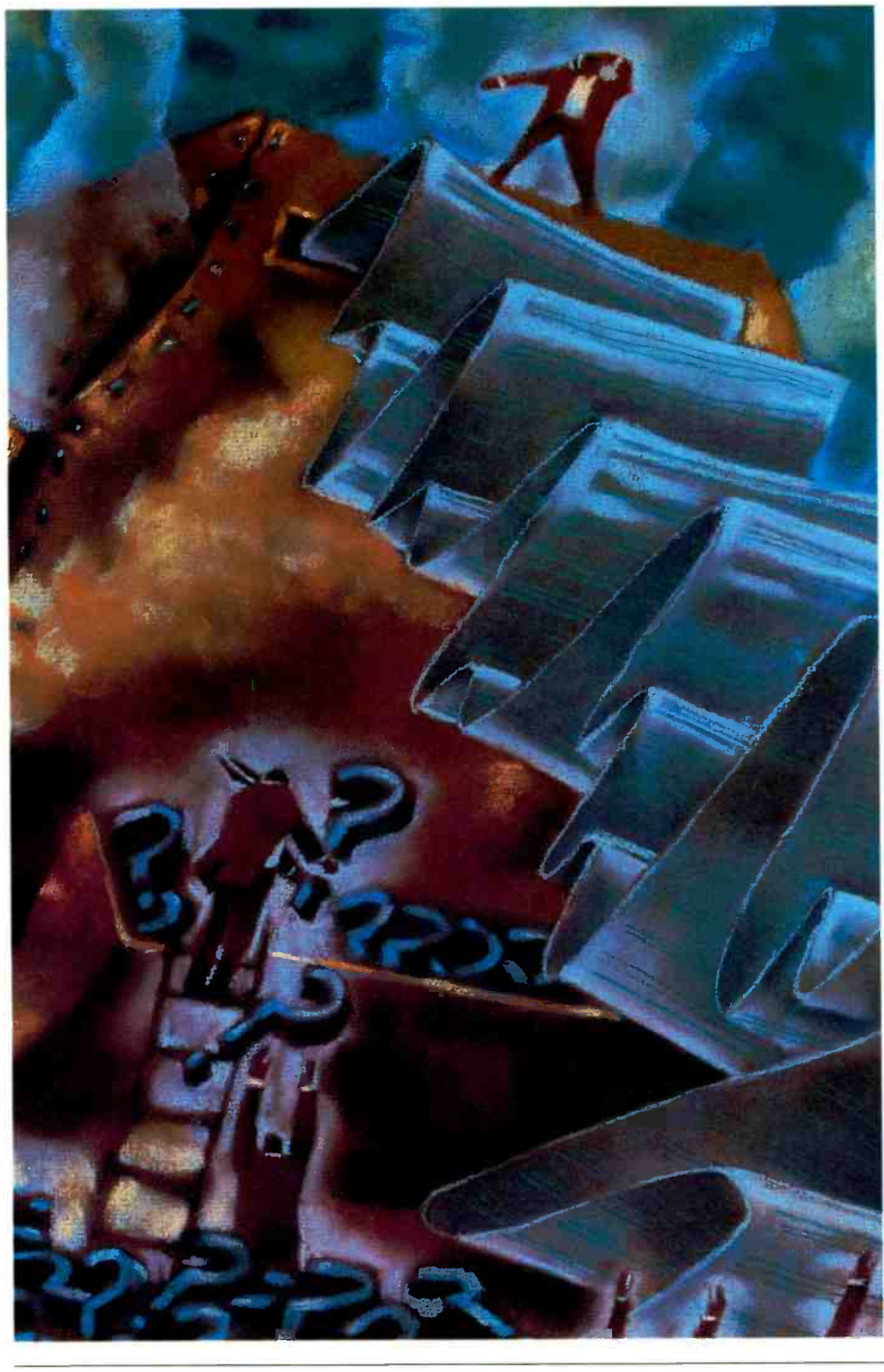
The book is a storehouse of information that will be of lasting value to anyone involved in the design of filters, A-to-D conversion, convolution, Fourier and many other applications, with not a soldering iron in sight.

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

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

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

# NO IFS– NO BUTS



***Does the classic IF routine unnecessarily complicate program and encourage bugs? Yes, but there is a solution, writes Frank Pettit.***

That every non-trivial programme contains at least one bug is an accepted part of computing. But from my own experience as programming skills improve, the count of IFs per programme decreases while program success increases.

The result of this observation has been analysis of domain partitioning (see box), a phenomenon that takes place whenever an IF is encountered in a programme, resulting in partitioning of a data domain and its corresponding function.

**Logical origin of IFs**

High-level programming languages were derived from formal logic, which includes the propositions p and q: "if p then q", closely associated with the implication: p implies q, and also with the Boolean: p Or Not q. But why was the fuzzy IF... form ever introduced into programming?

IFs can result in non-analytic programs which cannot be "proved" and are fairly certain to contain complex domain partitioning conditions possibly leading to those unwanted behaviourial characteristics known as bugs.

In the programming world an inordinate amount of time is wasted on debugging programmes – even high flying professionals cannot escape from the problem. In addition, valuable time has to be devoted to teaching principles of debugging. In any software production kit, whether assembler, C, or dos, a major component of the kit is the debug software.

Having traced a bug we normally cheer, denote the conditions which exist "when the bug appears" and set about constructing a

trap, by slipping in either an IF with a clutch of ANDs, or a few IFs with some ORs and NOTs. Unfortunately we often fail to consider how the IFs will affect domain partitioning.

An important question is when does an IF cease? At the end of a repeat? At the end of a block or procedure or function - do IFs affect behaviour throughout programme execution? The main consideration is, at a given point in programme execution time, how many IFs actually remain effective (**Fig. 4.**)?.

In my view, the answer governs the true complexity of the programme and hence its reliability. I believe determining dynamic data complexity is more appropriate than the popular view that complexity is determined by number of variables in a program.

### Making matters worse

As a result of slipping in the standard "IF-cure" for a bug, further domain-partitioning complexity is introduced into the program, possibly creating even more bugs. In other words, we can introduce non-analytic temporal IF-persistence and extreme partitioning complexity. This IF-cure normally introduces a kind of superbug which is usually untraceable and very often catastrophic.

Yet since founding of the Computer Teaching Centre at Oxford, debugging has never been taught and system programmers are not allowed near the system. Debug kits can only slow the tracing of "obvious" faults and fail when tracing "difficult" faults.

Key to successful programs is good design not skilful application of complex debugging kits. The best way is to avoid the awful traps into which IF...ENDIF, IF...GOTO, and IF-THEN-ELSE programming and there are many ways which this can be done.

### Transformations of IFs

AND: OR *and* IF: AND *transformation*

The famous DeMorgan theorems of Not (a or b) = Not a And Not b, and Not (a and b) = Not a Or Not b allow us to transform between And and Or operators, transforming between conjunctive and disconjunctive forms.

But beware the story of a research-student whose program contained almost a page of IFs to obtain a value from a multi-condition field.

The program was successful but slow. After being treated to a personal seminar on better problem analysis and programming techniques and a rethink, the student returned with a revised offering and a triumphant claim of "its much better now - only one IF".

But that IF took the form: IF...AND... AND... AND... AND - almost a page of continued ANDs. Oh the sadness when the realisation dawned that the problem had not been transformed, simply the many IFs had been transformed into ANDs.

## Data and control domains partitioned by IF

Consider a simple domain with a few ordered items: α, β, γ, δ, ε.

Given a data item 'χ' which has a proper place in this domain, we can determine such conditions as:

if χ precedes δ.

The result of this test or query is that the original domain is partitioned into two sub-domains, one contains the precedents of 'δ', the other contains 'δ' and its successors. The variable 'χ' belongs in one of the two sub-domains.

### Domain of integers

This domain is two-dimensional, by name and value. Thus we could query:

"Which is the first named item to have less than a given value?" In conventional programming languages we would be tempted to use IF again as in:

```
for n := 1 to k do  if  l[n] < j  then....
```

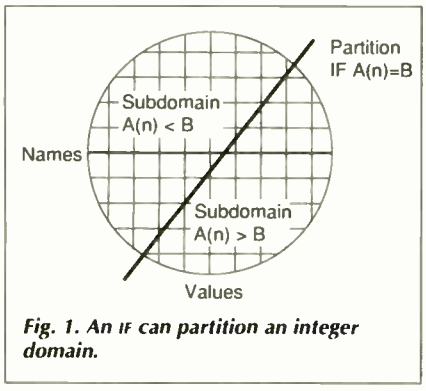



***Fig. 1. An IF can partition an integer domain.***

which results in a line which traverses the finite domain and again, partitions it (**Fig 1**).

This time, our partition can actually pass through some of the cells of our domain. Thus the partition has some cells either side, giving two sub-domains, while other cells are traversed by the partition, giving a third sub-domain. The situation is non-simple but long ago we learned how to choose "<" or "<=" or ">" or ">=" or "=" or "<>" when interrogating a data domain of integers. We also learned that the contrary of "<" is ">=" and that Not ">" is "<=".

When a computer program contains a number of IFs acting on the same data domain, the pattern of sub-domains becomes more complicated. For example three IFs, operating on an integer domain can produce a triangular sub-domain where the three partitions intersect (**Fig. 2**) and six surrounding sub-domains. There are also the three on-partition sub-domains and three compound sub-domains at the intersections of the three partitions. A total of up to thirteen sub-domains is possible from only three IFs.

So we are considering the effect of the program reacting with the data, not just whether we have chosen the correct relational operators and array elements.

### Domain of sets, records or strings

From this point of view, sets, records and strings behave in a similar way to valid integers, giving the possibility of multiple sub-domains and greater complexity with each extra IF-query.

### Domain of reals

Real numbers provide additional difficulties (**Fig. 3**) as the partitions resulting from IFs are of finite width. Further, the cells have indeterminate values giving uncertainty of cell area. Now that our partitions and cell boundaries have uncertain but finite dimensions, counts of sub-domains can also be uncertain.

We have learned to limit the range of relational operators by not using "=" and "<>" tests. Some of the higher level languages have limited provision for comparison or relational operators. Algol-68 has no means of comparison for equality or inequality between reals.

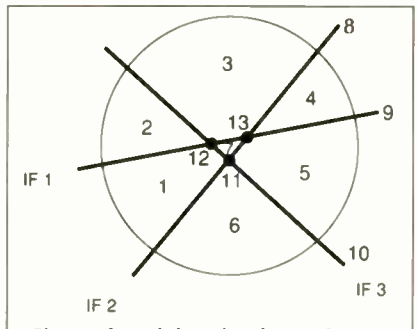



***Fig. 2. The subdomains due to three intersecting IFs.***

However, we are aware that the "proper" way to do computer arithmetic is to use mathematical libraries produced by specialists in numerical analysis. The Nag library is a fine example.

Even so, we must give valid data to the library routines and make provision for the error conditions which are bound to occur in practise and which are directly indicated by the library routines. We usually cater for this by slipping in a few more IFs, just to make sure.

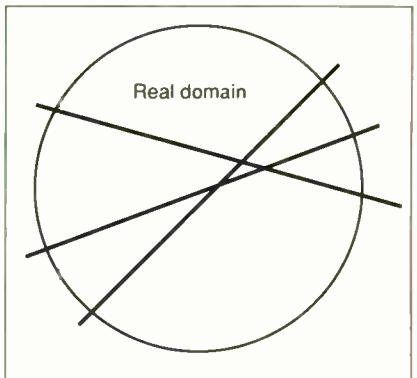



***Fig. 3. IFs produce real domain partitioning.***

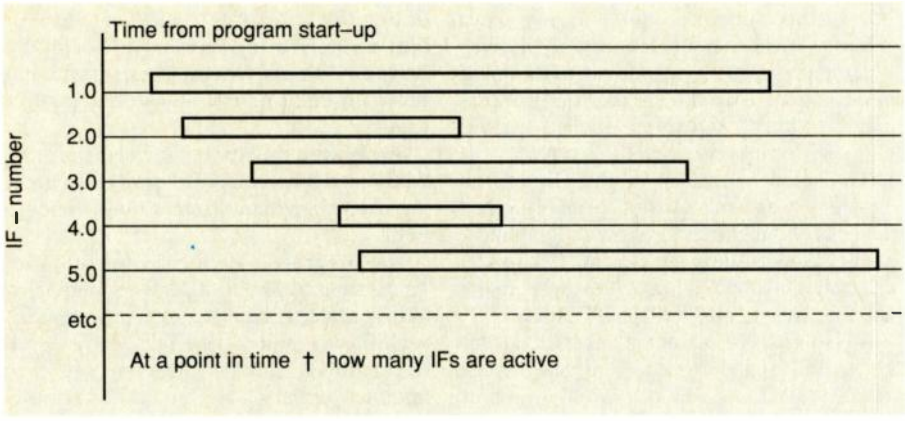



*Fig. 4. Temporal persistance of program IFs.*

The program remained successful but slow. A further briefing, a data-control transform plus a case-structured selector was substituted – program successful, fast – and no IFs.

In a recent instance, a program suffering multiple failure modes was dissected, to isolate almost all IFs. The data structures and each of the algorithms were removed and stored in disc-files. They were then re-loaded into a standard program framework and all failure modes had vanished. No debugging, no re-programming!

IF *:function transformation*

Take the simple problem of "Into C place the higher of the values from A and B".

An old-style Fortran-IV solution would be:

```
C = A
IF(B .GT. A) C = B
```

A modern alternative is:

```
IF A>B THEN C := A ELSE C := B
```

but the IF can be expunged by the use of a function. A function solution in Fortran (and others) is:

```
C = Max(A,B).
```

In this revised approach to programming, many IF-structures can, with considerable advantage, be replaced by functions. The efficacy of the IF... is in the domain of programmer - the function is a trusted routine with efficacy bounded only by the published data domain of the Function.

IF:*boolean transformation*

As a more interesting example, let us search for a peak and a trough in a varying data stream. The program segment

```
FOR n = 2 TO k-1
IF (a[n] > a[n-1]) AND (a[n+1] < a[nl])
THEN peak = n
IF (a[n] < a[n-l]) AND (a[n+l] > a[nl]) THEN
trough = n
NEXT n
```

might, with any luck, provide the positions of a peak and a trough. The simple algorithm can be modified to collect a sequence of peak and trough positions in integer arrays.

But there must be further tests to handle a sequence of repeated data values, disturbed by "noise". This normal signal condition can result in a galaxy of erroneous peaks and troughs. To correct for these circumstances, we would scatter IFs allover the place and produce a slow, delicate and un-debuggable algorithm.

Detection of a peak is when (not if but when!) data values stop rising and commence to fall.

A trough is indicated when values stop falling and commence to rise. These are two-state conditions which can be set as Boolean expressions.

To cater for noise, we use a smoothed version of the data and instead of comparing adjacent items, we compare items two or three positions apart. This removes most of the IFs. Then we set Boolean variables in place of the IFs and have an algorithm which will operate reliably under highly variable data streams:

```
rising  := this > previous;
falling := this < previous;
peak    := rising AND next < this:
trough  := falling AND next > this;
```

This can be taken further to include automatic detection and replacement of outliers (rogue values) in data sets of widely differing characteristics.

These ideas were first introduced for analysis of on-line lunar radar data during the Apollo moonflights in the late 1960s. The same logical algorithm has been applied with confidence to many bio-medical and engineering problems.

IF : *arithmetic transformation*

A common problem is to partition a range of values to provide upper and lower acceptance limits as in:

```
IF x < lower  THEN out-of-range
IF x > higher  THEN out-of-range
IF (x > lower) AND (x < higher THEN in-
range
IF (x = lower) OR (x = higher) THEN limit of
range
```

We could set this directly into almost any programming language, and be fairly confident that such errors as do occur will probably be non-serious. But we could encounter oddities such as two differing conditions being satisfied simultaneously when using those wretched real numbers.

But normal arithmetic can be cajoled into producing unique results:

**required test** lower < x < higher
**indicator** k := sign((lower - x)*(x - higher))

This indicator will take the value of -1 when out-of-range; 0 when limit-of-range, and +1 when in-range giving a fast, unique selection with not an IF in sight.

### Reliability and IF

The case for avoiding IF is further strengthened by hardware considerations. With many pipelined computers, to encounter an IF means unloading the pipeline and reloading it with the new work before processing can recommence. This can consume enough time to destroy the advantages of pipelining.

Some array processors need to have programs with no array bounds checks and certainly no IFs checking the array boundaries in the parallel maths unit. A few supercomputers rely for their speed on Fortran-derived code with no IFs and some signal processor computers have no provision for IF in their instruction codes.

### Are there any jobs left for IF?

What uses are left for IFs? Maybe to escape from a loop? But this too can be a source of mystical failure. Many loops are compiled into machine-code subroutines, making use of stacks.

To exit a subroutine under strange conditions can store up stack problems which only strike after multiple re-use causes failure of run-time stack management.

Safe loop exit depends on the language, software and conditions of use. (To avoid loss of much software-theorists hair, keep this hint secret...escape from a BASIC FOR-loop by setting the control variable to its final value, an n = k, rather than by an IF... GOTO...). Using WHILE has its own horror stories.

By deduction from the preceding facts and ideas, I believe we can propose that only programs without IFs can be bug-free. Computer programs are presented in the imperative style - so why were sloppy implicative/hypothetical forms ever introduced into programming languages?

The temporal connotation of ACTIONS by a program suggests use of the decision "WHEN condition...." which would have retained the imperative style and avoided the hypothetical form.

This would have given program designers a different attitude of mind. The concept of: "I wonder what would happen if...."? and "let's see if this will fix it...!", would no longer encourage today's shoddy work. ■

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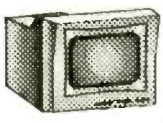

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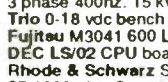

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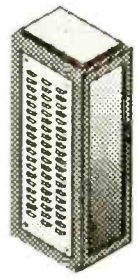

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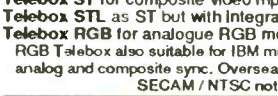

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# REGULARS

## LETTERS

### Second wave

The approach to unravelling Maxwell's waves adopted by Marti Nissinen (*EW + WW* August 1991) can be further extended by using the principle of projective geometry. This is to say that all the essential features of a "pure" sinusoidal EM wave in three dimensions (ie wavelength, amplitude and phase) will remain dimensionally unaltered by orthogonal projection into the Euclidean plane under such a condition. For example, the amplitude of a pure sinusoidal EM wave of constant frequency may be regarded geometrically to be a spiral on the external surface of a cylinder of fixed radius; its projection into the plane is a straight line enclosed in a rectangle. The exchange of energy quanta between EM waves of differing amplitude, wavelength and frequency can then be massively simplified using the modulo four geometry of orthogonal knots.

The conclusion to be drawn from this approach is that the definition of electromagnetic phenomena in terms of the mathematics of continuous functions is a tautology in that the ability of human beings to carry out any kind of mathematical manipulation has its origin in the quantized electrochemistry of the brain. The tautology can be eliminated simply by re-defining mathematics in terms of electromagnetism, as outlined above.

**B E P Clement**
Crickhowell
Powys

### CD-I vs CDTV

I was disappointed by the article on CD-I ("Vision of the future", *EW + WW* August pp. 636-640).

Just when the author was about to make a proper technical comparison between CD-I and CDTV (which I would really like to read), he dissolved into vague generalities. "Because it is based on older technology, CDTV is inherently more limited..."

Both machines are based around 68000 chips running compact multi-tasking operating systems. OS-9 is some years older than the Amiga Exec, but both have good reputations and are well documented. In both machines, the main processors are supported by graphics and audio chips.

The CD-I is planned to have 24-bit colour at launch time; the CDTV has 12-bit colour, but a simple plug-in up-grade to 24-bit colour has been demonstrated by Commodore. Both will show Kodak Photo-CDs.

