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## + WIRELESS WORLD

July 1993

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### AUDIO

**Digitally  
controlled  
preamplifier**

### REVIEW

**Quickroute is  
best route for  
Windows?**

### DESIGN

**Phase  
comparators in  
PLL systems**

### CIRCUITRY

**Towards the  
distortion-free  
silicon switch**

### APPLICATIONS

**Two terminal  
chips provide  
electronic keys**

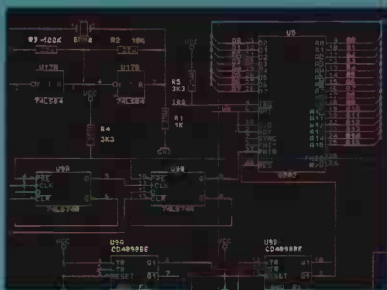


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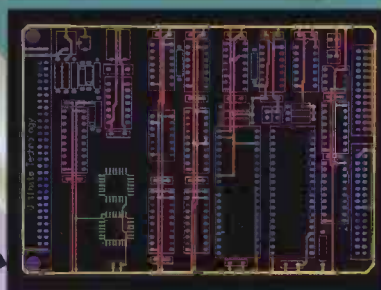
# FROM CONCEPT TO ARTWORK IN 1 DAY



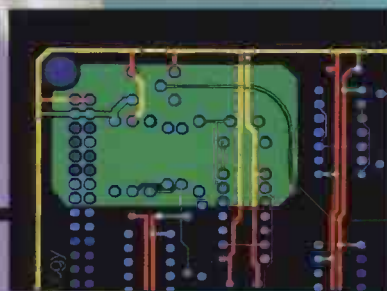
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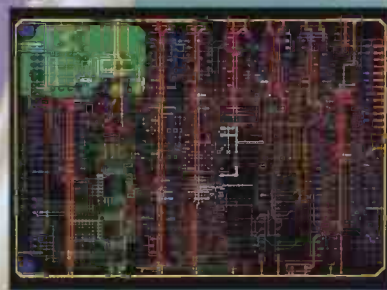
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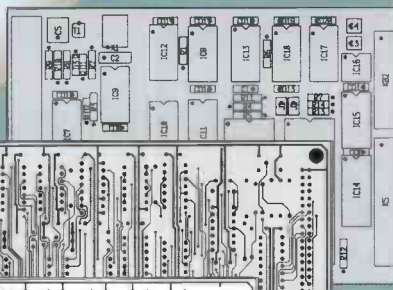
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## NEW

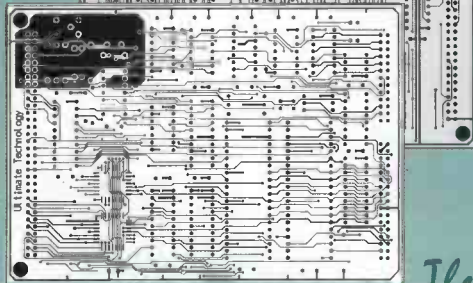
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Even though William Waldegrave's White Paper on science and technology looks half promising at first sight, I sit here writing this to the sounds of the great and the good braying about the imminent public spending round or, to be more precise, public spending cuts.

Of course there is not enough money in the Treasury because the main consequence of high unemployment is double edged: a run-away benefits bill and a shrinking tax base from which to pay for it. Borrowing to pay for benefits will lead to ruin. Welfare must be cut and taxes raised to pay for the shortfall but please, let us learn something, and ensure that this unenviable situation never happens again.

Contrary to some strands of political thought, public-spending our way to full employment is not possible; artificially stimulated employment programmes simply cannot thrive in a larger free-market world. We need a strategy to compete on equal terms with our trading partners.

The Japanese trading surplus – some \$70bn at the last count – is based on supplying things which people want to buy. Applied science, mostly electronics, is at the root of that country's manufactured products and its transfer into industry did not happen by Government decree.

The transfer occurred because Japan's companies realised that long term investment in applied technology would result in superior products for its customers. Contrary to popular belief, the Japanese Government has made only a limited contribution to this process. For instance, there is very little public funded pure science in Japan. It takes the view that if a scientific programme does not result in saleable technology, there is little point in pursuing it. It is therefore logical to foster science within the R&D departments of manufacturing companies. The success of this strategy needs no further telling.

Contrast Japan's situation with that of this country. Our major electronics companies

have been dominated for so long by padded defence and monopoly telecomm business that they have long since forgotten how to compete in making things for civilian homes and cars. While government contracts have generated new technology, very little of it has been saleable to you, me and, more importantly, to our trading partners. With a paradigm change which has occurred since the ending of the cold war, much of our industry looks as dated as pictures of the Berlin Wall – in philosophy if not in technology.

And back to Waldegrave's initiative. The enthusiastic noises of 'technology transfer' and 'technology foresight' don't make up for the fact that the Ministry of Defence's £2.6 billion annual research budget accounts for nearly half the Government's research spending. And it shouldn't require a Government science minister to tell our electronics companies that ordinary people want to buy camcorders and highly intelligent food mixers, not sonar systems and weapons control mechanisms. But then again, companies on which we must depend such as GEC have shown themselves to be deeply unimaginative so perhaps it does.

Looking at Japan's success, I don't believe there to be a requirement for direct intervention with government money for science; pure science and big science may be prestigious but they don't pay the bills. It would be much better to encourage R&D spending within companies by tax breaks for this activity and, at the same time, prevent Corporation Tax being optional for large companies.

There is a new industrial revolution taking place in the wake of the cold war and it is well accepted that profound changes in industrialisation are always accompanied by temporary levels of high unemployment and recession. Japan has been preparing for this since 1945. Shouldn't we as a country be doing more than we are doing?

Frank Ogden

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# UPDATE

## NT users risk hefty bills

Computer users wanting to upgrade to the recently announced Microsoft *Windows NT* could end up spending another £3000 on technical assistance if two simple checks are not made. They must ask to see a list which Microsoft says it will publish, identifying all existing PC software which will not work with *NT*. They must also raise any queries within 30 days, the time Microsoft says it will give for free help before demanding an annual subscription for technical support.

MS-dos is the operating system used by 100 million IBM-compatible PCs, and 25 million of them also use *Windows*. *NT* replaces both interfaces, because it works as an operating system and program organiser, looking from the screen like *Windows*.