The CDTV will accept a keyboard, mouse, joystick and disk drive and will then run general computer software – games, paint programs, etc, so the user is not limited to the rather expensive CD disks. So far as I know, the CD-I cannot be accessed as a general-purpose computer.

There must be some other differences which justify the remark about "old technology". More facts, please!

**Don Cox**
Middlesborough

### Satellite in a spin

It is with reluctance that I have to write such a critical letter with reference to the Hypothesis feature "Satellites Ride the Solar Wind" (*EW + WW* June 1991). Quite apart from his audacious claim to inventing the "Sailsat" the concept is devoid of analytical merit.

There is no way for a comsat or any other satellite to maintain a stationary position above any latitude-longitude point on the earth's surface if the orbital plane does not contain the equatorial plane.

The gravity force referred to is always radial and does not have a component to pull it back to the equatorial plane the diurnal effect of the sun and the moon have a much more pronounced effect on the inclination vector than any gravity anomalies (though important for geosynchronous orbits).

Other errors abound, but even in geostationary, or any, orbit there are periods of eclipse (by the earth, moon system) for considerable periods especially around the equinoxes.

The small inclination he ultimately "settles" for, 2.5°, is quite laughable considering that a number of scientific satellites in geosynchronous orbit are allowed to drift up to 3° without sailsats of any kind. However the sub-satellite track then describes an elongated figure of eight

Numerous complexities are omitted; an associated drift in the orbital nodes is one which by international agreement has to be closely controlled.

Perhaps Paul Birch could do no better than be referred to the numerous published papers in the *Journal of the British Interplanetary Society* where the analysis is correct,

### Back to the future

Hugh Pincherie (Letters, *EW + WW* August 1991) suggests that a superconducting Faraday cage might be used as the basis for a "stasis device", ie a stationary volume of space wherein time is slowed or stopped relative to time in the space surrounding it. Such a device may quite simply be demonstrated to be incompatible with the laws of conservation of energy and of momentum, and therefore impossible in the Universe as we presently understand it.

**James M Bryant**
Newbury
Berkshire

### Back to the future II

High Pincherie's letter (*EW + WW* August 1991) regarding the possibility of time-travel, or at least the production of time dilation effects by the use of gyroscopic motion, may seem off-beat. But there are several anomalies connected with gyroscopes that still remain unexplained. This is evidenced by such machines as those of Strachan and Kidd that appear to lose weight when measured against a counterbalance.

It is doubtful whether the slowing of time would be achievable by gyroscopic spin, as the material is unlikely to hold together at relativistic speeds.

The most interesting aspect raised by Mr Pincherie is the question of variation of relativistic effects with direction, contrary to Einstein's General Theory.

However, a recent experiment to duplicate Michelson-Morley has shown a different value for the velocity of light dependent on direction. Maybe the ether needs to be revived for a complete understanding of physical science, as instanced by Dr Aspden's book "*Physics Unified*".

The Hayaska-Takeuchi experiment is further evidence of a speed dependent weight reduction that cannot be accounted for by the Theory of Relativity, but is adequately explained in Dr Aspden's paper "*The Theory of Antigravity*".

Einstein struggled for many years to unify field theory by relating electromagnetic and gravitational interactions, but died before accomplishing the task. Even today there is a weak link between quantum physics and relativity. Many questions still remain unanswered and modern physicists may not be as close to the Grand Unified Theory (GUT) as they think.

Levitating gyroscopes are a phenomenon in which there has been government, academic and commercial interest, but sadly the scientific community is slow to follow. This is indicative of an authority that will not concede to accept the antigravity phenomenon, but is more willing to accept the abstract philosophies of time-travel.

**George Overton**
The Anti-Gravity Society
Tadley
Hampshire

and to a publication of the European Space Agency ESA SP-1053". An Introduction to Geostationary Orbits", November 1983.

**A Pathan**
School of Engineering
Sheffield City Polytechnic

## CFA questions...

The correspondence on the crossed-field antenna has rumbled on for long enough. I told Mr Hately, its inventor in 1987, that it would not be credible until proper measurements had been made to establish what its typical radiating efficiency was. These measurements were needed because current physics shows that the radiation efficiency is probably small. That is to say that any given effect claimed for the CFA could probably be produced using a much less powerful transmitter and an efficient antenna.

In the intervening years a lot of hype has appeared in this magazine in praise of the CFA, and a few letters urging caution. Not once have you printed the essential quantity required to judge the antenna, which is the field-strength produced at a known distance when a known RF power is input to the antenna.

At this year's International Conference on Antennas and Propagation (Icap), a paper was presented on the CFA, giving the field strength as 2V/m at a distance of 500m from the CFA, measured in an area of good ground conductivity in the Nile delta region of Egypt. At last a figure had been published that would give an idea of the CFA's efficiency. Simple theory shows that this level of field at this distance can be produced by transmitting from a quarter-wave monopole antenna radiating 10.1kW.

In the trade it is known that a quarter-wave monopole for medium wave broadcasting can usually achieve 90% efficiency, and we therefore arrive at the result that 12kW transmitter with a quarter wave monopole will easily produce in practice the field claimed for the CFA in the Icap paper. The paper does not give the input power to the CFA, but the nominal transmitter power was – wait for it – 60kW!

On the assumption that 60kW was delivered to the CFA, its radiation efficiency was in the region of 20%. This in itself is higher than I suspect is being achieved, and considerable allowance must be made for tolerances in the measurement technique (which is not described) and radiation from the feeder (which is probably significant).

Plenty of radio amateurs (myself included) would be able to produce better efficiency at HF with the traditional piece of wire bought for £5 from Woolworth's than these results quoted for the CFA.

In medium-wave broadcasting, for any given application one has to decide on the required transmitter power and antenna efficiency by trading-off the antenna efficiency against the cost of a high-power transmitter. A cheap inefficient antenna will require a powerful and expensive transmitter. The optimum usually occurs with antenna efficiencies of 60-90%. The economics therefore make the CFA an unlikely candidate for any application below 30MHz.

I strongly advise anybody contemplating the purchase of a CFA to make sure before ordering that the product carries proper certification by a competent agency (such as the BSI or the NPL), that its radiation efficiency has been measured, and that the result of the test is stated. An additional test, essential for personal safety, is determination of the exact intensity of the fields in the region near the antenna. You would require adequate testing for a microwave oven or a vacuum cleaner, and it is perfectly possible to be equally scientific about antenna measurements.

On the theoretical side of the argument about the CFA, it should be said that the physical interpretation of Poynting's theorem of 1884 has always been problematical and liable to error. Poynting's theorem makes no statement about the direction in which energy flows, because the three major terms in his equation are all scalars. The theoretical basis for the CFA (Poynting vector synthesis) is therefore nonexistent. It is also ridiculous to claim, as the CFA's inventors have done, that rewriting Maxwell's equations the other way round will allow important new ideas to be deduced. The equations of applied mathematics don't work like that. They simply state that the quantity on the left equals the quantity on the right, without implying anything about cause and effect.

It is also in my view wrong to claim that the H-field plates in the CFA produce significant H-fields close to the antenna. What is true is that both pairs of plates will produce E-fields and H-fields. When the field equations are solved for the region near the CFA, it is most likely that the H-fields near the antenna will turn out to be insignificant. The experiment described in your March 1989 issue by Kabbary, Hately and Stewart to investigate this effect is entirely spurious, because the rf driving voltage is wrongly applied. Figure 3 in that article shows the rf voltage applied between the inner and outer regions of a conducting sheet, the regions being separated by a circular gap. To represent the CFA plates the rf obviously should have been applied between the sheet and the ground plane.

To sum up, I would say that the CFA is a typical inefficient small antenna. Nothing magic is happening, and when the hype is stripped away we are left with very little. Is it unreasonable to request that no more articles appear on this device until the radiation efficiency can be reliably measured? Without this, anything else is a waste of your readers' time.

I notice with pleasure that your August edition contains a letter on time machines. This holds the promise of plenty ofmaterial in months to come that is cranky, entertaining and undoubtedly more academically respectable than the crossed field antenna!

**Alan Boswell**
Chelmsford
Essex

## ...and reflections

I always thought that brief letters stood a greater chance of being printed without cuts, but you made a critical cut in my two paragraph letter (*EW + WW* August 1991).

The point about CFAs is that it is claimed that they produce waves with a tightly curved wavefront and that they can therefore be reflected by a much smaller reflector than would otherwise be the case. Simply claiming that the waves "are smaller" is a very vague way of putting it, and not what I intended to say.

**David Gibson**
Leeds

## Diary Note?

WH Powell of Warwickshire (EW + WW August 1991) can relax. To the rescue is one of a series of regular events updates to be sold on modest subscription. If W H Powell, or any other reader, would like a free copy write to the address below, marking your envelope EW.

**G Beaumont**
Events Publications
PO Box 2500
London N4 4QE

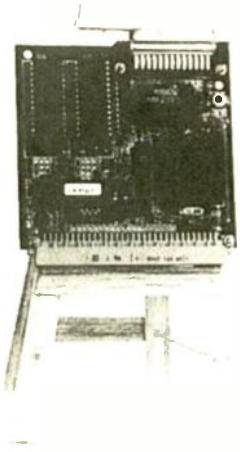
## Jiggers

Your article "End of the beginning" (Pictures from the Past, *EW + WW* July 1991) refers to the name "jiggers" given to aerial coupling transformers in earlier times, and suggests that the reason for this name has been forgotten. My investigations find that the terms "jig" and "jiggers" may have been introduced by James Erskine-Murray. I quote from his Handbook of Wireless Telegraphy, 1907:

"I... propose to adopt a good old English word which signifies a periodic motion of high frequency, to stand for 'a damped train of electrical oscillations of a frequency of the same order as is employed in wireless telegraphy;' or the corresponding 'oscillatory currents, voltages, or magnetic fields of high frequency,' associated with them in the sending or receiving circuits of a wireless installation. The word chosen is brief and descriptive, viz, jig. It may be qualified where necessary to prevent confusion – thus an electric jig, a magnetic jig, an Irish jig – all implying periodic motions of very high frequency. A transformer of the high frequency currents used in wireless telegraphy has been called a jigger, hence it also seems natural to call these currents 'jigs'..."

Indeed we might have ended up with the "kilo-jig" and the "mega-jig", but things worked out differently.

**Peter E Musk**
Rickmansworth
Herts



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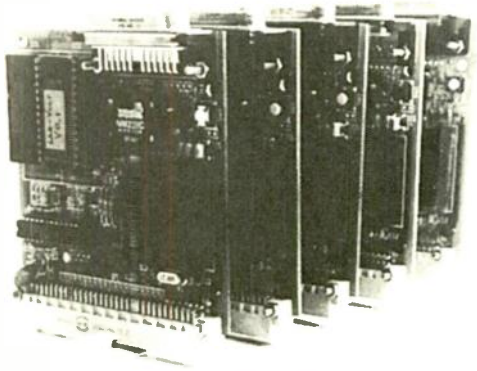

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CIRCLE NO. 135 ON REPLY CARD

# REGULARS

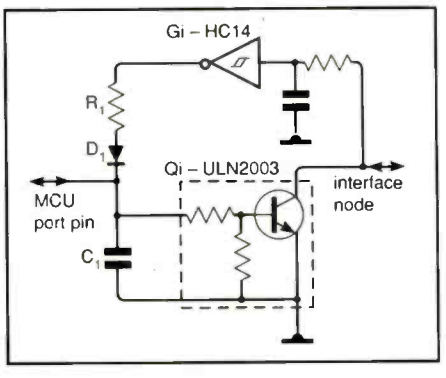
CIRCUIT IDEAS

## Bi-directional i/o for microcontrollers

I/O pins on microcontrollers which are configurable as either input or output are not usually capable of driving much of a load in one role or providing any schmitt action to shape inputs in the other. For useful interfacing, one must therefore provide drivers or schmitt outputs with, possibly, filters which effectively ruin any chance of software pin assignment.

This circuit does, however, allow more flexibility. The darlington output driver and the schmitt input gate go to the same pin, contentions being handled by software. Values cannot be shown, since they have to be determined by drive capability of the controller concerned and loading on the pin.

**Input.** Set the port pin to "output" and program it low, switching $Tr_1$ off to prevent it affecting the interface node. Data on the node is inverted by $G_1$ and it may be found




*Bi-directional buffer allows configurable i/o pins on microcontrollers to be software controlled without any need for hard wiring.*

that there is now contention with the port, so $R_1$ is inserted. To read, the port is momentarily configured as an input. Any tendency for $Tr_1$ and $G_1$ to latch disappears when it becomes an output again. If $Tr_1$ conducts briefly, use $C_1$. Do not make $R_1$ too high, or the port pin voltage might not reach 1 because of loading by $Tr_1$.

**Output.** When the port is high, the output of $Tr_1$ goes low, so that the output of $G_1$ is high and is out of contention with the port. When low, it works against $G_1$ output for a short time until $Tr_1$ goes off and $G_1$ is low: this sets the lower limit of $R_1$. When the port goes high, it again works against $G_1$ for a short time; some n-mos controllers have weak pull-ups and the diode assists the action.

**David Gibson**
Leeds
West Yorkshire

## Dial a harmonic

Setting a switch allows the selection of a harmonic of 2nf of an input, for use with a modulator.

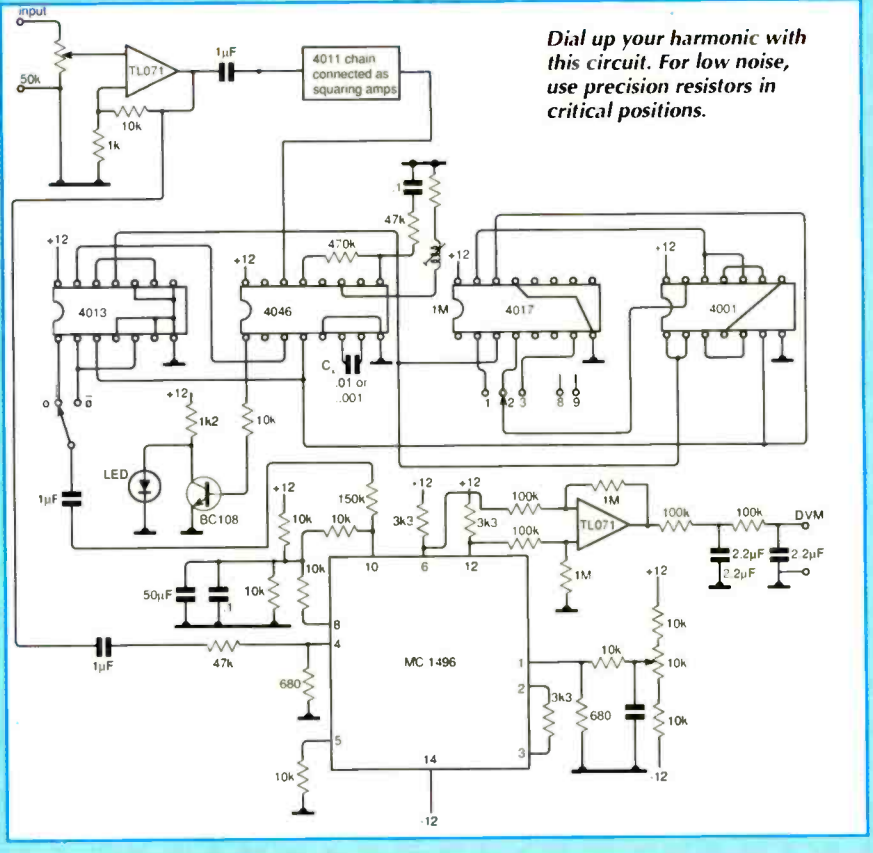
At the input, the signal meets a low-signal amplifier and is then squared in 4011 comparator, which provides a stabler input and does not need a multi-turn control. The signal from the amplifier also goes to the modulator.

Squared signals are the reference in a phase-locked loop, the n-divider to produce a 2nf frequency consisting of the 4017, a 4001 and half a 4013, which divides the 2nf to give in-phase and antiphase harmonics (nf and -nf). Capacitor $C_x$ determines the range over which the circuit operates and the led indicates lock.

The second TL071 takes the sum and difference frequencies of the two inputs. If the difference is zero, the output is DC, indicating the value of the harmonic n.

You should balance the 1496 modulator by the potentiometer, using an oscilloscope on the TL071 output, with no input (pin 4 shorted).

**E Rangel Marins**
Instituto Nacional de Tecnologia
Rio
Brazil




*Dial up your harmonic with this circuit. For low noise, use precision resistors in critical positions.*

# Programmable waveform generator

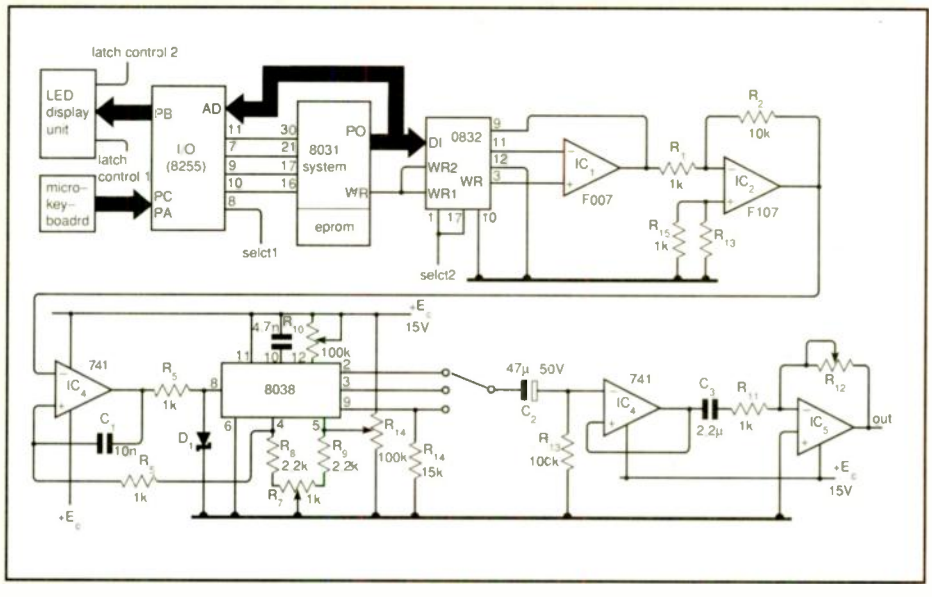
This provides three-function waveform generation from 0.01Hz to 1MHz under the control of a microprocessor, which also indicates frequency digitally.

Control voltage for the 8038 function generator comes from the micro via an 0832 8-bit D-to-A converter, a buffer, a voltage amplifier with a gain of ten and a voltage follower. Sine (top switch position), square and triangular (bottom) waves are taken out through a further voltage follower and variable-gain amplifier, the micro indicating frequency via the 8255 programmable peripheral interface and led display. It is assumed that a linear relationship exists between control voltage and frequency.

Sensitivity to frequency control is adjusted by the values of C, $R_8$ and $R_9$ and $R_{6,7,10}$ adjust waveform shape. Output voltage is about 20V.

**M T Songping Liu**
China

*(If Mr Liu would like to let me have his address, I will send his cheque. — Ed)*




***Waveform generator controlled by microprocessor, which also gives a direct indication of frequency.***

# UHF VCO

A simple UHF voltage-controlled oscillator for satellite receivers, offering a frequency range of 1200-2100MHz, output power of +7dBm into 50Ω, Varicap range 0V-50V and supply requirement of ±12V.

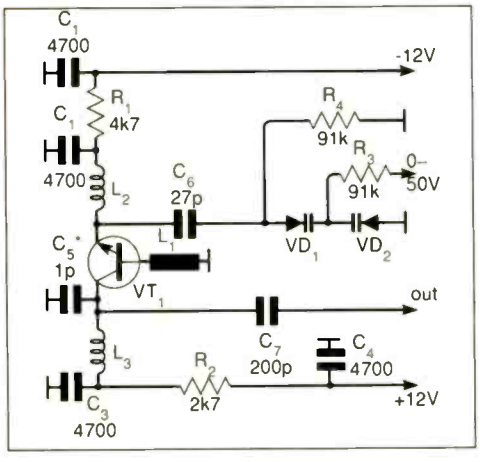



*Fig.1. UHF voltage-controlled oscillator for satellite broadcast working.*

**Figure 1** shows a design using inexpensive components. Parasitic inductance is a major problem at these frequencies, since it is comparable with designed inductance in the resonator circuit and makes decoupling difficult. In this design, some of the problems are avoided by connecting load to the collector and the resonator components to base and emitter.

Construction is much more important in this type of equipment than that for lower frequencies, so a description is needed; **Fig.2** shows a successful layout. A 1.5mm double-sided glass-fibre board, measuring 35 by 30mm is used. Ground pads under $C_{2,3,5}$ are connected the back plane by plated-through holes. Leads on $R_{1-4}$ an $C_{6-7}$ must be short. It would have been possible to use only one Varicap, but the transistor base would have been taken directly to ground and matching would have been difficult.Capacitors $C_{1-4}$ are disc ceramic; $L_{2,3}$ are 2 or 3 turns of 0.4mm wire on a

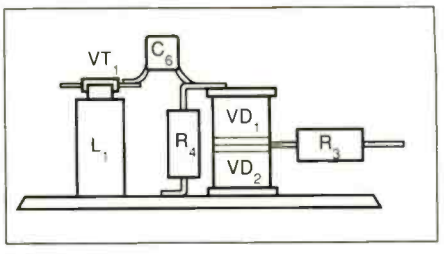



***Fig.2. Suggested layout of UHF VCO reduces problems set by stray inductance assuming same proportions as intended variety***

diameter of 3mm; $L_1$ is 2.5 by 7mm copper foil, 3mm of it being soldered to ground; the transistor is BFQ69, BFR93, BFR34A or an equivalent, mounted directly onto inductors $L_{1-3}$.

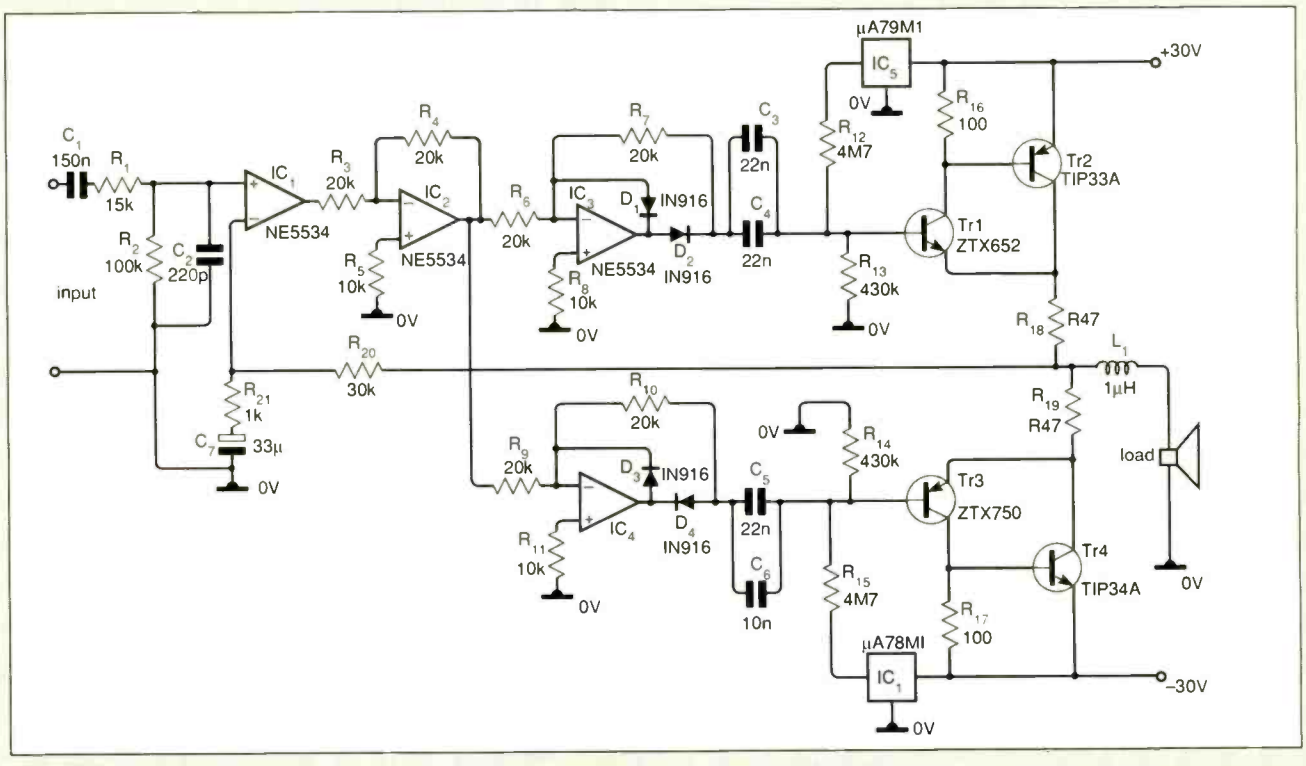
**Raimundas Markevicius**
Vilnius
Lithuania

# Class-A push-pull amplifier

Mr Richards provides a circuit for an amplifier in which the output bipolar transistors are permanently forward biased. Input signal divides into two halves by means of the diode-feedback "perfect" diodes IC3,4, while IC2, a simple inverter, is needed to allow overall feedback to be in the correct phase. We have no further information on the circuit.

**W O Richards**
Battersea
London SW11

***Amplifier has permanently conducting output transistors. Phase splitting is by unity-gain diode-feedback stages and $IC_2$ arranges the various inversions to present overall NFB to $IC_1$.***



# REGULARS

## NEW PRODUCTS CLASSIFIED

# ACTIVE

### Asic

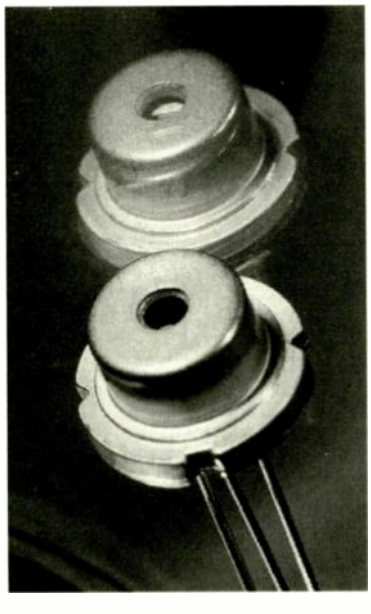
**Gate array library.** The VGT353 is a three-layer metal 1μ gate array library that increases the number of usable gates on the array by 80% and performance by 20% compared with the corresponding two-layer process. Up to 130,000 usable gates are available on a single array. VLSI Technology, 0908 667595.
For more information on asics, see the literature section of this review.

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

**18bit adc.** The PCM1750 dual 18bit cmos a-to-d converter has serial data outputs and is for digital audio applications. It includes separate sample and hold circuitry for each channel so that the inputs are sampled in phase. Switched capacitor techniques are used in the conversion stage and the entire conversion process takes 4.5μs. Input level is 5.5V peak to peak with full power input bandwidth of 500kHz. Burr-Brown International, 0923 33837.

**Video dac.** A triple 8bit 30MHz video d-to-a converter is for use in high-resolution TV, satellite TV encoder

***Seeing is believing: the HL7851G is a visible light laser diode for optical disc systems.***



and decoder systems, image processing, and computer colour graphics. The MV95338 is a variant on GPS' VP101 video dac but at a lower cost. It is a drop-in replacement for the Brooktree BT101 and works with GPS' D2MACchip set. It uses video control inputs to provide the video pedestal levels needed to generate RS343A compatible video signals into a doubly terminated 75Ω load or RS170 signals across a singly terminated 75Ω load. GEC Plessey Semiconductors, 0793 518000.

**12bit adcs.** The Max183 a-to-d converter has a 3μs conversion time. Also available are its two sisters – the 5μs Max184 and the 10μs Max185. Power consumption for all three is typically 90mW. They have +5, +10 and ±5V input ranges and a reference input that is internally buffered. Data access time is 100ns and there are three-state data outputs and standard control inputs for connection to most microprocessors. Maxim Integrated Products, 0734 845255.

### Discrete active devices

**Transistor array.** A transistor array for use as an output device in fast video amplifier circuits consists of a complimentary pair of silicon bipolar transistors connected as emitter followers. Collector-base breakdown voltage is 120V for the npn transistor and -80V for the pnp. Cut-off frequency for each chip is 1GHz. The CR820 is expected to be used in black and white video monitors and other applications where discrete steps of brightness are required. Motorola, 0908 614614.

**Barrier diode.** The U1GWJ49 is a 1A schottky barrier diode with a reverse recovery time of 35ns. Repetitive peak reverse voltage ratings of 30 and 40V are available and maximum forward voltage is 0.55V. It comes in a SOT-89 housing but is also available in axial leaded packages or a miniature I-flat package for surface mounting. Toshiba Electronics, 0276 694600.

### Digital signal processor

**DSP chip.** A DSP IC has an architecture optimised for signal processing algorithms and executing code written in high level languages including ANSI C and ANSI numerical C. The ADSP21020 has independent parallel computational units with 32 and 40bit IEEE floating point precision and 32bit fixed point. Executing an arithmetic operation takes a single 40ns machine cycle on the fastest-100 grade. The 1024-point complex FFT executes on 0.77ms. Analog Devices, 0932 232222.

**MPU training system.** A range of C3M digital signal processors is based on the TI3020 processor and offers users a way to use and learn digital signal processing. Among the range's capabilities are real-time signal processing, digital and adaptive filtering, acoustic measurements, speech recognition, and digital radio. All models have a fast no-wait state memory. The range comes with software consisting of a cross assembler, monitor/debugger, and simulator. The units are linked to host computers via a parallel port. Flight Electronics, 0703 227721.

### Linear integrated circuits

**Low-power op amp.** The Max406 op amp has a 1μA quiescent current that is relatively constant over the entire supply range in unity gain stable and high-speed operating modes. The output can source 2mA when powered by a 9V battery and smaller loads with a supply down to 2.5V. Common-mode input voltage range extends from the negative rail to within 1.1V of the positive supply. The output stage swings from rail to rail. Input offset voltage is specified at 0.5mV maximum and input bias current is less than 0.1pA. 2001 Electronic Components, 0483 742001.

**Clock generator.** A dual video and memory clock generator, the ICS2494, has provision for external frequency input; the internal clock stays locked when the external frequency input is selected. It has a buffered Xtal out and integral loop filter components. It works up to 135MHz and comes in a 20-pin DIP. Amega Electronics, 0256 843166.

**Op amp.** The AD745 monolithic FET-input op amp has a current noise of 6.9fA/√Hz at 1kHz and voltage noise with 10kHz inputs of 2.9nV/√Hz (4nV/√Hz guaranteed and tested maximum). Its 0.0002% total harmonic distortion at 1kHz makes it suitable as a preamp or current-to-voltage converter in systems with high source impedance. Bandwidth is 20MHz and slew rate 12.5V/μs. Analog Devices, 0932 232222.

**350V op amp.** The Apex PA41 op amp is of linear mosfet design and can work from ±175V rails, drawing a quiescent current of 2mA. But it can drive 60mA continuously with no secondary breakdown problems. Slew rate is 40V/μs and full power bandwidth is 26kHz. It maintains unity gain operation even when driving capacitive loads up to 10nF. Microelectronics Technology, 0844278781.

**Linear amplifier.** The Elantec EL2071 is a wide bandwidth fast settling monolithic amplifier which uses current mode feedback and is for closed loop gains of ±7 to ±50. It has a 150MHz -3dB bandwidth at a gain of 20 and a 2.5ns rise and fall time for a 2V step. It consumes 15mA of supply current which reduces to 1.5mA with the disable feature on. Microelectronics Technology, 0844 278781.

**Voltage monitor ICs.** The MC34161 and 33161 are universal voltage monitor ICs for implementing over, under and window detection of positive and negative voltages. The circuit consists of two comparator channels each with hysteresis, pinned-out 2.54V reference, two open collector outputs that sink more than 10mA, and a mode select input for programming the functions of the two channels. They are fully functional from 2 to 40V for positive voltage sensing and from 4 to 40V for negative sensing. Motorola, 0908 614614.

### Memory chips

**36bit fifo.** The LH5420 36bit fifo has two fifo buffers which operate in parallel but opposite directions for bidirectional data buffering. There is a word width select option for 9, 18 or 36 bits on one port to allow word width matching between two data buses with no extra logic needed. This means two of the units can be used as a bidirectional interface between a 64/72bit databus and a 73/64,36/32, 18/16 or 8/9bit databus. The unit is organised as 256 word x36bit x 2 with either 15/25, 20/30 or 25/35 access/cycle times. Sharp Electronics, +40 23775-0.

**256K eprom.** A 16bit 256K eprom is available with 45, 55, 70 and 90ns speeds and a 40ns version is due out soon. The Microchip 27HC1616 was developed for 16 and 32bit applications. There is no need for cache ram as the microprocessor can address the eprom directly. Package options include 40-lead plastic dip,

44-lead PLCC,40-lead cerdip, and 44-lead LCC. Thame Components, 0844 261188.

**Microprocessors and controllers**
**486 microprocessor.** The 486DX microprocessor runs at 50MHz letting it perform 50% faster than the current 33MHz version. It is compatible with MS-Dos, OS/2, Windows 3, and Unix software bases. The chip has 1.2 million transistors and has line widths of 0.8μm. Intel, 0793 696000.

**Optical devices**
**Laser diode.** The HL7851G is a 785nm laser diode for use in optical disc memory systems. It has a multiple quantum well structure and an output power of 50mW. Because it uses shorter wavelength visible rather than infra-red beams, smaller pits can be used in the disc increasing the recording density. Typical threshold current is 60mA and typical operating current 160mA. Hitachi Europe, 0628 585000.

## Oscillators

**Clock oscillator.** The CS6691 is a 32.768kHz clock oscillator with a typical current consumption of 30μA. It uses discrete components to minimise power consumption and includes an H-cmos buffered output. Accuracy is ±100ppm over the range -10 to +60°C at a supply voltage of 5V DC. Rise and fall time is 10ns maximum. Total Frequency Control, 0903 740000.

## Power semiconductors

**Power mosfet.** A 200W 200MHz power mosfet, the 2SK1575, uses a lateral construction to give better high frequency performance. Because the substrate forms the source electrode, ground inductance is smaller than with bipolar transistors where the substrate is the collector electrode. The negative temperature coefficient of mosfet drain current provides protection against thermal runaway. A drain-source withstand voltage of more than 180V can be achieved, allowing circuit designs to be based on a supply of 80 to 90V. Typical drain efficiency is 55%. Hitachi Europe, 0628 585000.

**SM transistors.** A range of 50 surface mounted bipolar transistors and darlingtons dissipates up to 3W. The npn andpnp power devices in the BDS family come in SOT223 packages and work as switches and analogue drivers. Maximum collector-emitter voltages range from 32 to 120V and average collector currents are 3A (6 and 7A maximum). Maximum junction temperature is 150°C and, for ambient temperatures of 25°C, they dissipate up to 8W with an infinite heatsink. Philips Components, 071-580 6633.

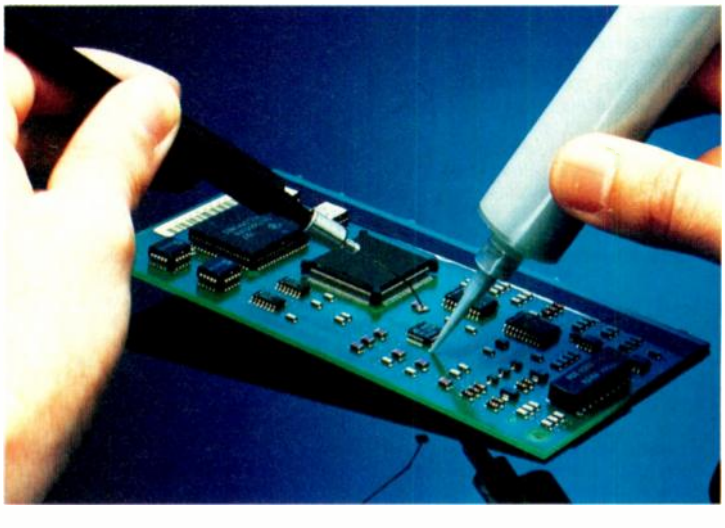
# PASSIVE

## Passive components

**Chip resistors.** CR10, CR21 and CR32 thick-film chip fixed resistors for surface mount assembly are available in bulk or tape packing with tolerances down to ±1%. The CRA3A has three resistors in an 1206 case and the CRA2A has two resistors in an 0805 case. The resistance values can be a mix from 1kΩ to 2.2MΩ in the E12 and E24 series. Noise is from 32 to 0.32μV/V. AVX, 0252 336868.

**Thin-film resistors.** The TO220 series of 20W thin-film power resistors is suitable for surface mount or through hole applications and comes in either TO220 plastic or TO257 hermetic metal packages. Resistance range is from 1Ω to 50kΩ, resistance tolerances are 0.1 to 0.5%

*Suck it and flee: the VPP803A vacuum pick up and place tool for small parts.*



absolute, ratio tolerances are from 0.01 to 0.1% and low TCR to ±10ppm/°C absolute and 1ppm/°C ratio. Stability is 250ppm after 1000h at 70°C. Electro-Films (Europe), 0784 246273.

**Wirewound resistors.** The K2 series of miniature wirewound resistors comprises 2.5W units with a 3.8mm diameter and 8.9mm length. Values are from 50mΩß to 1kΩ and standard 5% tolerance with options down to 2 or 1%. Construction is entirely welded while the coating is flame-proof and can withstand most cleaning solvents. They are available taped or in bulk. Meggitt Electronic, 0793 611666.

**Ceramic capacitors.** A series of radial leaded ceramic capacitors covers the range 1 to 47,000pF in a uniform 3.5mm diameter format. The DD003 units have a maximum inserted height of 6mm and maximum thickness of 2.5mm. They come with a choice of dielectrics including temperature compensating Class 1 types and high-K Class 2types. Most are rated at 50V DC but the high-K units also come in 12, 16 and 25V DC versions. Lead types can be straight, low profile or crimp. Murata Electronics, 0252 811666.

**Electrolytic capacitors.** MJ ultra-miniature electrolytic capacitors are 5.2mm high and work from -40 to +85°C. Capacitances are from 0.1 to 220µF ±20% tolerance and working voltages are from 4 to 50V DC. The radial lead units have a leakage current of 3µA and an allowable ripple at 85°C of 96mA maximum. Nichicon (Europe), 0276 685393.

**Electrolytic capacitors.** The AML138 range of axial miniature long-life electrolytic capacitors has specifications similar to DIN41257 but in cases 60% of the volume. This means that CV products up to 2200µF 16V are available on tape for automatic insertion. Mounting height is between 6.3 and 21mm and life is more than 20 years at 40°C. There are more than 100 units in the range with values between 0.22 and 15,000µF. Rated voltage is from 6.3 to 100V. Philips Components, 071 580 6633.