*NT* is aimed at business users, because it is good at controlling a network of separate PCs, but some individuals will want to benefit from its ability to multitask, or work fast on several programs at the same time using PC hardware which is commonplace (an 80386, or better, processor, with 8Mbyte of ram and a 100Mbyte hard disc).

Although Microsoft says it expects to start selling *NT* this month, and has already set prices, company founder Bill Gates told the *Windows World* exhibition in Atlanta in May that the company is still evaluating reports from more than 70,000 people using beta test trial software. Also, although Gates assured delegates that *NT* would: "run

existing dos and *Windows* applications", Microsoft's publicity material and technical staff are more guarded.

The publicity material claims only that *NT* will work with a "host" of existing dos and *Windows* applications.

Phil Buggins, Microsoft's director of systems marketing in the UK, admits that: "*NT* will not run on applications that go straight to the hard disc".

This blocks the use of third party software, such as the *Norton Utilities*, which PC users often rely on to save corrupted data. It also blocks the use of third party compression software such as *Stacker*, which effectively doubles the available space on a hard disc.

Without compatibility, every sale of *NT* will mean a lost market opportunity for any third party utility software that directly addresses a PC's hard disc. Symantec, publisher of Norton software, says it has no answers yet, but "is striving to develop applications which will be *NT* compatible as *NT* emerges". But it is handicapped because: "*NT* is a new operating system which is still at the beta stage". Stac Electronics, which sells *Stacker* compression software and is currently suing Microsoft for infringement of its patents on the technology, says it is also working hard to find a way of making its software work with *NT*, but has no answers yet.

Although it is clearly in Microsoft's

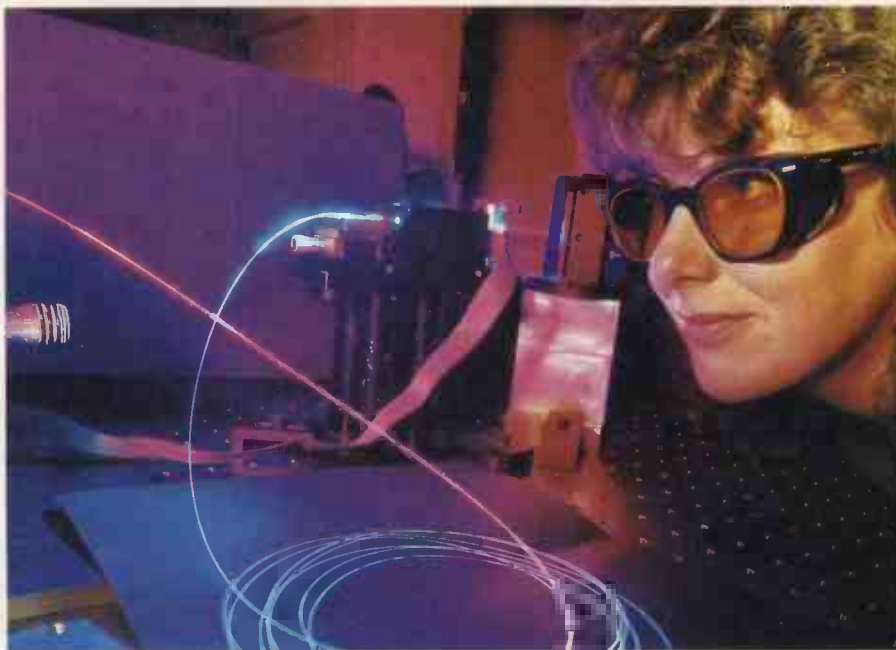
interest to control the lucrative market for third party utility software, the company says this is not the reason why *NT* has been made incompatible with it. The US Government will only buy computer equipment if it has C2 security clearance, which guards against either accidental or deliberate tampering with hardware, programs or data. Microsoft says the only way to achieve C2 security, is to make every program work through the *NT* operating system. Utilities bypass the operating system, so cannot work with *NT*.

Until now, Microsoft has given free technical help to users of its software. But anyone wanting help when using *NT* must pay Microsoft between £3000 and £10,000 a year, depending on the number of PCs they use. Challenged on this policy, and the risk to people who find that some of their existing applications will not work with *NT*, Microsoft has made two concessions.

Anyone who buys *NT* and cannot get it to work will have 30 days in which to raise a free query. Microsoft also pledges to publish a list of programs that will not work with *NT*, which customers will be able to read before buying.

In an unusual move Bill Gates admitted, even before *NT* ships for sale, that Microsoft is already working on an upgrade version of *NT*, code-named Cairo.

Barry Fox



The SP on sensors: Optical signal processing is just one of many new techniques being applied to sensor technology – others include neural networks and fuzzy logic. Now, in a colloquium to be held at the university on the September 9, Southampton University's Institute of Transducer Technology is hoping to demonstrate how these previously academic ideas are relevant to industrial users. Those interested in attending should contact Laura Brown on 0703 593545.

## Dr Virus faces extradition

Computer terrorist Dr Joseph Popp has been convicted of extortion by a court in Rome more than a year after being freed for the same charge by Southwark Crown Court, according to virus monitor *Virus Bulletin*

In December 1989, Popp mailed out more than 20,000 computer discs containing information on Aids. A virus on the discs would render a hard disc useless unless the user sent money to a PO Box in Panama.

Popp was arrested shortly afterwards and, after a lengthy fight, was extradited from the USA to the UK to face charges. While in prison awaiting trial, he is reported to have worn a condom on his nose and hair curlers in his beard, ostensibly to ward off radiation.

Southwark Crown Court freed him in November 1991 on the grounds that he was mentally unfit to plead. The case was left open.

Popp was not at the Italian trial where he was sentenced to two and half years in gaol. He has 60 days to appeal.

# Ghostbusters move into Canary Wharf

The Independent Television Commission believes it has found a way of killing TV ghosts. This is good news for 100,000 viewers in London, especially the Lea Valley area, who have had their TV reception spoiled by the Canary Wharf tower.

Then new technology in a TV set will work with an invisible reference signal, broadcast with the programme, to analyse disturbance of the received signal and compensate for it before the picture reaches the screen. The ITC will shortly test its ghostbuster circuitry in London and, if it works as well on the Docklands tower as laboratory tests predict, will ask the European Broadcasting Union to set a standard for Europe.

Manufacturers will then feel safe to invest in the mass production of microchips which can be built into set-top adaptors and future TV sets.