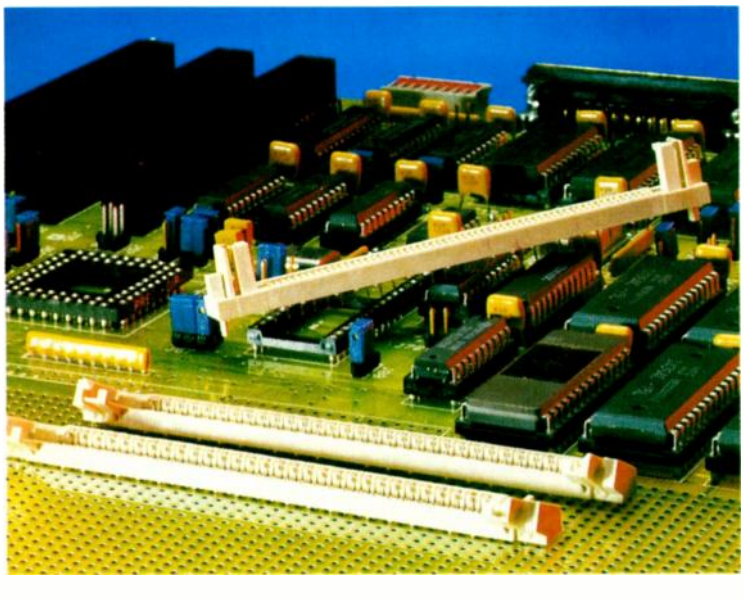
## Connectors and cabling

**Fibre optic connector.** A fibre optic cable connector which can be assembled in five minutes obviates the need for the contact face to be polished. It consists of a stainless steel ferrule containing a glass capillary within which a short length of fibre is secured by epoxy resin and precisely centred using trimming techniques. Because the contact face of the ferrule and fibre is already polished, it is only necessary to splice the fibre mechanically in the ferrule with the cable to be terminated. Hakuto International, 0992 769090.

**SIMM connector.** The Amp Micro-Edge SIMM connector for leadless single in-line memory modules has a low-profile high-pressure tin-plated contact which accepts standard module board thicknesses between 1.19 and 1.37mm. The connector wipes the board pad during card installation and provides a minimum normal contact force of 200g. Jermyn Distribution, 0732 740100.

**All-weather terminals.** Terminal assemblies that are impervious to corrosion at the crimp have been designed by combining shrinkable tubing and Molex Perma-seal crimp technologies. The terminals and pieces are pre-insulated but instead of using pieces with moulded or extruded insulations, these terminals have insulators made of nylon dual wall shrink tubing. Time 24, 0403 864947.

*Low profile: AMP SIMM connectors protect your modules while you're changing.*



## Displays

**5mm leds.** A range of 5mm diameter leds are fitted with an internal resistor which eliminates the need to wire a current limiting or direct drive resistor to a PCB. At an ambient temperature of 25°C and operating at 5V, the red leds have a typical luminous intensity of 4.5mcd at 10mA forward current. They are also available in green and yellow.Camden Electronics, 0727 864437.

**Filters Solder-in filter.** A solder-in filter has a maximum installation temperature of 400°C and comes in an hermetic package with glass-to-metal seals at both ends. Operating temperature range is -55 to +200°C. The high installation temperature is designed to get round problems caused when there is, say, an array of 40 to 50 filters in a bulkhead. With lower temperature ratings not all the filters will solder perfectly and the whole assembly usually has to be reflowed twice causing unreliable solder joints. AVX, 0252 336868.

**Tracking filter IC.** The IMP42C555-30 is a 30MHz programmable tracking filter with asymmetrical pulse slimming and phase equalisation. Applications include disc drives, video processing, networking and data acquisition. In disc drives using zoned density recording, the chip's automatic zone tracking feature lets zones be switched or unlimited zones added without exterral components or reprogramming. It also allows programming corner frequencies between 3 and 30MHz unboosted. It comes in 16-pin SOIC and DIL packages. Dialog Semiconductor, 0793 875327.

**SM filter.** The NFM52R surface mounting filter is available in four versions with cut-off frequencies of 10, 20, 50 or 100MHz. Maximum attenuation is 60dB and all types are rated at 50V and 200mA. They are housed in ceramic packages measuring 5 x 2.5 x 3mm and are suitable for flow and reflow soldering. They can be supplied in bulk or taped and reeled for automatic placement. Murata Electronics, 0252 811666.

## Instrumentation

**Bus monitor/tester.** Designed for fault finding on the IEEE 488bus and as a programming aid for GPIB devices, the Mini 488 bus monitor and tester has four modes of operation - tristate, slow, fast, and single stop. Each mode provides a different level of access to data on the GPIB bus. It has an alphanumeric display that can be hexadecimal or binary and LEDs to indicate the state of each handshake and control line. An SRQ button simulates a service request. Amplicon Liveline, 0273 608331.

**Digital multimeter.** The Q19001 10A digital multimeter has a 0.7% basic accuracy. Measurement ranges are: 200µA to 2A (plus 10A on a separate terminal) over six ranges; 200mV to 1kV DC over five ranges; 200 to 750V AC over two ranges; and 200Ω to 2MΩ over five ranges. The display is a 3.5 digit LCD. Resolution is 0.1mV to 1V DC, 0.1µA to 10mA, 100mV to 1V AC, and 100MΩ to 1kΩ. It has a 2.8V/mA diode check and it measures 75 x 130 x 25mm. Electronic & Computer Workshop, 0376 517413.

**LCR meters.** Two LCR meters can measure R+Q, L+Q, C+R and C+D at frequencies from 100Hz to 100kHz. The SR715 has four and the SR720 five selectable measurement frequencies. Drive voltages are adjustable from 0.1 to 1V. Measurement rates of 2, 10 and 20 per second are available and up to ten measurements can be averaged to produce a single result. Fieldtech Heathrow, 081-8976446.

**Multimeter.** The Escort EDM82 multimeter is a DC and AC voltmeter, 20A ammeter, ohmmeter, diode and transistor tester, capacitance tester, frequency counter, logic probe, and continuity tester in one instrument. It has a high voltage warning detector, auto ranging and peak hold functions. Its fire retardant case measures 90 x 37 x 193mm and the unit weighs 420g. HT Electrical, 0384 288504.

**Fault finder.** The Huntron Switcher 640 is an automatic scanning and comparison unit for use with the Tracker 2000 analogue signature analyser. The Tracker isolates faulty and failing components and the Switcher automates the process by comparing the analogue signatures of a suspect component with a known good component and reporting the differences. L& M Test Services, 0280813707.

**Function generator.** Pure sine waves and built-in modulation are two attributes of the DS345 30MHz synthesised function generator. It can produce frequency, amplitude, phase, and burst modulations as well as linear and logarithmic sweeps. Users can pick sine, square, ramp, triangle or arbitrary wave shapes. Modulation trigger rate can be set from 0.001Hz to 20kHz with two digits of resolution. LambdaPhotometrics, 0582 764334.

**OTDR.** The Siemens K2300 optical time domain reflectometer (OTDR) comprises a mainframe and various plug-in modules including dual 850 and 1300nm multimode. The optional

built-in printer prints the trace and all related information in less than 30s. The standard disc drive allows trace storage. The companion Batch software package can print an entire disc of traces, including length and loss measurements. Laser Lines, 0295 267755.

**Signal generator.** The SMGL is a multipurpose signal generator covering 9kHz to 1000MHz in 1Hz steps. It delivers a power output of 2W (+33dBm) which can be attenuated in 0.1dB steps down to -118dBm. Non-harmonic spurious signals are less than -70dBc, residual FM is less than 4Hz and SSB phase noise is 144dBc at an RF of 100MHz. It has RF sweep facilities, 40 nonvolatile memory stores, and an IEEE 488.2 control interface. Rohde & Schwarz, 0252 811377.

**100 MHz oscilloscope.** The Kikusui Cor5501U digital storage and real time oscilloscope has 100MHz real time bandwidth, two channels, CRT readout, cursor measurement, comment, and ALT/MAG timebase functions, as well as a 20M sample/s rate simultaneously on both channels, acquisition and save memories of 4K word/channel, pre and post trigger, and up to x1000 horizontal magnification. A GPIB interface is optional. Telonic Instruments, 0734 786911.

## Literature

**Product catalogue.** Amplicon's product catalogue has 288 pages and more than 40 new product families. The firm's Live Lines newsletter is included to provide a quick visual reference to some of the products in the catalogue as well as giving in-depth technical features and applications stories. Products listed include a data acquisition board, fibre optic or coaxial GPIB bus extender, GPIB interface for Mac II computers, and an input scanner and keyboard. Amplicon Liveline, 0273 608331.

**Analogue components.** A 28-page selection guide for analogue components includes charts for each product area such as op amps, isolation amplifiers, d-to-a converters and 12bit multichannel data acquisition systems. A summary of video and audio products is also provided. Some products have block diagrams to explain their operation. Burr-Brown International, 0923 33837.

**Asic range.** An asic product catalogue details the full range of ES2's services. It is divided into sections on asic design, prototypes, production parts, processes, qualification, packaging, testing, and special silicon products. Current processes are 1.7µm effective (2µm drawn), 1.1µm effective (1.5 and 1.2µm drawn) and 0.8µm effective (1µm drawn). All are based on double layer metal n-well cmos technology. The firm can also offer MIL883 compliant asics. ES2, 0344 525252.

**Asic shortform.** A 93 page shortform catalogue gives details of VLSI Technology's full asic capability including gate array, cell based functional system blocks, and microprocessor cores. The range includes a 32bit risc processor. Details of asic design tools sold by subsidiary Compass are also included. VLSI Technology, 0908 667595.

## Production equipment

**Vacuum pick-up tool.** The VPP803A is for picking up and placing small parts such as chips and miniature components especially in surface mount applications. The vacuum can be adjusted to up to 16in of mercury. The kit comprises the vacuum pencil, three sizes of tip, five sizes of pad, and a 6ft input air hose. The control box measures 9.5 x 19 x 6.7cm. I&J Fisnar, 0101 201 796 1477.

## Power supplies

**DC/DC converters.** Two families of DC/DC converters for circuit board mounting have been introduced. The Modupower MP7000 series is available with 3.3, 5, 12 and 15V outputs and MP9000 series units are rated at 2, 6 and 20W. Both mount onto the board with a DIP socket. Ambar Components, 0844 261144.

**DC/DC converters.** The FCI range of 1.8, 2.25 and 3W DC/DC converters is available in 16 or 24-pin packages for auto-insertion or surface mount designs. The range provides 5, 12, 24 and 48V input and single and dual outputs of 5, 9, 12 and 15V with input voltage variation of 5 or 10%. They have a fully isolated design rated at 500V and 1000MΩ. Microelectronics Technology, 0844 278781.

**Eurocard supplies.** A range of Power Technics Eurocard power supplies are 100W units that meet UL, CSA and VDE standards and take up a cassette space of 3HE/5TE. There are single, dual and triple output versions with adjustment available on each output. A power failure signal is generated for external use as well as an input inhibit facility. Efficiency is 75%. Pascall Electronics, 081 9790123.

**Switched mode units.** A family of configurable switched mode power supply units have outputs from 150 to 650W. Each of the 41 models in the Ferrus range can be specified to accept AC or DC inputs with various outputs to suit customer requirements. Auxiliaries providing up to six further outputs can be specified

as either mag amp, switching regulator, linear or semi-regulated topologies. Input scan be either 110/240V AC or 24/48V DC. Thame Power, 0844261682.

**1.5W converters.** The TPD-Hi Traco DC-DC converters are rated at 1.5W and cover three input ranges from 4.75 to 5.5V, 10.8 to 13.2V and 21.6 to 26.4V. Providing six single and six dual voltage rails, the devices are packaged in plastic cases measuring 32.8 x 20x 10.5mm and are configured for PCB mounting. I/O isolation is 4kVAC RMS. Verospeed, 0703 641111.

## Radio communications products

**Yagi antenna software.** The Yagi Optimizer software for antenna design has been upgraded with frequency-swept performance graphs, allowance for conductor losses and other features. Up to 50 element scan be optimised to meet user-defined criterla of gain, side-lobe suppression, VSWR and broadband performance. IFW Technical Services, 0235 535981.

**Mobile antennas.** A range of VHF and UHF mobile antennas has Dura-Flex elastomer shock springs and comes with a bright finish or a black chrome. Mounts include 0.375in snap-in, 0.75in hole, magnetic, and Quick-Grip. The Antenna Specialists, 0101 216 349 8400.

## Transducers and sensors

**Ultrasonic sensors.** Selectron Lyss has introduced a range of ultrasonic sensors in M18 format which will detect targets within 600 or 1000mm depending on type. An analogue output option is available for the 1000mm version giving a 0.1V output corresponding to the target distance. Also available is a 45 x 70 x 49mm unit with a range of 2000mm. Centiflex Systems, 0799 27602.

**Pressure transducer.** A pressure transducer has been introduced that is compatible with hydraulic fluid and can measure up to 38MPa sealed gauge. Over pressure ratlng of the PDCR360 is 57MPa. The monitored pressure is denoted by the pulse repetition frequency of 0 to 10V (nominal) square-wave output at between 1.7 and 9.3kHz (0 to 38MPa). The total error band from -31 to +96°C is ±2 to ±2.75% corresponding to frequency errors of ±152 and ±209Hz, respectively. Druck, 0533 314314.

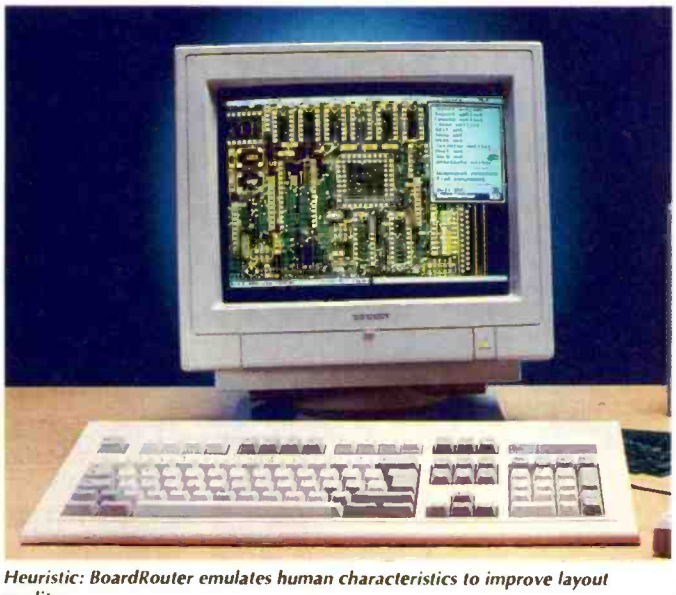
## Computer-aided design

**Engineering workstation.** The MS6000 is a microform digitiser and workstation that accepts all common microfilm formats includlng 35mm. It can be used as a reader and printer for viewing and laser printlng engineering drawlngs, editing and enhancing stored film images and producing copies up to A3. Images can be converted from film for storing on digital media or transferred to a computer assisted drawing system. Bell & Howell, 0784 251234.

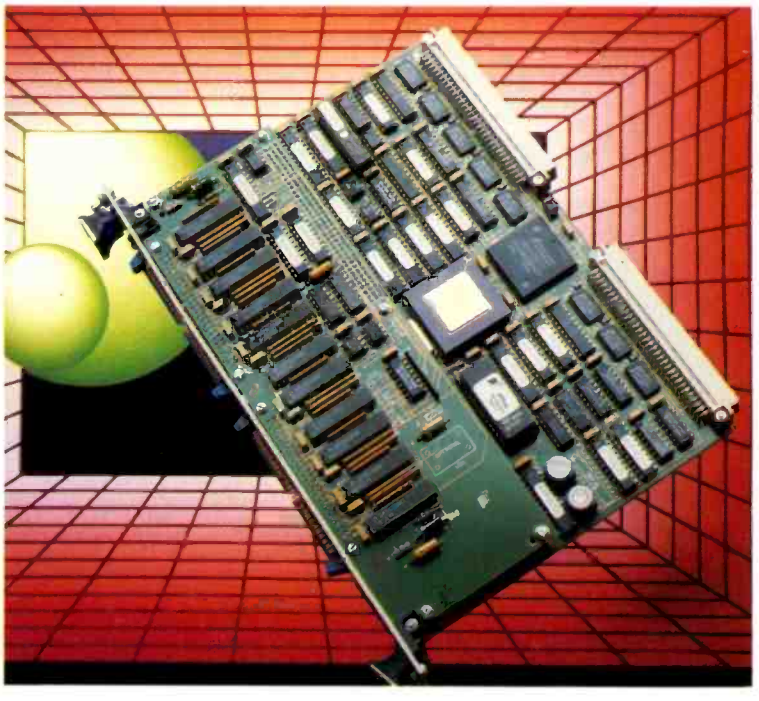
# COMPUTER

## Computer board level products

**Port boards.** Two PC/XT/AT (ISA) compatible board level products provide dual independent RS232 and RS422/485 ports. The PC48AT has two independent serial interfaces via nine-way male D connectors. Each port is jumper selected to be RS485 full duplex, half duplex, multi-drop operation, or RS422 full duplex with RTS-CTS control lines. The PC49AT also has two Independent serial interfaces, one RS232 via a 25-way D connector and one RS422/485vla a nine-way D connector. Amplicon Liveline, 0273 608331.



*Heuristic: BoardRouter emulates human characteristics to improve layout quality.*



*Boldly going: PeriTech's VME940 can send data at 50M byte/s between systems.*

*Take a peak: MicroEye image capture system escaping from the undergrowth.*

**Converter card.** The API36005 synchro/resolver to digital converter card plugs directly into the PC bus structure. Data can be passed to and from the instrument at rates more than an order of magnitude faster than conventional IEEE bus test systems. The card contains a broadband instrumentation-grade angle position indicator which accepts synchro/resolver signals of 11.8, 26 or 90V line-to-line and converts them to 16 or 20bit binary information. Data Device, 0635 40158.

**VMEbus interface.** A PerlTech VMEbus chassis-to-chassis interface can transfer data at up to 50Mbyte/s. The PTVME940 integrates up to 16 VMEbus systems in a parallel network. The boards uses the VME64 operating mode and high speed fifos under the control of a 68020 processor to supervise the data transfer operations and execute the resident network firmware. Dean Microsystems, 0734 845155.

**Image capture card.** The MicroEye RT real time image capture card for PC based applications feeds images into a 32K buffer at frame rate and with a resolution of 512 x 512 pixels. A second 32K buffer on the card provides a graphic overlay plane. A copy plane facility lets images be transferred out of the image buffer into the graphics plane for comparison purposes. A library of C language routines Is supplied. Digithurst, 0763 242955

## Data communications

**Modems.** Two modems use the Toshiba T-slot. The MicroQuln provide asynchronous, synchronous and fax dial up speeds up to V32(9600bit/s). And the MIcroQuad provides all the above except V32 but

has a software upgrade facility to V32. Other standards covered include V27ter, V26bis, V22bis, V22, V23, V21, and MNP 4 and 5.They have AT autodialing and answering and a built-in SDLC synchronous adapter. Kerridge Network Systems, 0635 524155.

## Development and evaluation

**Development system.** The MPE PLD development system for GALs and PLDs integrates the logic design software and the device programmer. It also has Jedec file support and documentation tools.The hardware consists of a PC plug-in card connected by ribbon cable to an external pod housing the zif programming socket. Three pods are available. Devices can be programmed from logic equations or from standard Jedec files. MicroProcessor Engineering, 0703 631441.

**68040 system.** A development system for the 68040 processor consists of C compiler, C source level simulator and debugger, and assembler. They are available for PCs and compatibles, Sun 3 and 4 workstations, Apollo, HP9000, DEC station and Vax VMS computers. Code produced by the compiler and assembler can be executed and debugged by the X-ray 68K debugger, making it possible to carry out software and hardware development in parallel. Microtec Research, 0256 57551.

**Computer peripherals Keyboards.** NMB mechanical and membrane keyboards are available in two versions - the RT101 using the industry standard keyswitch layout, and the RT101+ with a large AT-style enter key. They are compatible with IBM PC, XT, AT and PS/2 systems and have a slide switch for changing between the systems. Numeric pad and cursor keys may be used simultaneously without toggling Num Lock keys. A 2m cable is provided as standard. Jermyn Distribution, 0732 740100.