Almost everyone with a TV set suffers some ghosting. The TV aerial receives its main signal direct from the transmitter, but also picks up a weaker signal which has been delayed by reflection from a building or hill. The reflection shows on screen as a faint replica of the main image, displaced sideways a little.

There is no easy way of correcting for this because different frequencies behave differently when reflected, and no two

domestic situations are ever the same.

Viewers have become more aware of ghosting after seeing satellite picture signals which are clear and ghost free because the aerial dish focuses tightly and will only accept signals coming direct from the satellite.

Broadcasters in Japan and the US are using or developing ghostbuster systems, but they cannot be used in Europe because they rely on reference signals broadcast in several of the unused lines of picture at the extreme top and bottom of the screen. In Europe these lines, called the vertical blanking interval or VBI, are used to carry teletext.

The ITC uses a very brief signal in just one VBI line, (line 318), which still remains unused by teletext throughout the whole of Europe. The signal is a radar chirp, a brief pulse of energy that sweeps up from zero frequency to 5MHz in 24µs, and then cuts off sharply. The rest of the picture line, which takes another 40µs to scan across the screen, is left empty so that the TV set can analyse any delayed reflections that arrive after the chirp.

A ghostbusting TV set will come with a memory, into which the manufacturer has frozen a digital replica of the standard chirp. The TV set then continually compares all chirps received off-air with this replica. When the received chirp is followed by another unwanted echo, the set analyses the



*ITC tests will shortly establish the usefulness of new television technology designed to removing ghosting.*

echo's delay and frequency content. Because the original chirp contains all the frequencies that can be present in a TV signal, analysis of the echo's content gives a tell-tale signal which represents the ghost distortion.

A filter circuit, automatically shaped by the tell-tale, then subtracts a mirror image of the distortion from the received signal. So the picture displayed on screen is ghost free.

Many modern TV sets already convert the incoming signal into digital code, anyway, for ease of processing. So the main cost of ghostbusting will be in the cost of the analysis and filter chips. If Europe can agree a single standard for the chirp, manufacturers can mass produce the chips, and so keep the price to viewers low. **BF**

## Recovery – or restocking?

Green shoots are being seen in the electronics industry according to recent surveys. But there are fears that this may reflect component shortages leading to double ordering artificially inflating order books.

World Semiconductor Trade Statistics (WSTS) predicts that the semiconductor market will grow from \$60 billion last year to \$72 billion this year, a 20% increase. And in the UK, the component suppliers association Afdec, claims that the three months to the end of March have produced the "most dramatic" increase in electronic component sales since it began its surveys several years ago.

The WSTS report predicts increases of 10.8, 7.6 and 12% in 1994, 1995 and 1996, respectively.

Last year, the Japanese market made up 32.4% of the world market followed by the USA with 30.8%, Europe 19.2%, and Asia Pacific and the rest of the world 17.6%.

The largest growth in 1993, WSTS

believes, will be in the USA with 28%. Western Europe will grow by 18%, Japan 12%, and the rest of the world by 24%.

The \$60 billion market is split up as \$50 billion for integrated circuits and \$10 billion for discrete, with expected growths in 1993 of 23 and 7% respectively.

Within the IC segment, mos microchips and mos memories show the greatest expected growth at 33.6 and 27.3%, respectively, followed by mos logic at 14.8%, analogue ICs at 14%, and bipolar ICs 2.9%.

In Europe, mos microchips are expected to grow at 46.9%, mos memories at 18.6%, and analogue ICs 12.6%.

Afdec puts the semiconductor growth for the first quarter at 33.4%, passive components 6.5%, and electromechanical products 8.9%. The average growth rate is 22%.

Garry Kibblewhite, Afdec chair, believes that the sector is heavily into growth following six consecutive months of strong

performance with no apparent signs of a down turn.

But he warned that the stronger market is already having negative as well as positive impacts on the industry.

On the plus side, prices and margins are strengthening which means profitability levels are higher. But the introduction of allocation schemes for logic and linear semiconductor devices has, according to Afdec's statement, "already led to the blights of double ordering and component shortages."

Afdec believes this trend will continue into other component areas and give forecasters "a slight headache due to the artificial inflation of order books".

For some component sectors, price increases have been unexpectedly high and many are wondering what happened to the apparently strong long term agreements to insure against price hikes and component shortages.

## End of cold war triggers heated security battle

The end of the cold war has led to the release of a military mobile phone technology, called code division multiple access, for consumer use. Until recently CDMA was a military secret, designed to protect radio signals from jamming interference.

As the cold war ended, US military contractor Qualcomm of San Diego proposed the use of CDMA as a third generation cellphone system. Qualcomm spotted that once the system did not have to contend with deliberate jamming, its inherent resistance to interference could be exploited to carry more calls at the same time.

Qualcomm has claimed that CDMA can squeeze up to 20 calls into the frequency space which existing, first generation, analogue cellphone systems need to carry one call. It can carry up to six times more calls than the new, second generation, digital cellphone services due for launch soon in the UK by Mercury, Cellnet and Vodafone.

Independent research by the Swiss PTT in Berne backs this claim. Qualcomm is winning commercial support, too. Nokia of Finland, Europe's largest cellphone manufacturer, and second only in the world to Motorola, makes analogue and digital cellphones. But Nokia now believes that CDMA may be the best technology for the next century and has set up a joint research project in San Diego with Qualcomm.

Yrjo Nuevo, Nokia's senior vice president responsible for technology and a specialist in digital signal processing, said: "We want to be as big in the US as Europe. We cannot always walk behind Motorola."

CDMA is a digital system like GSM to be

used this year by Vodafone for its new micro cellular network and Mercury for its new One-2-One personal communications Network.

All convert speech into digital code before transmission. They differ in the way they make many calls share the same transmission channel. GSM/PCN uses time division multiple access to put eight calls into one channel. TDMA relies on the natural spaces between words of human speech. Each digitally coded conversation is chopped into short bursts, and the code bursts interleaved. The receiver stitches them together again.

CDMA leaves the code for each call as a continuous stream, and transmits every stream in the same wide frequency channel. So each conversation just piles on top of the others, creating an apparently random mix of digital code. Any eavesdropper simply hears a mush of hissy noise. But at the start of each call the receiver and transmitter exchange information and give the code stream an identifying label. This lets the equipment at each end of the call decode speech from the blanket of noise.

The military used CDMA because an enemy jammer has no way of knowing what noise is carrying speech. The CDMA decoders just ignore any jamming interference as noise, anyway. Also, because the code only makes sense to a receiver programmed with the correct label, conversations are very secure.

Nokia recognises that this last advantage is in practice likely to present more problems for CDMA than building the technology down to a price. Nokia is still

trying to resolve the muddle over the A5 encryption system built into the GSM and PCN standard.

As previously reported, the British government realised only last year that GSM/PCN's A5 encryption algorithm, devised in the mid 1980s, is so powerful that it helps criminals, terrorists and military enemies.

Nokia, like all other manufacturers of GSM equipment can only export A5 GSM equipment to NATO and known friendly countries such as Australia, New Zealand, Sweden, Switzerland, and Hong Kong. It cannot export to the former Soviet Union, China, Vietnam, Libya, Cuba, and Iraq.

But no-one knows about other countries that would like to buy GSM, such as South Africa, the Gulf states, Czechoslovakia, and Poland. Worse, GSM manufacturers do not know whether they will be able to export equipment with a watered-down encryption system, called A5X, which is under rush development.

Admits Timo Ruikka, Nokia's Legal Counsel in Helsinki, "the rule book ends by saying that governments must decide each case on its own merit. There is only one sure way to find out whether you can export, and that is to submit a licence application and find out." But the standard for A5X has not yet been agreed, and it will take at least a year after that to make A5X microchips. No government can decide on export controls until it knows what A5X is.

Forewarned and forearmed, Nokia hopes that by getting in early on the development of CDMA, the issue of encryption can be resolved before the service is ready for sale.

## Is the DTI out of this world?

The DTI has been accused of inhabiting a different world after a spokesperson said at a recent seminar on implementing the EMC directive that the cost of the necessary equipment, around £60,000 to £100,000, was very reasonable.

The attack came from David Mawdsley, managing director of Laplace Instruments. Mawdsley said: "In today's economic climate, nobody is going to invest in expensive equipment unless they absolutely have to. Maybe they [the DTI] live on a different planet."

The European EMC regulations specify maximum levels of conducted radiation emitted from electrical and electronic equipment. UK products marketed in other EC countries need approval by 1994.

*Is the expense of EMC testing stopping UK industry complying with EC regulations?*





## COMPUTER ICs

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SAAS050 TELETEXT CHIP EX EQPT	£5
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27C64-25 used/wiped	£1.50 100+ £1
27S191 PROM	£2
D41256C-15 256Kx1 PULLS	9 FOR £5
80C31 MICRO	£2
P8749H MICRO	£5
D8751-8 NEW	£10
D41257C-15 (256K x1 DRAM)	£1 ea
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## CRYSTALS

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36M81875 36M83125 36M84375 36M900 49M504 54M19166	
54M7416 57M75833 60M000 69M545 69M550	

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TXAL225 8A 500V 5mA GATE	2/£1 100/£35
BTA 08-400 ISO TAB 400V 5mA GATE	90p
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## DIACS 4/£1

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TIL81 PHOTO TRANSISTOR	£1
TIL38 INFRA RED LED	5/£1
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100n 250V radial 10mm	100/£3
100n 600V Sprague axial 10/£1	100/£6 (£1)
2µ2 160V rad 22mm, 2µ2 100V rad 15mm	100/£10
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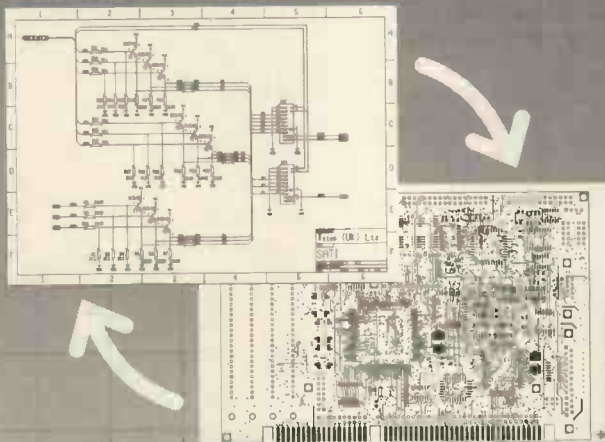
Finally an upgradeable PCB CAD system to suit any budget ...

# Board Capture

BoardCapture - Schematic Capture

- Direct netlist link to BoardMaker2
- Forward annotation with part values
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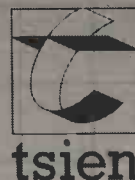
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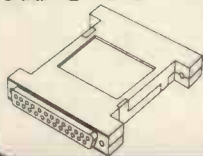
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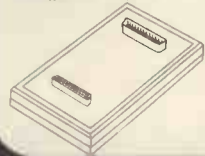
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# RESEARCH NOTES

## BRILLIANT SOLUTION FOUND TO NOISE POLLUTION—make less noise!

Acoustic researchers at Pennsylvania State University are hoping their work on weakening the sound radiation characteristics of materials could lessen the noise nuisance of modern living. Noise is one of the most pervasive forms of pollution, affecting everything: from our working efficiency to our health. In some situations – on a car production line, inside a helicopter or near a turbine – the din can be mind-numbing. Perhaps it is just as well that the process of transducing mechanical energy into sound is usually so inefficient. Even when noise creation is deliberate, as in a bell, only a tiny percentage of the mechanical energy is radiated as sound.

Over the years there have been a number of different approaches to reducing the unwanted sound emissions from mechanical structures, some of them – like antisound – extremely hi-tech and ingenious. But why not simply approach the problem at source and reduce still further the efficiency with which a structure radiates sound into the air?

That approach is now being adopted by Gary Koopmann, professor of mechanical engineering and director of the Center for Acoustics and Vibration at Pennsylvania State University in the USA. Koopmann believes that it is possible to hush the din of many mechanical structures by converting their structural surfaces into weak acoustic radiators. It is not that the energy disappears; it is simply that the surface is more efficient at converting mechanical energy into heat and less efficient at converting it into sound.