**Dot matrix printers.** The IBM Personal Printer Series II is a range of dot matrix printers with flexible paper handling. It comprises the 238X and 239X printers in nine-wire narrow and 24-wire carriage formats. The control panel lets the user check the status of a print job at a glance. The standard parallel interface operates with all IBM compatible PCs and there is an optional serial interface for connection to workstations running AIX and other systems. Lexmark International,0705 321212

## Computer security

**Computer locks.** A range of computer locks made to BS5750 includes units which can electronically immobilise the screen or keyboard or mechanically prevent tampering to the computer case. There are also models for security covers, storage cupboards, desk drawers and floppy disc boxes. The locks are made to individual requirements. Lowe & Fletcher, 0952 680381.

**Safe software.** The S versions of the V series processors have a security feature based around a customer-specific conversion table stored in the internal rom. Real-time conversion of every machine-code instruction on the V25S and V35S chips uses the conversion table to give protection against software piracy. The contents of the table are known only to the customer and cannot be accessed by any program, in-circuit emulator or other hardware device. NEC Electronics, 0908 691133.

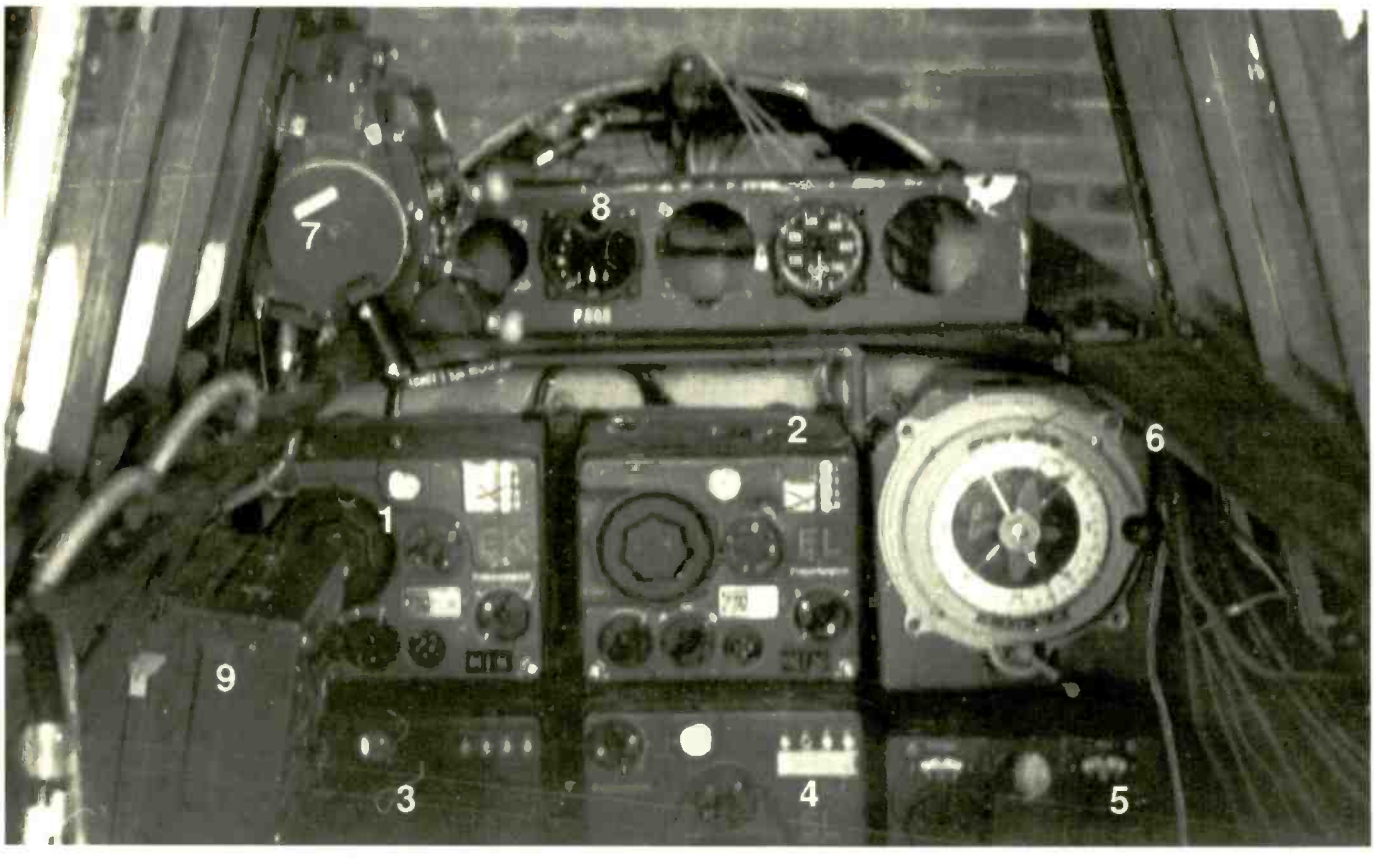
## Software

**Management system.** The Atoms automated test operations management system for test and process engineers provides data management of test or process parameters. Windows 3 multi-tasking software integrates data acquisition, analysis, reporting and database functions. It is built for an IBM AT, PS/2 or compatible computer. Biodata, 061 834 6688.

**OS-9 release.** The 68040 based Version 2.4 of OS-9 is available on the CPU-30 general purpose VME single board computer, the CPU-33 68030 VMEbus entry, and the CPU-40. A range of turn-key OS-9 2.4 systems has also been introduced for industrial and desk-top use. The 2.4 release has features such as write-through disc caching to optimise disc I/O. Force Computers, 0296 625456.

**Auto-router.** The Tango-Route PRO is an auto-router for use with a 386-based PC with 387 maths coprocessor or a 486-based PC with at least 4Mbyte of ram (8Mbyte recommended). It supports most graphics adapters up to 1024 x 768. Features include non-uniform routing grids and off-grid routing to handle most board densities and combinations of design rules and pad sizes. It has true diagonal routing, net-by-net variable track widths, and copper sharing (T-routing). Pentica Systems, 0734 792101.

**PCB autorouter.** BoardRouter is an autorouter for use with the Board Maker-2 cad system for pcb design. The PC-based software combines a gridless channel routing algorithm with heuristic attributes. It can handle all parts of a pcb's circuitry including those with metric pitch such as many of the new surface mount devices. Tsien, 0223 277777.




# AVIONICS — 1940s Luftwaffe style

November 1940 issue of *Wireless World* carried an item on radio equipment which, for the time, was particularly unusual. It was an article describing equipment found in crashed German aircraft.

As the piece pointed out, the samples were not in the prime of life when received, but no time was lost in gluing them together again so that aircraft and equipment could be tested against their Allied equivalents.

In single-seat fighters such as the Messerschmitt 109, the transmitter receiver was of a fairly rudimentary type. It was continuously variable from 2.5 to 3.7MHz and was mounted behind, and out of reach of, the pilot, so that the frequency had to be preset before take-off. Range was around 35 miles.

But larger aircraft carried rather more exotic equipment. When a crew member could be spared to concentrate on radio operation in aircraft such as the ME.110, Heinkel 111 or Junkers 88, then the FuG 10 was installed – perhaps the most extensive


*Fig.1. (top left) Cockpit assembly of the FuG 10 in an Me110 fighter. The observer sat behind the pilot and, at least in the early days, was aircraft commander. At (1) and (2) are SW and LW receivers; (3) and (4) are the transmitters; (5) is the remote aerial matching and tuning control; (6) compass repeater and loop bearing indicator; (7) is the D/F loop control and polar diagram selector; (8) is the Lorenz blind-landing indicator and (9) the intercom amplifier panel.*

*Fig. 2. (left) Receiver unit of compact design for panel mounting. Chassis were die-cast.*

*Fig. 3. (right) Pentode receiving valve, one of only two types used throughout the equipment.*

*Fig. 4. (above) D/F loop was a frame aerial but with a massive dust-iron core. Performance was effectively that of a much larger frame, but it could fit into a small blister on the fuselage skin.*

piece of equipment then in use in any air force.

FuG 10 was in four main parts and was no lightweight. It weighed well over 350lb and was compared in the *WW* article to a contemporary 500cc motor-bike. There were LW/SW transmitters and aerial matching unit; for navigation a D/F set with remote control for wave-change and polar diagram selection and a compass repeater (the compass was in the tail, away from magnetic components); a blind landing system of the Lorenz type first used in the mid-1930s in Germany and later adopted world-wide; and an intercom audio unit for crew intercom, to produce a side tone for CW keying, modulation for voice communication and pulses for ground-based D/F.

In pre-war and early war-time days, the Beobachter or observer was commander of the aircraft and operated D/F and communications gear. But as the war went on losses mounted and the observer/commanders, who were very experienced ex-pilots, were pressed into service as pilots again and the pilot became responsible for command and navigation. Hastily trained personnel had to map-read and use the D/F system. They sat next to the

pilot (no dual controls) and had no table to work on – as was the case in the RAF. This meant that the FuG 10 operational parts had to be mounted on the dash, although its generator, D/F loop, blind-landing receivers and aerial matching were elsewhere. An extremely compact, modular design was adopted, as the picture shows.

There were only two kinds of valve in the whole arrangement: a type RV12P pentode receiving type, usable as triode, mixer etc, with side contacts and a ring seal; and a high-power transmitting valve putting out about 65W from each transmitter. ■

*"The Electrical Experiment" by Van Loo showing early investigation of the Leden jar.*

# The Leyden jar enigma

***On the tercentenary of the birth of Pieter van Musschenbroek, the pioneer of Leyden experiments, Leonid N Kryzhanosky tracks the early history which led to subsequent development of the modern capacitor.***

The earliest electronic component, the capacitor, will soon be 250 years old, and despite forecasts made in the late 60s, world production of discrete capacitors has kept expanding, now exceeding over two hundred thousand million units per annum.

The first capacitor, baptised the Leyden jar, and its discharge through a human body, the Leyden experiment, are inseparably associated with the name of the Dutch physicist Pieter van Musschenbroek (1692-1761).

Without engaging in the still unsettled debate on the priority of the invention, undoubtedly most Western European scientists first learnt of the Leyden jar from the January 1746 letter of Musschenbroek to the Paris Academy of Sciences[1].

The Leyden experiment was an 18th century scientific sensation. Everybody admired a long bluish spark and was surprised by "electrical commotion" resulting from a discharge of the Leyden jar through the experimenter's body. It became "painfully clear" that the Leyden jar was capable of accumulating large quantities of electricity and storing them for a long time.

### Pictures of the Leyden experiment

In the Arkhangelskoye Museum located in the environs of Moscow, a painting titled *The Electrical Experiment* (dated 1777) by Charles-Amadee-Philippe Van Loo (1719-1795) describes an early experiment.

Before the advent of the voltaic pile (1799), the laboratory sources of electricity constituted exclusively of machines based on frictional electrification. Such a machine is shown in the painting. This is a glass globe which, when rotated, is rubbed against an amalgamated leather cushion to produce an electric charge (earlier it was rubbed just against the hands of an assistant).

*Pieter an Musschenbroek. An engraving by I. Koubraken after the painting by J. M. Quinkhard 1738).*

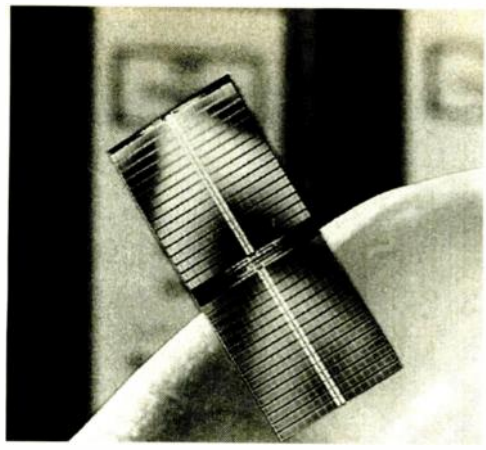
In the centre of the painting a girl stands on an insulating support with a rod in her left hand nearly touching the rotating globe. Sparks jump between the globe and rod. The human body as a whole is a good conductor so that the rod in her right hand is also charged. The latter rod is dipped into the water-filled glass held by the principal actor of the episode, the black boy.

The glass is the proper Leyden jar in its original form, the glass serving as the capacitor dielectric, and the water and the boy's hand, as the inner and outer electrodes, respectively (using the modern terminology). The painting shows charging of the capacitor: the boy is going to bring his free hand closer to the rod, which will result in an electric spark jumping between the rod and his finger, and the capacitor will be discharged through his body, giving him an electric shock.

### Law of charge accumulation

Immediately after their acquaintance with the Leyden jar, researchers began to ask why it produced such amazingly strong effects (shock and spark).

It had been recognised that the larger the prime conductor, the more painful would be the sensation caused by a discharge of the prime conductor through the experimenter's body. But the Leyden jar produced much stronger effects, despite its relatively small size. Two researchers established independently in 1746 that the greater the surface



*16 million capacitors on this memory chip owe their existence to van Musschenbroek*

area of the electrodes and the thinner the glass, the more electricity would be accumulated by the Leyden jar.

These researchers were the British portrait painter Benjamin Wilson (1708-1788)[3] and Dutch professor Jean-Nicholas-Sebastien Allamand (1713-1787), of Swiss descent[4]. But how did they establish the above law using the then experimental techniques? The answer is a Leyden jar with both electrodes of water, the jar being filled with and immersed in water.

Such a setup is represented in a popular book by Leonhard Euler (1707-1783) published in St. Petersburg[5]. It allows simple variation in the geometry of the Leyden jar under investigation. The researchers used their own body as a 'sensing device'.

The same year 1746 saw the advent of metal foil coatings used as electrodes[6].

## Franklin's experiment

Benjamin Franklin (1706-1790) of Philadelphia was also captivated by "Musschenbroek's wonderful bottle". He had found, among other things, that charges equal in magnitude and of opposite sign are stored in the Leyden jar. Franklin undertook to find out where exactly the charges resided. For this purpose, he charged the Leyden jar, then drew out the rod from it and poured the supposedly "electrified" water into an empty jar. The Leyden experiment with the new jar failed but upon filling the original jar with fresh "electrified" water, he discharged it through his body receiving a shock as if the "electrified" water had not been poured out, "which demonstrated the power to reside in glass as glass", not in the water, according to Franklin's letter of 1748[7]. The experiment has been described by many historians who explicitly or tacitly agree with Franklin[8].

## Addenbrooke's study

Curiously enough, a 20th century study showing that Franklin was wrong[9] has been ignored by many historians.

Addenbrooke built a dissectible capacitor made up of three hollow cylinders, a glass one and two metal ones, the latter fitting the former on its inside and outside, respectively. He charged the capacitor, then disassembled it carefully and brought the metal cylinders into contact with each other to discharge them should they be charged. Then he reassembled the capacitor which was found to be charged virtually to the same extent, as in Franklin's original experiment.

However, Addenbrooke did not jump to the same conclusion as Franklin. He performed a similar experiment with a paraffin-wax cylinder in lieu of the glass cylinder and obtained a result opposite to Franklin; the reassembled capacitor with known uncharged electrodes was found uncharged – the charges being found to reside on the electrodes of the capacitor.

Addenbrooke thus established that "Franklin's effect" was due to a water film which normally covers the glass. If the glass is thoroughly dried and the experiment is performed in a dry atmosphere, Franklin's effect would not be observed.

Of course, in Franklin's experiment, ion conduction by the glass does takes place but is relatively insignificant; so is the electrical effect of glass.

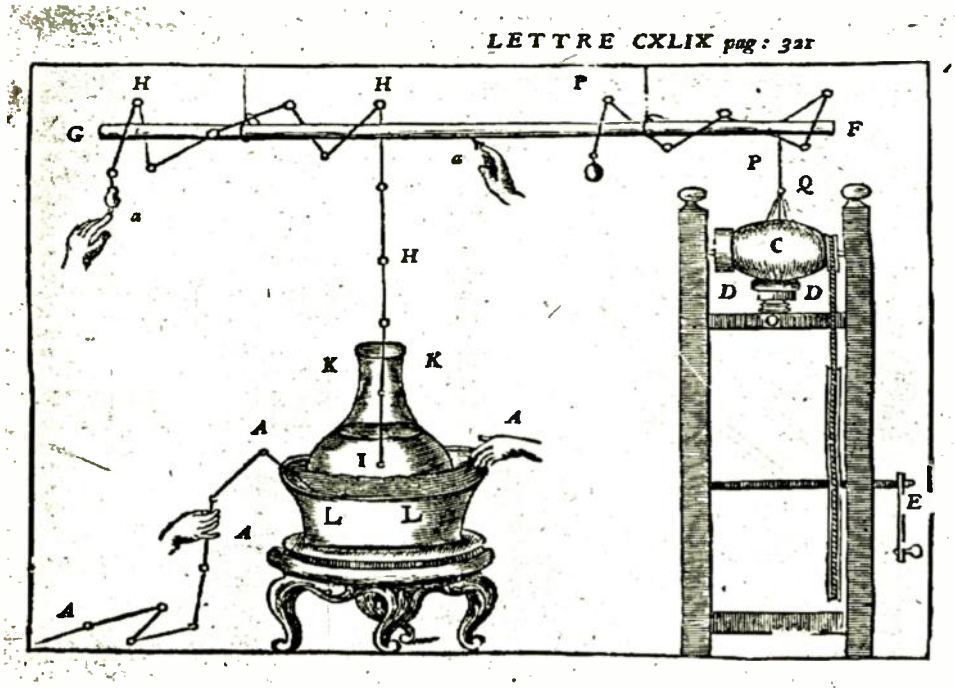
Note that a possible water film on the rim of the Leyden jar does not prevent charging of the jar since the mobility of ions on the glass is low. The water film and the low mobility of ions account for a phenomenon observed by Franklin on a dissectible parallel-plate capacitor[10]. If we charge the capacitor, remove an electrode and touch different points at the glass surface one after another, then a spark jumps each time between the finger and glass.

In contrast, an assembled capacitor will be discharged almost completely in one touch.

The Leyden jar gained a paramount importance in wireless telegraphy in 1898 when Karl Ferdinand Braun (1850-1918) patented a transmitter in which a dipole was excited through an oscillatory circuit containing a Leyden jar – virtually the only capacitor type of the time – which substantially increased the transmitter power and hence transmission distance[11].

The Leyden jar has been subsequently replaced by other capacitor types but was used in radio engineering even in the early 1940s[12].

*Illustration from Euler's book depicting an experiment to determine the effect of stored charge in a Leyden jar of variable geometry*





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11. F. Braun. Methoden zur Vergrosserung der Senderenergiefurdrahtlose Telegraphie (sog. Energieschaltung), Physikalische Zeitschrift, 1904,Vol.5, No.8, pp.193-199.
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*The author is with the A.S. Popov Central Museum of communications, Leningrad.*

# FERN ELECTRONIC FILTERS

Fern Developments Limited, 7 Springburn Place, College Milton North,
East Kilbride, Glasgow G74 5NU. Tel: 03552 29464. Telex: 776665. Fax: 03552 63273

## QUALITY SIGNALS FROM QUALITY PRODUCTS

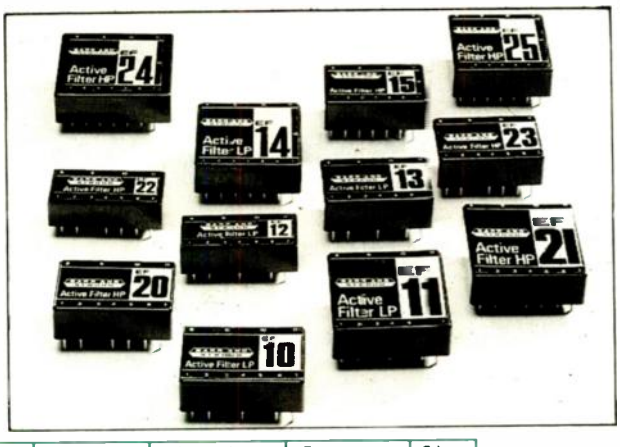
## General Purpose Low Pass, High Pass & Universal Active Filter Modules

LOW COST

To meet the need for easily incorporated filtering elements in such as experimental rigs, test signal conditioning, servo loop modification or instrument design, Fern Developments offers a range of Active Filter Modules.