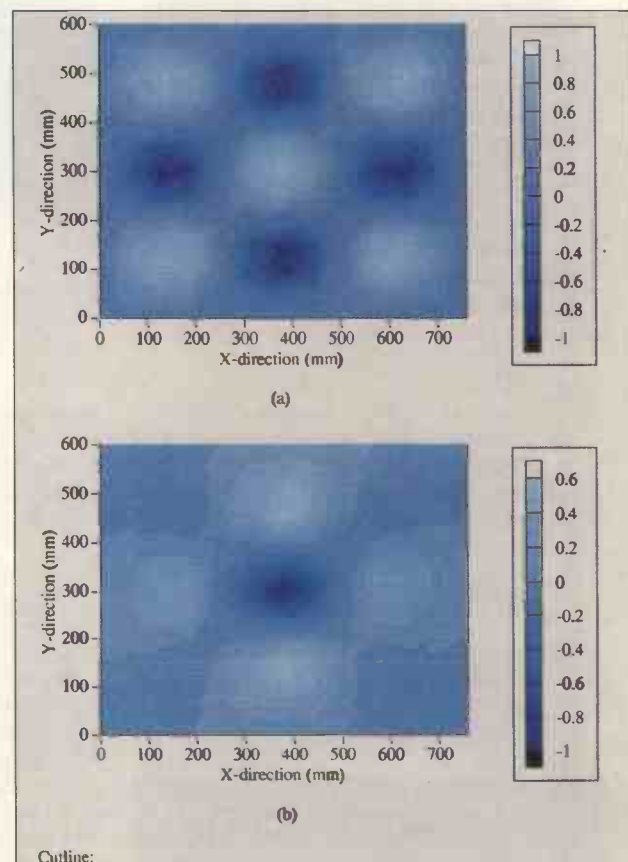
Using conventional materials, engineers have long been able to vary the thickness of a material or distribute small masses on a metal plate to create “weakly vibrating modes”. But until recently they were limited in making major changes because of the inherent properties of the materials. Koopmann believes that with new materials and composites it will be possible to make design changes that do not affect the

strength of a component but which will markedly reduce its acoustic radiation efficiency.

Fibre-reinforced composites offer the possibility of changing up to six variables, including fibre orientation and fibre density. Using finite element modelling, Koopmann and his colleagues are successfully designing materials that minimize noise. They are also having considerable success with sandwich composites that have conventional high-density materials on the outside and inner cores designed to absorb acoustic energy. Such materials could absorb noise over a wide frequency range in applications such as aircraft cabins and gearbox casings.

The teams are now involved in a joint project with the Chrysler Corporation to design low-noise compliant automotive parts. These are any parts that vibrate from the force of engine combustion including valve covers and sump covers. This work at Pennsylvania State University will require the team to move on from studying idealized structures such as flat plates to working with components that have quite complex geometries.

The ultimate challenge facing Gary Koopmann and his colleagues is the design of weak acoustic radiators that have some form of intelligent control. They intend to experiment with actuators and sensors embedded in the actual composite material. Using a range of polymers and ferroelectric ceramics they hope to be able to control vibration modes and eliminate unwanted forces. Koopmann admits, however, that the



*Upper picture shows the pattern of a vibrating surface that couples strongly with the surrounding fluid or air to generate unwanted noise. The lower picture shows the same radiating surface optimised to produce the weak radiator behaviour.*

problems with this approach are less material and more cerebral. Sophisticated intelligence, using neural networks, will be vitally necessary, he thinks, to keep track of what each sensor and actuator is doing.

## Rocket fuel powers GaAs chip technology

An improved technique for growing stable insulating films on the surface of gallium arsenide semiconductors could make them easier to process and also suitable for a wider range of uses. The technique, developed at the Georgia Institute of Technology in Atlanta, could also be used with other III-V compounds to produce stable nitride films at low temperatures and without damaging the crystalline structure of the underlying material. Researchers say that it could even be used to passivate an entire device, protecting it from corrosion, mechanical damage and electrical deterioration.

In spite of its attractive optical properties and increased operating speed, gallium arsenide has a major disadvantage when compared with silicon: it does not naturally form stable insulating oxides on its surface. Gallium arsenide devices must therefore be specially passivated using high temperatures or high energy particles, both of which can damage the fragile structure of the semiconductor crystal.

The Georgia Tech process, developed under the direction of professor Paul Kohl, achieves passivation by means of chemical energy without the need for crystal-damaging thermal or kinetic interactions. Temperatures are kept down to within the range 300°C to 400°C.

The process begins with thorough cleaning of the gallium arsenide, followed by treatment to remove as much arsenic as possible from the surface. The chip or sample is then heated in an oxygen-free chamber to which is added small amounts of



*At low temperatures and without damaging the crystalline structure, Georgia Tech researchers have produced stable nitride films on GaAs which could significantly ease processing.*

hydrazine, better known as a rocket fuel. Because it is an unstable molecule, hydrazine splits off two reactive nitrogen atoms. These interact with the gallium on the surface of the chip to form a nitride

compound that is electrically insulating and chemically stable. It is also mechanically hard.

Kohl and his team now plan to optimise the process by determining the processing steps, temperatures and film thicknesses that provide the highest quality films. They also intend to demonstrate the technique on fully fabricated semiconductor devices and to test it in other applications such as capacitor dielectric layers.

## Carbon molecule that puts buckyball in the shade

University of Michigan chemists have synthesised what they believe to be the world's largest pure hydrocarbon molecule. It is a (relatively) huge sphere, big enough to

hold 1000 carbon atoms with room to spare!

The new monster molecule consists of 1134 carbon atoms and 1146 hydrogen atoms, and has a molecular weight of 14,776. Its volume is a hundred times greater than that of a "buckyball", the recently-discovered geodesic dome-shaped 60-carbon molecule.

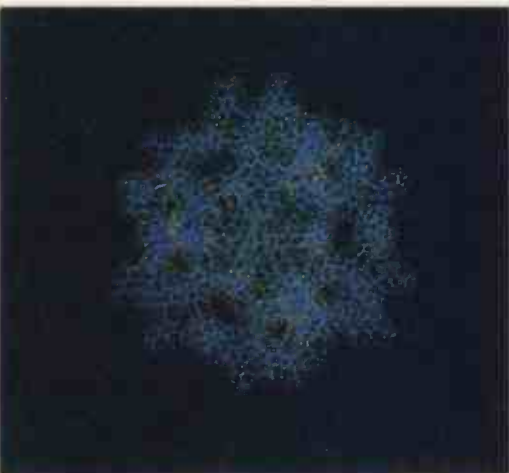
According to Jeffrey Moore, assistant professor of chemistry at Michigan, these giant carbon molecules might be combined to function as a light harvesting device that could focus energy from sunlight and transform it into chemical energy. Moore also believes that the jumbo molecule, which is essentially a hollow sphere, could have potential applications as a drug delivery

*1134 carbon atoms and 1146 hydrogen atoms give a molecular weight of 14 776, and a volume a hundred times greater than that of a buckyball 60-carbon molecule.*

system – a sort of micro-pill.

The new molecule, described for the first time at a recent meeting of the American Chemical Society, was synthesised from 94 units of a phenylacetylene. It has an unusual repeating fractal pattern linked by triple chemical bonds. As the molecule grows its branching arms interlock with each other to form a sphere, the structure of which has been verified by nuclear magnetic resonance spectroscopy.

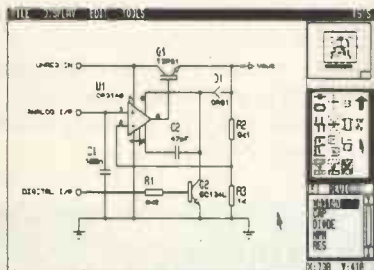
Jeffrey Moore says that new molecule is a bizarre entity which has required a great deal of clever chemistry to get it to react with other substances or even to make it soluble in common solvents. Also, unlike many other synthetic polymers, the new hydrocarbon sphere varies only slightly in its chemical structure. Moore thinks that this uniformity could make it a valuable yardstick for measuring the size of any ultra-small particle or structure.



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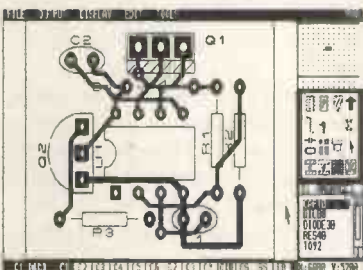
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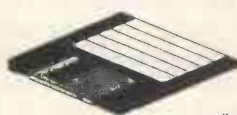
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## Ferrofluid reveals secrets of the deep

Ferrofluid may be familiar to loudspeaker engineers and other electronic specialists – but could it soon become a valuable aid for scientists predicting atmospheric changes?

Designers of high-powered tweeters need something to extract heat from a rapidly oscillating voice coil and transfer it to a bulky heat sink, usually the magnet, turn to ferrofluid for the answer. The fluid itself consists of a suspension of microscopic magnetic particles, prevented from clumping together by means of a surfactant. At \$2000 a pint from Japan it's not something you can slosh about too readily. But it does have a variety of useful applications apart from just loudspeakers. One of the most intriguing was presented at a recent meeting of the American Physical Society by Peter Rhines, a professor of oceanography at the University of Washington.

Rhines had the idea of using ferrofluid to make a model of the Earth's oceans and atmosphere, something that is otherwise virtually impossible except under weightless conditions. It was also impossible economically until he found a US company who would make the stuff for just \$1 a gallon!

Rhines and his fellow researcher Dan Ohlsen took advantage of the fact that ferrofluid, when poured into a tank of inert

fluid of similar density, will coat any object exerting a magnetic field. They made a model Earth – a plaster sphere containing magnets – and lowered it into the tank containing ferrofluid and a mixture of oil and freon.

What happened then was that the ferrofluid coated the plaster Earth with a fluid layer, just as the oceans and the atmosphere coat the real Earth. Rhines found that he could then model basic atmospheric and ocean phenomena by spinning the model Earth and using magnets outside the tank to create waves and to mimic broad ocean and air circulation patterns.

Much of this experimental work has an incredibly Heath-Robinson flavour about it, more reminiscent of 19th century science. Take for example the method of modelling the Earth's natural movements. Rhines found that by turning the tank in a circle once every five seconds imitates the forces of the rotating Earth, while a shower-head device pulling liquid to the centre was used to mimic a roaring westerly wind.

But why adopt this kitchen table approach when there are advanced computer programs available to model the Earth's behaviour? Rhines believes that his approach could well challenge or improve computer models.

"Computer models like observations at sea – involve a whole complex of problems. In the lab we take a few features and look at them in isolation. This brutal simplicity sometimes reveals phenomena computer models can't".

A complete ferrofluid Earth model still nevertheless involves serious challenges for Rhines and his team. One of their first ferrofluid Earths ended up with two equators – ideal for tourism, but hardly a very good approximation to reality! By redesigning the magnet shapes they have now overcome such teething troubles, though the inky black colour of the ferrofluid still presents difficulties in seeing precisely what is going on below the murky surface of the model ocean. Rhines thinks that ultrasonic probes might provide the answer. ■

## Active slot-line antenna for millimetre waves

A group working in the Department of Electrical Engineering at the Texas A&M University has recently published details (*Electronics Letters*, Vol 29, No 6) of a new active slot-line antenna. It amounts to an integrated oscillator, transmission line and antenna, all on one piece of circuit board. This new active radiating element, say its developers, could offer a simple

lightweight, low cost and easily reproducible signal source for transmitters, power combiners and mixers.

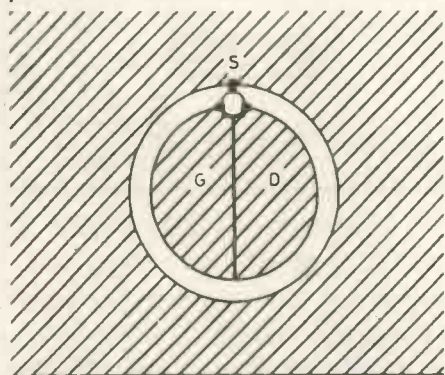
Design of the slot-line antenna is extremely simple, consisting of two central halves separated by a gap of 0.5mm. The two halves are connected respectively to the gate and drain of an Avantek ATF-26836 fet and facilitate DC biasing. The slot, which is etched on the PCB, serves as the resonator, the frequency of which is 7.735GHz – within 4% of the design figure.

A reflector placed behind the PCB to optimise the output power in the forward direction, which on test proved to be 21.6mW, representing a DC to RF efficiency of more than 18%. The spectrum of the radiated signal is also extremely clean, as is its polar radiation pattern.

The authors suggest that active slot-line techniques of this kind would be well suited to mass-production devices that could be employed as the active components of quasi-optical millimetre-wave systems.