They are "ready-to-use", encapsulated, compact filter units, each containing a basic filter function and adjustable by user for cut-off or centre frequency. Adjustment is simple, generally requiring the addition of 3 or 4 external resistors, sometimes a capacitor; all in acordance with simple design equations or tables of values given in the data sheets.

All low pass and high pass filters in this range offer the choice of Bessel, Butterworth or Chebychev responses selectable by the user.




| Filter reference | Mode | Attenuation rate dB/octave | Frequency setting range Hz | Price 1-OFF |
|---|---|---|---|---|
| EF10 | Low Pass | 12 | 1 to 300 | £28.00 |
| EF11 | Low Pass | 18 | 1 to 300 | £32.00 |
| EF12 | Low Pass | 12 | 100 to 30K | £28.00 |
| EF13 | Low Pass | 18 | 100 to 30K | £32.00 |
| EF14 | Low Pass | 24 | 1 to 300 | £36.00 |
| EF15 | Low Pass | 24 | 100 to 30K | £36.00 |
| EF20 | High Pass | 12 | 1 to 300 | £28.00 |
| EF21 | High Pass | 18 | 1 to 300 | £32.00 |
| EF22 | High Pass | 12 | 100 to 30K | £28.00 |
| EF23 | High Pass | 18 | 100 to 30K | £32.00 |
| EF24 | High Pass | 24 | 1 to 300 | £38.00 |
| EF25 | High Pass | 24 | 100 to 30K | £38.00 |

| Filter reference | Mode | Attenuation rate dB/octave | Frequency setting range Hz | Price |
|---|---|---|---|---|
| EF40 | LP/HP/BP/BS (Universal) | Depending on mode selected | 0.1 to 200 | £34.00 |
| EF41 | LP/HP/BP/BS (Universal) | Depending on mode selected | 10 to 20K | £34.00 |
| EF42 | LP/HP/BP/BS (Universal) | Depending on mode selected | 100 to 200K | £38.00 |
| EF43 | LP/HP/BP/BS (Universal) | Depending on mode selected | 0.001 to 100 | £38.00 |
| EF44 | LP/HP/BP/BS (Universal) | Depending on mode selected | 1 to 1K | £34.00 |
| EF45 | LP/HP/BP/BS (Universal) | Depending on mode selected | 100 to 30K | £34.00 |
| EF60 | Low Pass/ High Pass | 24 | 0.2 to 2K (HP) 1 to 10K (LP) | £40.00 |
| EF61 | Low Pass/ High Pass | 24 | 3 to 30K | £40.00 |

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on All Models
1-4 List Price
5-9 Less 5%
10-24 Less 10%
25-99 Less 20%
100-200 Less 30%
200-up on Quotation

### High Slope Active Filter Modules

EF 16 (ANTI-ALIAS)

This low pass module is based on a new class of monotonic passband, equal ripple stop band filter functions. Referred to as an LSM (least square monotonic) filter it provides sharp cut-off, high stop band attenuation and improved group delay response. A prime use for this module is as an anti-aliasing filter in A/D conversion applications.

- Frequency cut-off range 2Hz to 20kHz
- Minimum stop band attenuation 60dB
- Stop band attenuation roll-off 100dB/octave

EF 16X (POST PROCESSING)

This low pass module is intended for use as a post processing Filter, ie to follow analogue to digital conversion in a signal processing system.

Its specially shaped passband compensates for the distortion introduced during the digital to analogue conversion.

The EF 16X compliments the EF 16 when the latter is used as an anti-alias Filter.

Both have the same format in terms of dimensions, pin connections, frequency range and stopband attenuation response shape.

**EF26**

This high pass filter is based on a conventional elliptic design having an equal ripple pass band, sharp cut-off and high stop band attenuation. It has many applications such as the removal of low frequency interference mains or rectifier hum from signal paths. It can be used with the EF16 to form a band pass unit.

Roll-off rate is 80dB/octave, stop band attenuation 60dB and cut-off frequency range 2Hz to 20kHz.

**Eurocard Mounted EF16, 16X and EF26**

To simplify connection both filters can be supplied mounted on a standard single Eurocard fitted with a 32-way connector. The card accommodates 4 sets of frequency determining resistors which can be switched, either locally or remotely, in a binary format to provide a maximum of 15 cut-off frequency settings.

| Price 1-4-OFF | |
|---|---|
| EF16, EF16X, Module | £69.00 |
| Module Mounted on Eurocard | £149.00 |
| EF26, Module | £69.00 |
| EF26 Mounted on Eurocard | £149.00 |

Volume Discounts
As Above

All Above Prices
Exclude VAT

### Voice Frequency Filters Types EF117, 118, 118A, 119

These modules are designed primarily for use as voice frequency channel filters in telecommunications. They provide separate band pass, low pass and high pass units, enabling the user to select the most cost-effective arrangement. Common specification points are an attenuation in the stop band of > 40dB, with a pass band insertion loss of nominally 0dB.

Other basic specifications are:

- EF117 – Band Pass 300Hz to 3.4kHz
- EF118 – Low Pass d.c. to 3.4kHz
- EF118A – Low Pass d.c. to 1.8kHz
- EF119 – High Pass 300Hz to 50kHz

Volume Discounts As Above

| Price 1-4-OFF | |
|---|---|
| EF117 | £58.00 |
| EF118 | £38.00 |
| EF118A | £35.00 |
| EF119 | £30.00 |

# Pressure sensing

Motorola produces a booklet entitled *Pressure Sensors* which, not surprisingly, is concerned with that company's range of fluid pressure sensors using piezoresistive elements to give ranges from 1.5 to 100 psi.at up to 60mV full-scale output. An important part of the publication is to do with interfacing the devices, which are available as ported, assembled units or as unported elements, giving absolute, differential or gauge pressure measurements.

A number of interface circuits are shown, of both the simple type and slightly more exotic variety with more precise offset and span settings. **Figure 1** is a precision pressure-to-voltage converter using a quad op-amp, which will drive either a DVM or a microprocessor. The span is determined by the setting of $R_g$ and offset voltage with $R_{OFF}$. Output is 8V at full application of pressure.

**Figure 2** is a portable manometer, using an MX2050P device to provide a scale factor of 1mV/1mm mercury. The booklet provides a method of calculating the value of $R_g$. Types of op-amp used are not specified, but Motorola points out that the choice must be relevant to the design aims with regard to temperature, drift and noise. For example, this manometer design offers error better than 0.5% over the normal ambient range and could easily be degraded by an unwise choice of active and passive support components.

**Figure 3** is a barometer, which displays kPa on a 199.9mV digital voltmeter. Calibration is as follows, assuming one does not have access to a vacuum pump. Record reading and local pressure; with a change in pressure, record new pressure and reading; adjust cal so that the change in reading equals the change in pressure, repeating as necessary; adjust offset to make displayed reading equal local pressure. (100kPa = 29.529 inches mercury.)

*Motorola Ltd European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP. 0908 614614.*

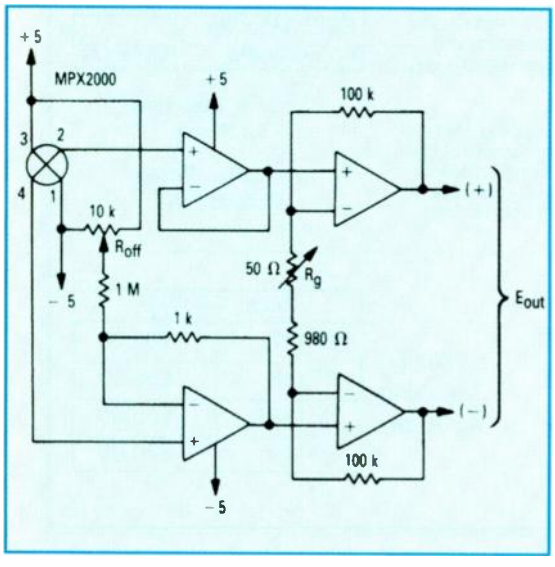



*Fig.1. Precision pressure-to-voltage converter using Motorola MPX2000 series of piezoresistive transducers. This is the more advanced version of two shown.*

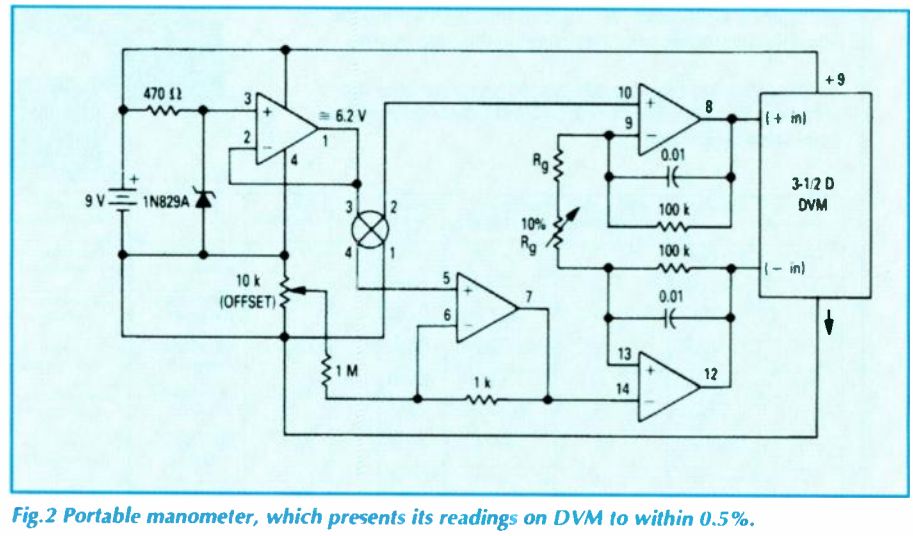



*Fig.2 Portable manometer, which presents its readings on DVM to within 0.5%.*

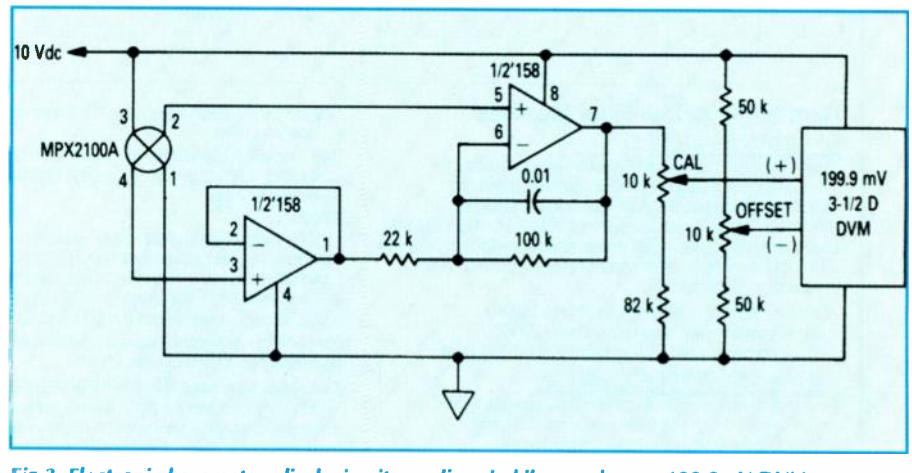



*Fig.3. Electronic barometer, displaying its readings in kilopascals on a 199.9mV DVM.*

# Hand-held, low-cost data logger

Application Note AN175 from NEC describes a data logger that does not rely on the assistance of the usual PC, but which uses an NEC µPD75308 microcontroller to provide a very economical instrument for use in chain stores and the like.

A simple solution is shown in the diagram, in which the µPPD75308 possesses features on-chip that render it particularly suitable for the purpose. There is, for example, an LCD controller/driver; a real-time clock timer; a general-purpose 8-bit timer; interrupt controller; 32 I/O pins; and ample rom and ram.

The LCD controller drives up to 17 seven-segment characters or eight starburst alphanumeric characters or a combination. Data storage is provided by the 8K sram, which needs 5V during data access, although since the micro works from a 2.2-6V supply, one supply will suffice.

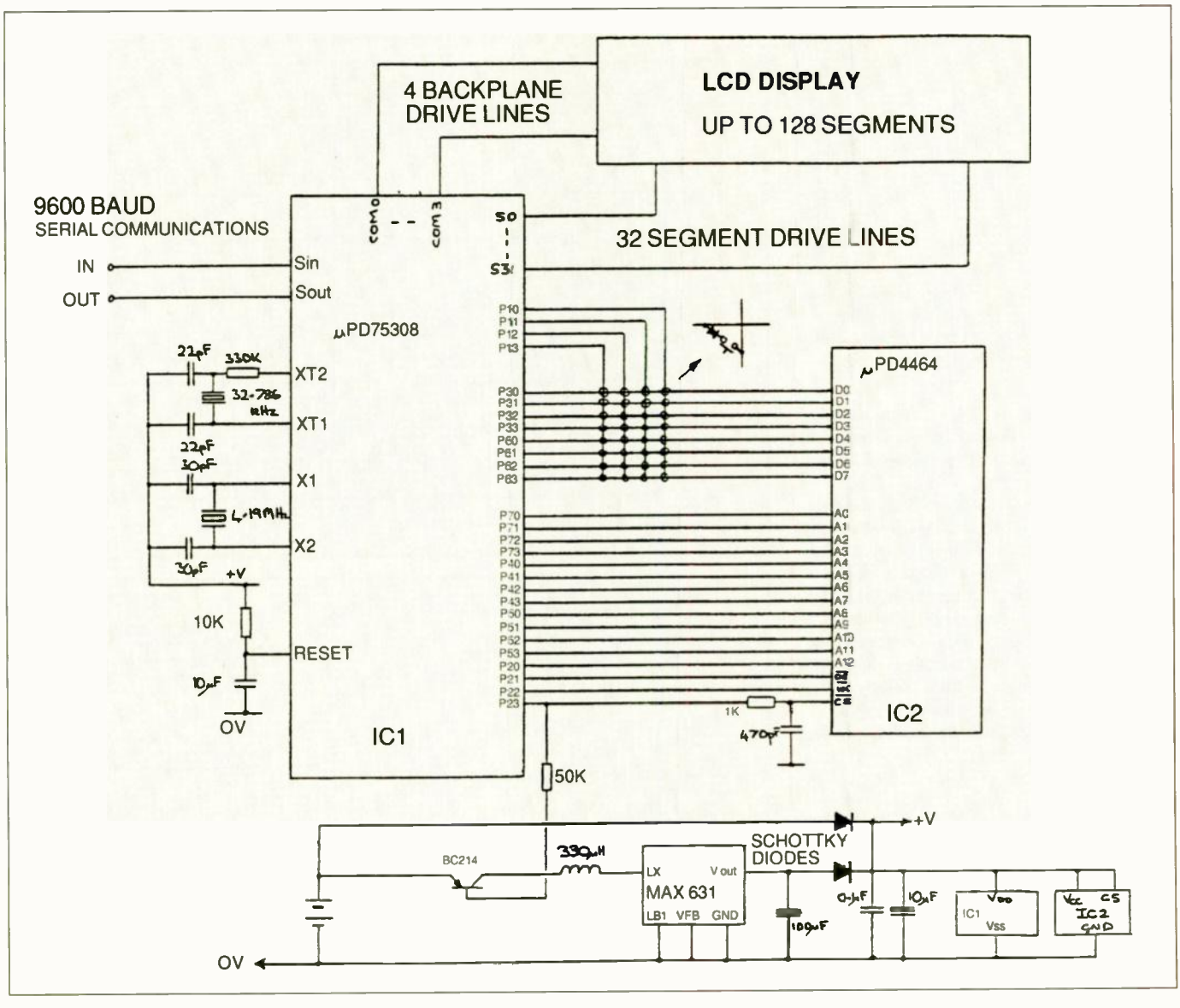
One port is a serial comms bus, supporting half-duplex RS232C at up to 9600 baud, and four more ports form the address and control bus for memory and control operation of the Max632 voltage booster during memory access in circumstances when the micro is powered from a lower voltage.

Two ports form the memory data bus and carry key-scan lines for the keyboard, Port 1 being keyboard input on four lines with interrupt.

µPPD75308 is either masked for large-scale users or is one-time programmable for development. There are in-circuit emulators, relocatable assemblers and PC simulation.

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

***Minimal data logger/retriever from NEC, meant for use in large stores or, perhaps, meter reading.***



# Stepper-motor driver

International Rectifier's PIH2001 hybrid power device is intended to drive stepper motors; its single in-line package contains all power and control functions to establish pulse-width modulated current control. Inputs are TTL-compatible. As a result of the use of PWM, a high motor speed is allowed, and the mosfet drivers enable high-speed chopping for better performance and a wider choice of motor.

Half a PIH2001 is shown in **Fig.1**. If the current in this motor phase (A) is to flow in A+, Q1 is turned on. Resistor Rs senses current in the winding and feeds the control IC with the information. When the current reaches the correct level, $Q_1$ starts to chop to keep the current constant until the input

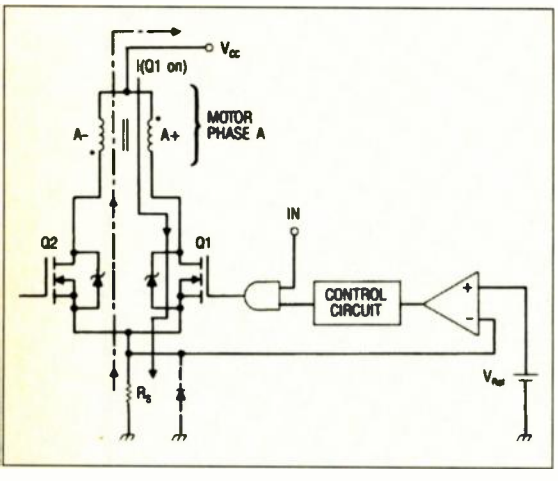



*Fig.1. One side of the International Rectifier PIH2001 stepper motor driver/controller. Mosfets allow high-frequency chopping and an extended choice of motor.*

controlling this phase (IN) changes state, $Q_1$ turns off and the other half of the device takes over in the same way. **Figure 2** shows the relevant waveforms.

A practical arrangement in **Fig.3.** shows control circuit details; each is supplied from its own regulator. The reference voltage for the control IC inputs is obtained from the potential divider on the external regulated supply $V_b$, which in practice is obatinable from the motor supply via a zener regulator, as can the control circuit supply if the motor supply is 30V or over. Typical values for external components are shown in **Fig.4**.