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

Simple design slot-line antenna suited to mass production



## ET programme targets Puerto Rico

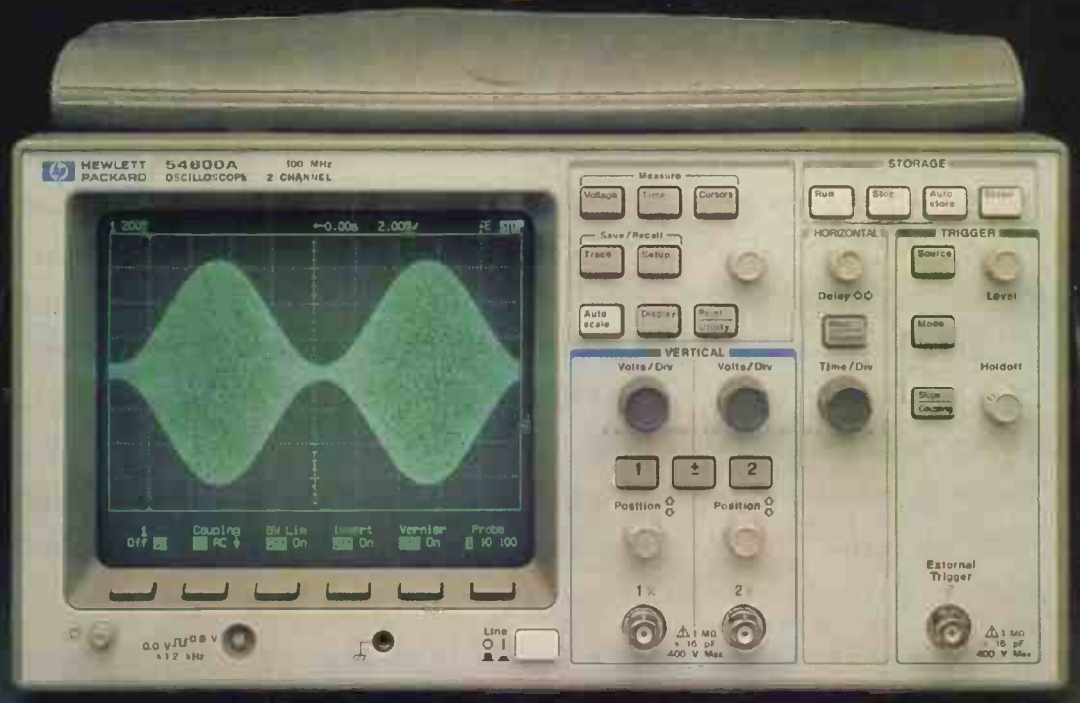
The re-inaugurated Seti (search for extra-terrestrial intelligence) programme which began in October is now producing lots of intriguing signals – but as yet none of them are intelligent enough to qualify as extra-terrestrial.

Jill Tarter, Head of Nasa's Targetted Search, said recently on the BBC World Service astronomy programme *Seeing Stars* that 206h of listening to the output of the Arecibo dish has so far provided confirmation of only one hypothesis: that Puerto Rico is second only to New York city in terms of its density of licensed transmitters. She says that she has heard them all.

Even when planet Earth is not transmitting directly, there is still no escape from earthbound intelligence... or what sometimes passes for it. Each time the moon comes over the horizon, Seti researchers at Arecibo are treated to a blast of reflections from FM radio and UHF TV transmitters. It is a particular problem when the moon is low in the sky, because terrestrial transmitters are usually optimised to produce a fan-shaped horizontal beam.

So far the only genuinely extraterrestrial signal has been a series of peaks around 1420MHz. But sadly no little green persons. 1420MHz is the natural emission frequency of neutral hydrogen, of which there's rather a lot out there.

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# UHF technology for the cordless revolution



If the cordless communications revolution had a single starting place, it was on TV. Already accustomed to compact, go-anywhere portable telephones as used by The Man from UNCLE and Captain Kirk, consumers knew exactly what to expect when the real products reached planet Earth: they demanded all the freedom of cordless operation, together with all the reliability and security of a hardwired network. The assumption today is that by paying a just little more, not only telephones but any type of electronic equipment can be freed from the restrictions of wires. The challenge for the electronics industry is to meet performance specifications which were drafted on the patios of Los Angeles scriptwriters. *Ian White* reports on how the semiconductor companies are matching up.

Consumers are stubbornly uninterested in radio propagation, or in the fact that channels are a finite resource. They are equally unconcerned about the difficulties of shoe-horning a high-performance radio transceiver and a full featured telephone into a tiny, lightweight package which needs no antenna, and whose batteries never run down. Cordless communication equipment must simply do its job, without involving the end user in any technicalities or compromise.

It is no longer feasible to plan a radio communications network on the basis that each mobile unit will have exclusive use of a single fixed channel as is presently the case with PMR and first-generation cordless phones.

What makes cellular telephones feasible is the computer-controlled network of base stations working with a microprocessor in every mobile phone. Together, these manage the

available radio channels to provide continuous communication for the individual customer while allowing simultaneous use of the same channels by customers at other locations. Similarly, microprocessors in the handset and the base unit of a second-generation (CT2) cordless telephone will negotiate to find a free channel.

As network specifications advance, increasing responsibility is being devolved to the individual mobile units, so the scale and complexity of signal processing in consumer communication equipment increases accordingly. And all this must be accomplished under downward pressures on size, battery consumption and cost.

Most new cordless links are being developed between 300MHz and 3GHz since this part of the radio spectrum presently offers the best balance between the availability of fre-

quencies and the availability of low-cost technology. Particular areas of worldwide development are between 800MHz-1GHz and 1.8-1.9GHz, in both cases primarily for telephones and related systems. 800MHz-1GHz is used for existing cellular telephone networks in Europe, the USA and Japan; and the same band will accommodate the next generation of digital cellular networks: GSM (Europe), IS-54 (USA and Canada) and JDC (Japan).