***International Rectifier**, Hurst Green, Oxted, Surrey RH8 9BB. 0883 713215.*

*Fig.4. Recommended component values.*

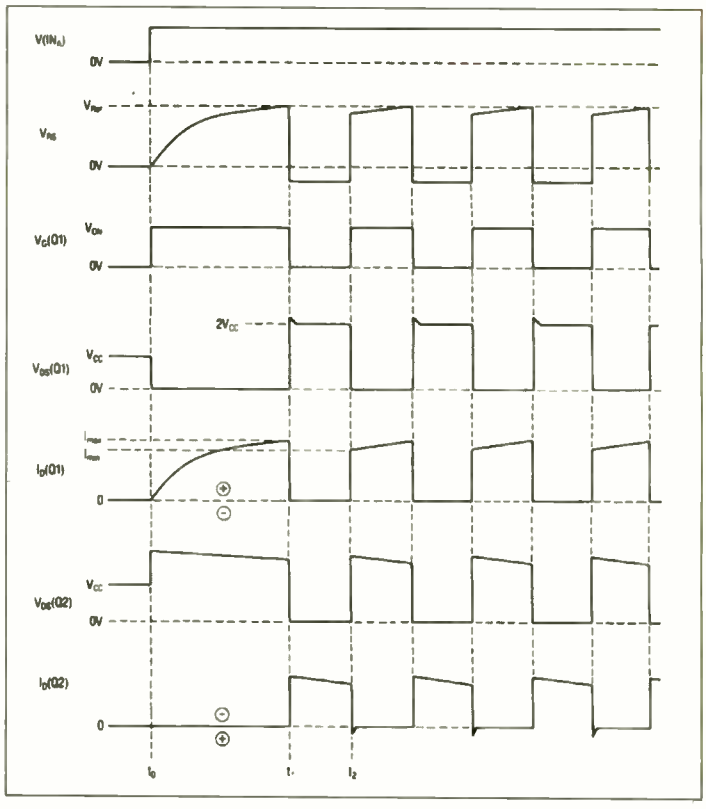



*Fig.2. Waveforms in the control circuit of half the device.*

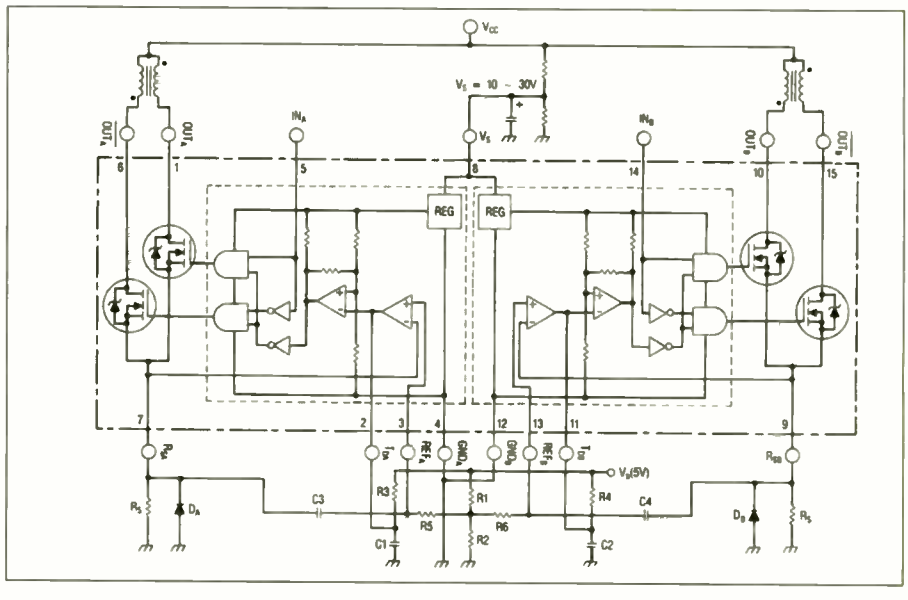
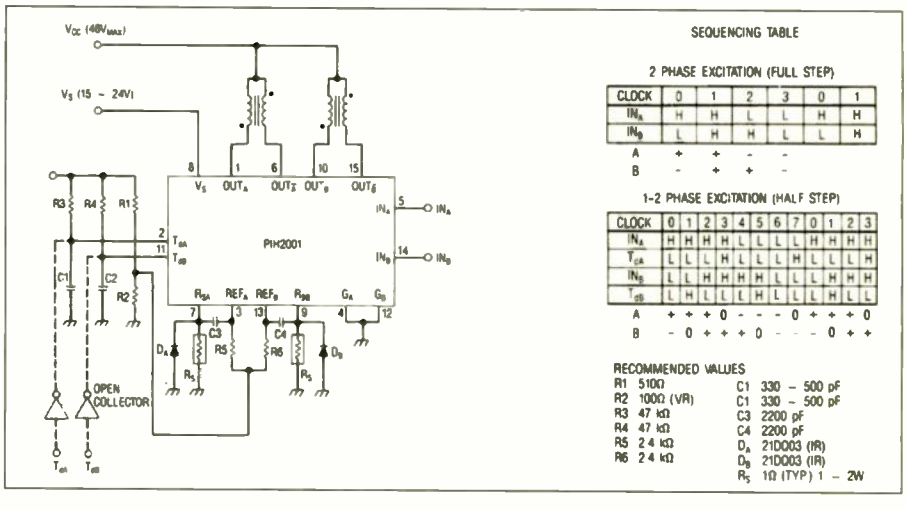



*Fig.3. Practical details of the device in use, showing the control circuit in more detail. All active circuitry is on-chip.*



# DSP chip with no parallel?

Performance of Texas Instruments TMS320C40 is impressive; with a 40ns cycle time it can perform 275 million operations per second with a data transfer rate of 320Mbyte/s. For calculations it can execute 25 million floating point operation per second (25Mflops).

But the innovation is an ability to configure any number of C40s into a multiprocessor array, allowing construction of a very impressive number cruncher.

***Parallel processing through six parallel 8-bit communication ports makes the TMS320C40 a landmark in chip development says Allen Brown***

### Architectural features

C40 is an enhancement of TI's C30, with common features allowing C30 object code to be executed.

The CPU has several sections (**Fig. 1.**) with a wealth of buses servicing each section. The multiplier performs either 32-bit integer or 40-bit floating point multiplications and the 40-bit result can be added to the contents of one of the extended precision registers (R0-R7) – all within one clock cycle (40ns).

Working in parallel with the multiplier is the arithmetic logic unit (ALU) which can act as a 32-bit barrel shifter. The normal arithmetic operations (add, subtract – fixed and floating point numbers) are performed by the ALU along with the standard logical operations (AND, OR and EOR). Two auxiliary register arithmetic units (araus) in the CPU can generate two simultaneous addresses with the necessary displacement, indexing, circular or bit-reversal addressing options.

Again these operate in parallel with the multiplier and ALU.

Address space of the C40 is 4Gigabits and most of this can be occupied by 32-bit external memory.

On-chip memory is partitioned into four sections; a 128 32-bit word cache, 2K of 32-bit words of ram in Blocks 0 & 1 and 4K of 32-bit rom. External memory of the C40 is mapped by either the local address bus or the global address bus. In a multiprocessor system each processor will need its own local memory and shared global memory which can be accessed by the other processors in the system.

As part of the general CPU architecture there is a primary register file containing 32 registers and an expansion register file consisting of two registers for coping with interrupts. As part of the primary register file there are twelve extended precision, 40-bit registers designed to maintain extended floating point precision. In the normal sense of a microprocessor these act as accumulators.

Eight auxiliary 32-bit registers (AR0-AR7) support a variety of addressing modes and are used to generate a 32-bit address for local or global memory.

Remaining registers support other system functions such as stack management, processor status, interrupt management, block

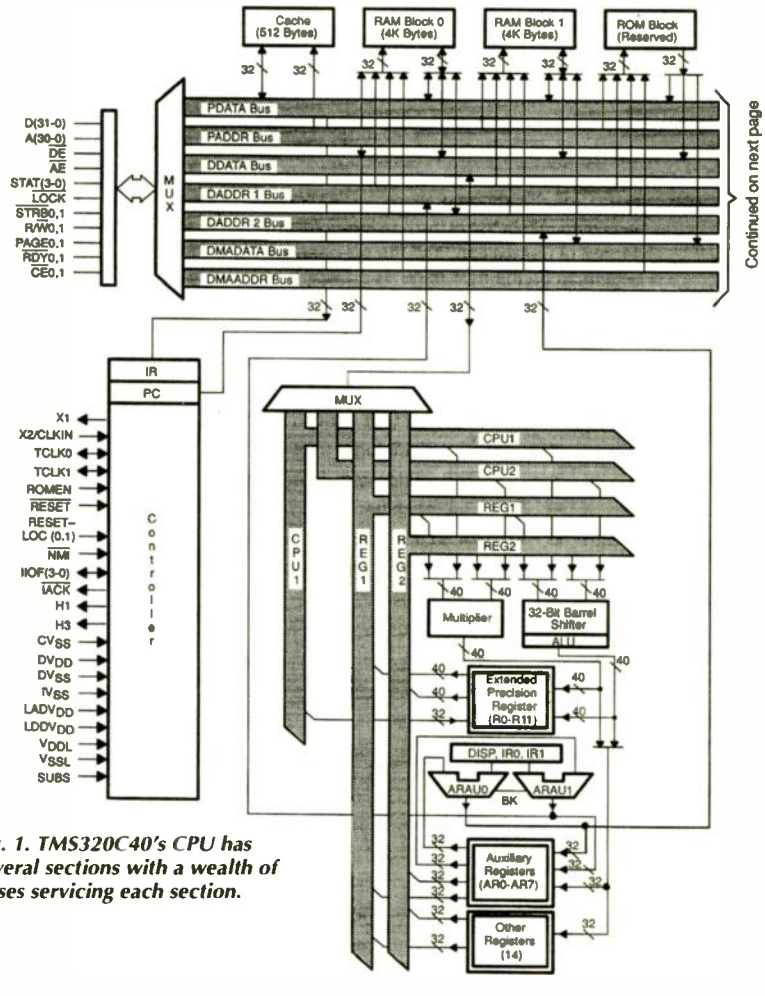



*Fig. 1. TMS320C40's CPU has several sections with a wealth of buses servicing each section.*

instruction repeats and various addressing modes. The components in the CPU are serviced by two 32-bit register buses (REG1 & 2) and two 40-bit CPU buses (CPU1 & CPU2), enabling the CPU to achieve a very high degree of parallelism – one of the principal attributes of the C40.

### Peripheral bus memory map

All internal peripherals are controlled by a set of registers mapped into the device's memory map in a peripheral bus memory map. The left hand side of Fig. 1. shows peripherals, consisting of the six 8-bit parallel, bi-directional communication ports and two timers. The peripheral module is serviced by an extraordinary wealth of the 32-bit buses: an interesting feature is the facility for concurrent data transfer via the DMA.

Data movement and its potential bottleneck has been tackled by including a dedicated coprocessor for controlling DMA operations through eight channels. The coprocessor can access all memory locations in processor address space.

Six communication ports provide efficient processor-to-processor data transfer and enable a closely coupled system to be realised.

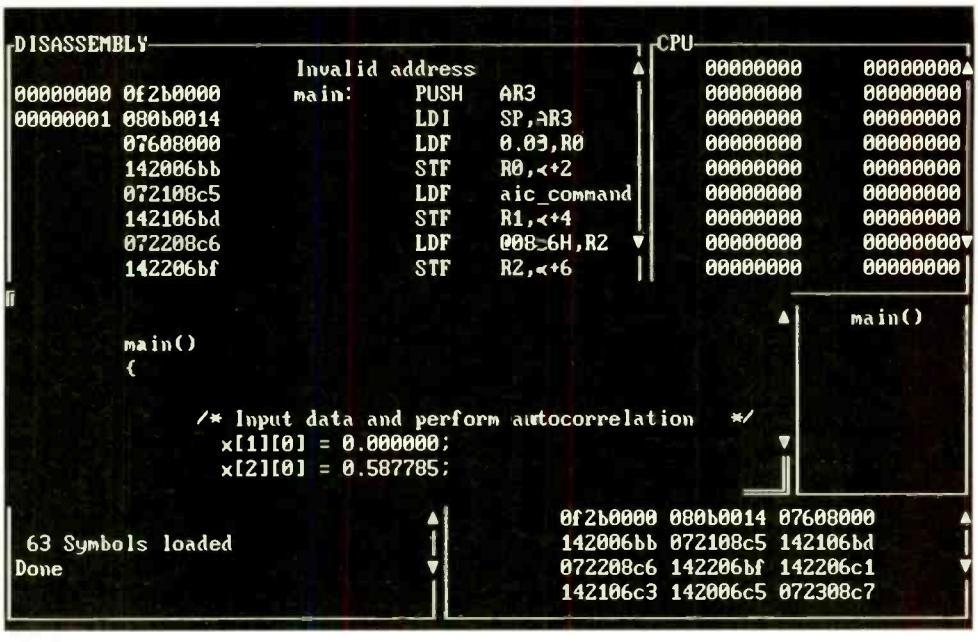



*Fig. 2. Display of the software simulator for the TMS320C40 showing source C code and assembly language.*

Each port has separate input and output fifos coupled to a port arbitrator unit – arbitration is necessary to control data buffering, handshaking and to manage the inter-processor data transfer. Ports also have their own interface and can accommodate a direct transfer rate of 20Mbytes/s without the need of additional logic. Arbitration is performed automatically to ensure synchronisation between system processors.

### Support tools

Software and hardware support includes a C compiler, a cross assembler, linker, software simulator, a XDS510 in-circuit emulator and an evaluation board hosting four C40s.

Software tools are compatible with operating systems such as VMS, Sun OS, MS-dos and for Macintosh with MPW. The C compiler conforms to the Kernighan and Ritchie standard and the software simulator has a window configuration (**Fig. 2**).

Usefully, the simulator can single step code while simultaneously displaying the C source code together with the assembly language code. The real-time operating system for digital signal processors, Spox, is also available.

### New applications

C40's provision for multiprocessor design, with its six communication channels, is ideal for realising a variety of topologies including hexagonal grid (honeycomb structure), 4-D hypercube and hex star.

New areas of application for C40s span advanced image processing (techniques such as maximum entropy spectral estimation), multichannel cross-correlation analysis and array processing for signals from microwave sources.

Similarity between the C40 and the new version of the Transputer (T9000) has not gone unnoticed and some projects are currently in design which include a mix of T9000s and C40s. ■

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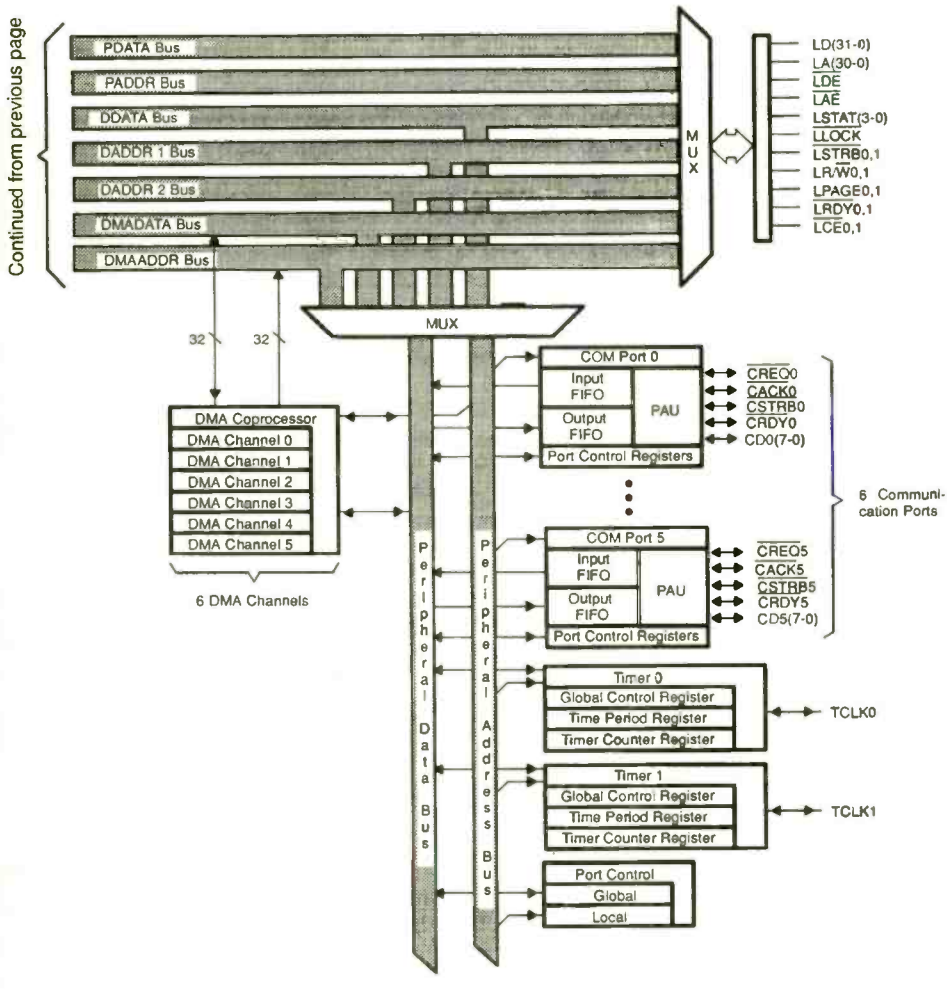


# All systems go for dab?

***Tests of digital audio broadcasting are producing excellent results. Can the practicalities of dab be overcome? Barry Fox and Pat Hawker investigate.***

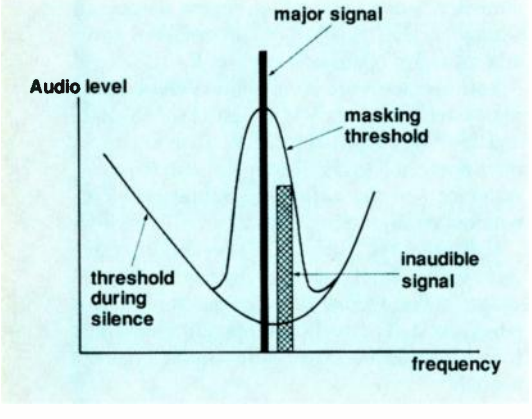
Success of the first live demonstration of digital audio broadcasting (dab) in the UK has been so dramatic that BBC engineers are now stuck with a problem. They have effectively proved the inadequacy of FM broadcasting

As a result of the demonstration, given by the BBC in Birmingham during the Radio Academy's annual Radio Festival, the current game plan (though "not a BBC commitment") is to press ahead for a public dab service as soon as possible.

Privately the BBC has doubts about the practicality of transmitting dab signals from satellites and allocation of suitable frequencies. So the corporation will now ask the government for a slice of VHF band for terrestrial transmission.

For quite different reasons, US broadcasters also want to use the dab system for terrestrial broadcasting. They fear that the wide coverage of a satellite system would spoil business for local radio stations, which rely on local advertising.

This puts the BBC and US out of line with the original thinking behind Eureka project 147, which came up with the dab technology. Until now the Eureka team, of




***Noise masking by a loud audio signal: low amplitude sounds close in frequency to a loud signal are inaudible – and not coded in mascam dramatically reducing the number of bits required***

which the BBC is the only UK member, has seen satellite transmission as an essential part of dab. This follows from the fact that dab has been under development for four years, with the investment of 360 man-years of engineer time and $50 million, all coordinated by DLR, the Aerospace Establishment, in Cologne.

Recently there has been a rush to prove the system in time for the next World Administrative Radio Conference (Warc), to be held in Spain early next February. The aim was for Warc to allocate an international band of frequencies in the 1.5GHz band (see box). But the UK government now seems keener on 2.5GHz. Hence the BBC's decision to forget about satellites for the time being and go for a slice in VHF Band I, II or III - whatever is available.

Companies participating in EU-147 include electronics manufacturers AEG, Bosch, Grundig, ITT and Philips, along with broadcast and telecommunication bodies such as the BBC in Britain, the Centre National D'Etudes des Telecommunications in France and the Bundespost in Germany. The British, French, Dutch and German governments have given financial support. Germany is particularly keen to start a terrestrial service. Receivers (from German manufacturers) could be ready by 1995.

### Moving target

Existing digital audio broadcast systems (eg Nicam and DBS) all suffer from the same problem; they only work when the receiver is getting its signal direct from a satellite or terrestrial TV transmitter, via a directional aerial. Fading and multipath will kill reception, so existing systems cannot be used with moving vehicles.

Before joining the Eureka project, the BBC tried using its transmitter at Pontop Pike in County Durham to broadcast digital radio programmes to cars using a radio-only version of the Nicam TV system. The test satisfied the BBC but there was no hope of making Nicam work for car radio.

The only way to make a digital system immune from multipath is to reduce the bit rate to very low speeds, so that there are very long gaps between bits. The receiver can then recognise and reject bits which arrive in the gaps as reflections.

First step in the dab process is digital compression, using the new systems which rely on masking; when two sounds of similar frequency exist together, the ear only hears the louder of the two. So only the louder need be coded. The original work on digital coding with masking was done five years ago by the Institute Fur Rundfunktechnik, the German radio research centre in Munich. IRT's system was called Mascam (masking-pattern adaptive sub-band coding and multiplexing).

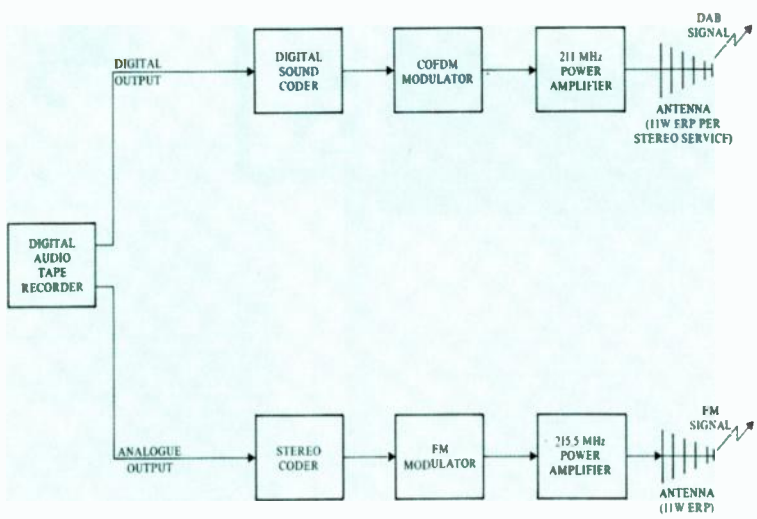
Filters divide the full frequency range of sound into narrow sub-bands. The sound in each band is continually analysed, masking effects predicted and only the minimum number of digital bits are needed to code each band. As all ears are different, and the sounds of music are infinitely variable, there can never be a cast iron rule book to guide the computer. Philips new digital compact cassette, DCC, and Sony's Mini Disc, rely on masking coding.

Two rival systems have been proposed for dab, both derived from Mascam. The French government's radio and communications research centre in Rennes, CCETT (Centre Commun d'Etudes de Telediffusion et de Telecommunications), offers Musicam (masking-pattern adaptive universal sub-band integrated coding and multiplexing). Aspec (adaptive spectral entropy coding) is a joint proposal from AT & T Bell Laboratories, Thomson Consumer Electronics, Germany's Fraunhofer Society and CNET (France's Centre Nationale d'Etudes des Telecommunications).

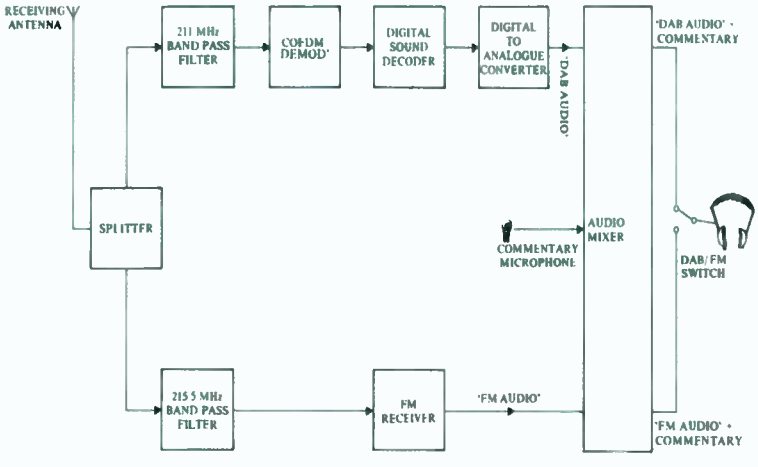
For the Birmingham tests the BBC was equipped to use either, and the final dab system will probably combine the best features of both.

### Birmingham witnesses dab excellence

The Birmingham experiments used VHF frequencies and a terrestrial transmitter, and proved without a shadow of doubt that dab works far better than FM. BBC engineers




*Transmitting equipment used in the Birmingham dab test: the system required just 11W of RF compared to 1kW for a comparable FM transmission.*




*Receiving equipment was installed in fifty-seater bus and allowed A/B comparison of reception quality. The results convinced even the most cynical engineers. All observers were particularly impressed with the resistance of dab to multipath distortion typical of standard FM transmissions.*

believe that if the British government will urgently allocate a 4MHz slice in any of the three VHF bands (I, II and III), a network of low powered transmitters could, by the mid 90s, start serving the UK with twelve digital stereo radio programmes, half from the BBC and half from commercial stations.

The BBC put the FM and dab transmitters on the top of a building in the city centre. Both broadcast with a power of 11W in Band III at around 215MHz. By comparison, at least 1000W is currently needed to cover a city with FM stereo.

FM stereo and dab receivers were installed in a fifty-seater bus, with audio headphones at each seat and a switch to give a direct comparison of FM and dab reception. The results surprised even hardened engineers.

As the bus toured the city centre the FM signals were frequently spoiled by hiss, flutter and pops caused by reflections of the signal from buildings and interference from cars, office computers and electronic cash registers. All the time the dab signal remained absolutely clear. It only failed briefly, when the bus went under a long underpass.

As an acid test, the BBC drove the bus radially out of town to see how far the 11W signals would carry. FM reception failed after 10km, but dab kept on working for 25km.

Tests in Band I and II will follow in London and Birmingham.

As well as being immune from interference, and carrying further, dab is also far more efficient in its use of radio spectrum. FM needs around 2.2MHz of the VHF band for each national radio stereo programme. The Birmingham tests proved that dab can reliably squeeze 12 stereo programmes in a 4MHz slice of the VHF band with a network of transmitters on the same frequency covering the whole country.

When dab broadcasting begins, the public will need to buy new receivers so FM broadcasting must continue alongside dab for decades into the future, much like the transition from 405 to 625 line TV.

The tragedy of the situation is that if dab had been ready a couple of years earlier, UK government could have allocated a 4MHz slice in Band II, to carry a mix of commercial and BBC national stations. Now the Radio Authority has been given chunks of Band II for Independent National FM Radio, which means there is no room in the band for dab. The most likely home for dab is thus Band I or III.

### Caution advised

But Michael Gerzon of the BBC has warned against standards being set too fast and early: "The Eureka researchers have had very little input from the audio industry about the practical effects of masking, and

## FREQUENCY REQUIREMENTS

Direct-satellite broadcasting still has no suitable international frequency allocation. Most engineers believe that an allocation of about 50MHz for space-broadcasting should be sought at around 1500MHz (L-Band) but there is more possibility of obtaining an allocation in the region of 2300MHz (S-Band) despite the technical and economic disadvantages of the higher frequency.

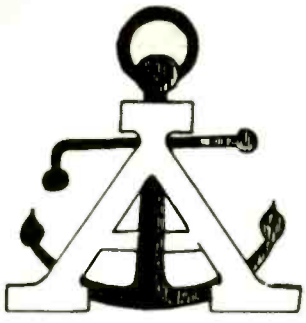
For terrestrial networks there would be advantages in reducing frequency to around 500 to 700MHz or, even better to VHF (30 to 300MHz). The private BBC tests at Croydon/Kenley-active-deflector last year (see *EW + WW*, December 1990, p.1106) used 531MHz whereas the Birmingham demonstration system (for nine stereo radio services and additional data) transmitted in a 3.5MHz bandwidth in VHF Band III (211MHz).

The BBC's "planned operational system" would offer up to 12 stereo radio services in a 4MHz bandwidth, and, importantly, could use a single frequency for a national terrestrial VHF network.

Bands I (41 to 68MHz) and Band III (174 to 216MHz) remain international "broadcasting" frequency allocations, although closed to British broadcasters for almost a decade, except for some "ancillary" applications. Much of this 69MHz of spectrum has since been allocated in the UK for "land mobile" services, but there remain unallocated portions and it would be entirely within the competence of the Radiocommunication Agency, with DTI approval and relatively simple international co-ordination with neighbouring countries, to re-allocate a 4MHz band to UK broadcasters.

The BBC indicated that possibly six of the 12 channels might be made available to independent Radio services although with the single frequency network (SFN) concept these would presumably need to be national rather than local services. A relatively minor objection to using such an allocation is that terrestrial dab services could not be set up identically throughout Europe where Bands I and III remain in use for television – although it would be possible even there to utilise "taboo" television channels for local dab relays. A UK SFN dab network could be fed from a "conventional" geostationary distribution satellite.

**Pat Hawker**



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## COSTS OF CAR RADIOS

Little has been published on the cost comparisons between car radios for FM and for terrestrial-dab requiring only a simple whip antenna. Henry Price (BBC) has written: "Computer-based technology will be used in the receiver to implement the advanced digital systems needed for dab. After suitable RF filtering, the dab signal will be digitised and all the subsequent processing will be done in the digital domain.

Carriers will be demodulated using fast Fourier transform processing. The desired audio signal will be selected by altering the demodulation process rather than by modifying or changing components. As far as the listener is concerned there will be no "tuning"and the receiver will be totally "push-button".

Virtually the whole receiver will be implemented using VLSI circuits. If world-wide frequency allocations are made available for satellite-dab and agreement can be reached on a single world standard then with large scale production, the cost of receivers would be extremely low. It is very important that this technology be inexpensive and readily available if it is to be attractive to developing countries, since in many of these countries it will be cheaper to install such a dab service than a terrestrial VHF-FM network. **PH**

how it can sometimes fail unpredictably. I am worried that this system is being rushed through without adequate knowledge of how it will cope with critical sound material".

Egon Meier-Engelen, Eureka team leader at DLR, pledges that whatever compression system the Eureka team finally adopt, it will be flexible so that future developments in coding technology can be implemented. The same receiver can cope with incoming data rates of 192, 128, 96 and 64Kbit/s.

Similarity between Musicam, Aspec and the Philips DCC and Sony MD coding systems, means that DCC and MD decks should be able to make direct digital recordings of dab signals.

### Tackling multipath

The compressed code still streams too fast to be immune from multipath. So the Eureka dab system spreads the bits over a large number of channels of closely spaced frequency. The technique, called CODFM (coded orthogonal frequency division multiplex), was proposed by the CCETT, and is analogous to sending a digital signal down a large number of thin parallel wires, instead of a single large cable.

The Eureka plan is to group a cluster of stereo radio programmes together in a slice of the radio spectrum which, with a frequency width of 7MHz, is equivalent to a single analogue TV channel. Each sound channel is accompanied by 4Kbit/s of data.

Because the dab system is so resistant to multipath, it can also cope with the area of overlap between different transmitters operating on the same frequency. This means that a dab network can operate across the entire country on a single frequency.

Originally the plan was to put 16 stereo programmes into the 7MHz slice. But latest Eureka thinking is that it may be possible to split each 7MHz frequency slice into four separate blocks, each 1.5MHz wide, with blocks carrying up to six different stereo radio programmes. This will let neighbouring countries draw radio boundaries by broadcasting on different blocks of frequencies.

## US STRATEGY

In the USA, the National Association of Broadcasters (NAB) representing many existing AM and FM broadcaster, has set up a dab task-force, chaired by Alan Box, and last January NAB's Radio Board of Directors unanimously adopted an eleven-point plan to implement dab for the entire radio industry. The decision represents a formal expression of a willingness to embrace new digital technology and an attempt to manage and influence that technology for the benefit of existing broadcasters.

The task force is seeking new dab spectrum and plans to establish a single dab technical standard. It will also seek to introduce dab in such a way as to minimise economic dislocation to broadcasters and also, in effect, to oppose entry of newcomers into any new satellite or terrestrial dab services. Nine American industry representatives visited Rennes, France last March to assess Eureka-147 dab technology. Apart from the Gannett representative (one of the several organisations that have been developing alternative dab system) all agreed that Eureka-147 "met or exceeded" expectations.

The task force considers that spectrum should be found in the region of 1500MHz (L-Band) although it recognises that the FCC and some European administrations are likely to press for an allocation around 2300MHz (S-Band) at Warc-92, despite the technical and economic disadvantages of the higher band.

In the US, space could still be found for dab in unused channels in the UHF television but at present these are reserved for possible "simulcasting" of HDTV.

At Rennes, a 16-channel demonstration system operated at 794MHz with 16-watts ERP (1-watt per programme) and there were also two very low-power gap-filling relays (0.016W and 1.0W ERP). Together these covered the city of Rennes to a distance of about 15 miles. Eureka-147 dab was demonstrated for the first time in the US at NAB-91 using American UHF channel 15. Further tests at L-band are planned by the Task Force this autumn. **PH**

## MOLYNINA ORBITS

An additional problem with direct-to-home satellite system for dab is that a geostationary satellite would not be suitable for mobile reception since it requires a "tracking" reception dish to cover the changes in direction of a moving vehicle. But the problem could be overcome by using multiple satellites in highly-elliptical (Molynina-type) orbits.

With the Molynina orbits, as used for many years by the USSR, a satellite at its apogee hovers nearly overhead its target area for some six to eight hours, permitting the use of high-gain receiving antennas pointed directly upwards. This means that a flat-panel antenna could be mounted on the vehicle roof, unaffected by the direction in which the car is moving. To provide continuous 24-hour service, four satellites in synchronous orbits would be needed. While each satellite would be capable of transmitting, say 100 stereo programmes simultaneously, serving several countries, it would take time to establish such a system and the launch and satellite costs would be substantial. For the UK, with its mature FM networks, currently being energetically promoted on BBC Radio, the VHF terrestrial SFN would seem likely to prove a more cost-effective approach, at least initially. The next step would be to agree a final specification on an international basis, particularly for the mascam-type bit rate reduction system for which there are already competing specifications. **PH**

Eureka also proposes that the signals be broadcast by satellite, with ground relays re-transmitting on the same frequencies to fill in areas of shaded reception.

### Satellite requirements

Conventional geostationary satellites are not ideal for dab. They hang too low in the sky in Northern countries. Two years ago the European Space Agency commissioned a report from British Aerospace on the use of highly elliptic inclined orbits, as pioneered by the USSR for its Molynina satellites (see box).

ESA's project is code-named Archimedes. Four spacecraft orbit the earth with each craft six hours behind the other and all following a highly elliptical path. So, like balls tossed in the air by a juggler, each spacecraft in turn rises very steeply into space over the targeted land area then falls, equally steeply, back towards the earth.

The BBC acknowledges the theory, but is not convinced that highly elliptical orbits will be ideal in practice – eg for reception inside buildings. In any case the BBC fears that disagreement over frequency allocations (and the UK's interest in 2.5GHz, which means lower signal strength on the ground because of greater atmospheric attenuation) will delay satellite dab until the next century. ■

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103

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# TAYLOR

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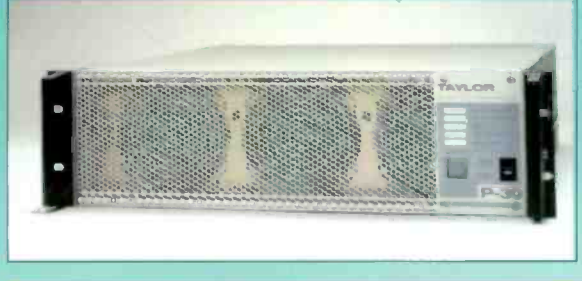
## *STEREO RADIO TRANSMITTERS & TRANSPOSERS*



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Crosstalk <40dB 1KHz
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Voltage 220-240V AC 50Hz (110-120V AC no cost Option F)

Output level 6.3dBmV (1506V) 75Ω (IEC Connector)

| | | |
|---|---|---|
| OPTION G | 50Ω no cost (N Connector) | |
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Output Power 30 Watts into 50Ω (N Connector)
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A.G.C. 40dB (± 20dB)

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19" Rack Mounting 3μ 500mm deep
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Input Impedance 75Ω. (IEC Connector)
Output Power 300 Watts into 50Ω (N Connector)
Voltage 220-240V AC 50Hz (110-120V no cost Option F)

### P30-300VFT 30 WATT BAND 2 TRANSPOSER £2928.00

Power: Specification as P30-300VF
Input: 88-110MHz/420-460MHz/900-920MHz 50Ω
(N Connector) Specify Frequency
Crystal Controlled Frequency Stability <5ppm
Gain 10.3dB
A.G.C. 44dB (± 22dB)

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*CIRCLE NO. 102 ON REPLY CARD*

Taylor Bros.(Oldham) Limited. Tel 061 652 3221 Fax:061 626 1736 Tlx:669911 Est 1965

# IC PROGRAMMING TESTING & ERASING SOLUTIONS

## PC82 UNIVERSAL PROGRAMMER & TESTER £395


Universal programmer. The complete designer's kit. This will program EPROMS, EEROMS, BPROMS, PALS, GALS, EPLD's, Z8 and 87XX microprocessors. A unique feature is the testing of logic parts such as 74LS393 etc. The PC82 can check and identify parts. Already programmed are the TTL & CMOS logic test vectors. Software is supplied to write vectors for most unique chips. One of the most popular programmers in the USA.

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PC82 can test and verify any TTL/CMOS logic chip, DRAM & SRAM. The software will also identify a TTL chip. Do you have a few TTL chips aside not knowing whether they are working?

### ADAPTERS FOR PC82 FROM £95

A wide range of plug-in adapters to expand the capability of the PC82.
Various PLCC convertors & 4 gang 28/32/40 pin Eprom, Gal & Pal. Popular CPU types include PIC 16C54/5/6/7, 8796/7, 68705, 87C751/2, & TMS320E25.

### DEVICE GUIDE

| | PC82 | PC84 |
|---|---|---|
| EPROM N/CMOS 2716-27010 (1 mBit) Vpp 12.5,12.9,21,25 | √ | √ |
| EPROM 27513,27011,572000/4000,8764-87256,CYC2XX SERIES | √ | — |
| EEPROM 2816,2816A,2817,2817A,2864A | √ | √ |
| EEPROM 9306,9307,9346,9356,93CS06,26,44,56,66,28256A | √ | — |
| BPROM 32×8 to 4096×8, incl. 63S080,7C28X,29X. | √ | — |
| PAL 10,12,14,16,18,20-L,R,X,P,1,2,4,8,10 (20&24-pin) | √ | — |
| GAL 16V8,18P8,20V8,22V10 | √ | — |
| EPLD 20G10,22V10, EP310,320,600,610,900,910,5C031,32,60,90 | √ | — |
| CMOS EPAL C16L8,R8,R6,R4,C18V8,C20G10,L8,R8,R6,R4, C22V10 | √ | — |
| MPU Z8,8741,42,48,49,50,51,C51,C52,C252,TMS7742,77C82,63701 | √ | — |
| Device testing TTL/CMOS logic, DRAM & SRAM | √ | — |

## FEATURES ALL MODELS

For the IBM PC, install the interface card and programming socket, load the menu-driven software and you have a complete design system at your fingertips.

### EASY TO INSTALL

The programmer comes with an interface card that plugs into any free slot of your PC. There is no DMA channel to worry about and it occupies limited I/O space. The programmer socket box is connected via a ribbon cable to the back of the interface card so that the socket box is external. After the interface card is installed the PC never need be opened again.

### SUITS ALL PC's

The programmers will run on any compatible IBM machines such as XT's, AT's, '386 and '486. Whether it be AMSTRAD or COMPAQ the programmers will work. The software is text only monographic so is compatible with any machine.

### SOFTWARE DRIVEN

All software for the programmers is supplied on 5¼" low-density disks. The software can be copied onto hard disk using the DOS copy command. Programs are supplied for the various features and are menu-driven. All programming is done from the menu, no hardware switches are needed. Just select the type and manufacturer and the programming is done automatically. Free software updates for new types which are continually being added.
The menu-driven software is a full editing, filing and compiling package as well as a programming package. Save to disk and load from disk allows full filing of patterns on disk, to be saved and recalled instantaneously. Device blank check, checksum, program, verify, read and modify are all standard features. Hex to bin file conversions included for popular file formats including Intel Motorola etc. 2 ways/4 ways bin file splitter for 16/32 bit file data. Selection of speed algorithm for FAST, INTELLIGENT, INTEL, etc.

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### ORDER INFORMATION

Please include £7 for carriage by courier, plus VAT on all UK orders. (£20 for exports.) All pricing for programmers includes software, interface card, socket box and full instructions. (Prices do not include VAT or carriage). ACCESS, VISA or CWO. Official orders welcome from Government bodies & local authorities.

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