Unlike the European and Japanese digital networks, which will use new channels, IS-54 is a hybrid network which will allow existing analogue equipment to work alongside newer digital equipment on the same channels. The same frequency area is also used for the UK's CT2 second-generation digital cordless telephones, whereas the next generation (Digital European Cordless Telecommunications or DECT) will be on 1.8-1.9GHz alongside other

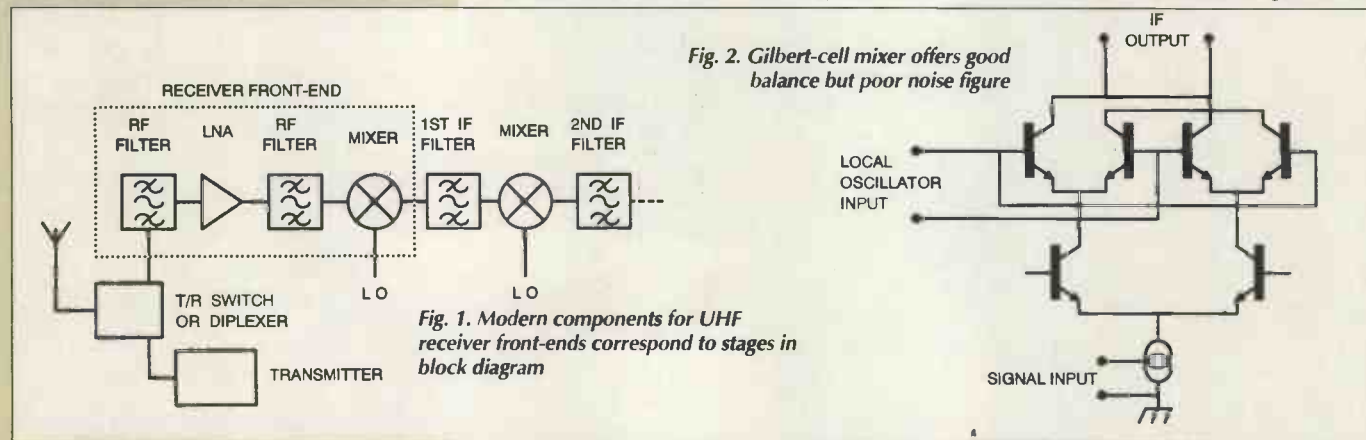


Fig. 1. Modern components for UHF receiver front-ends correspond to stages in block diagram

Fig. 2. Gilbert-cell mixer offers good balance but poor noise figure



## A practical architecture

The GEC-Plessey DE6003 is an advanced data transceiver which can add the cordless feature to a wide variety of other electronic products.

It follows US and proposed European specifications for licence exempt spread-spectrum communications in the 2.4-2.5GHz industrial, scientific and medical band. All the RF parts except the aerial are on-board: the host system has to provide only DC power and control data. But this level of 'plug and play' convenience in a package of just 75mm x 50mm requires some formidable RF technology.

### Receiver

The receiver is a conventional double-superhet as described in the main article. For improved reception, diversity is provided by two separate switch selected antennas. Signals enter the receiver via a band-defining filter and transmit/receive switch. After the low-noise amplifier the signal is converted by the first mixer to an IF of 350MHz. After passing through a filter the signal is amplified at the first IF and again down-converted to the final IF of 38MHz for final filtering and FM detection.

### Synthesiser and transmitter

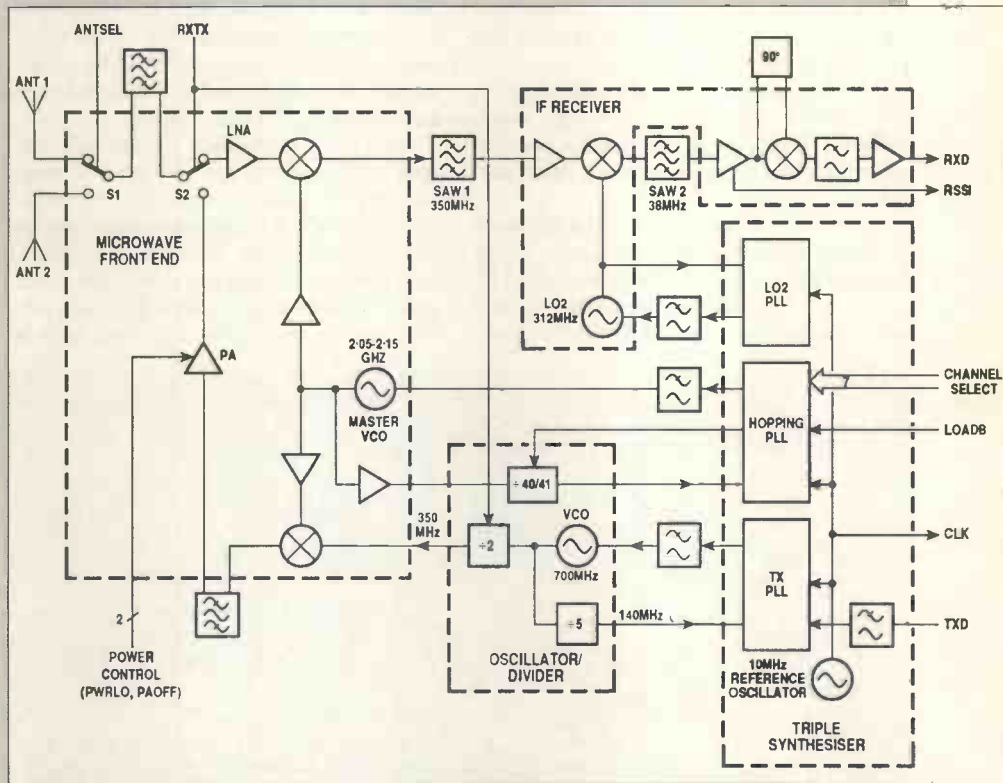
The heart of a spread-spectrum transceiver is the frequency synthesizer that provides the first local oscillator (LO) signal. Spread-spectrum relies on fast synchronized frequency hopping at both ends of the link, and the synthesizers must resume phase-lock very quickly to avoid corrupting the frequency modulated data. To minimize the transient between transmit and receive the DE6003 uses an up-converting transmitter with the same 350MHz IF as in the receiver. The transmitted data phase-modulates a 700MHz oscillator, the output of which divided by two to generate 350MHz. The 2.4-2.5GHz output from the transmit converter is filtered to remove spurious signals, and then amplified to selectable level of 10mW or 100mW.

The prototype used commercially available RF ICs, but the miniaturised production version has condensed all the

active functions into just four application-specific ICs. The asic of particular interest to this series is the GaAs front end device: this includes the entire receiver front-end and first LO, and also the transmitter up-converter, 10/100mW power amplifier and all antenna/filter switching.

Some interesting tradeoffs took place in the transition from the prototype receiver front-end to the asic production version. The prototype included a filter between the LNA and first mixer to suppress noise from the LNA on the image frequency around 1.4GHz, but this was abandoned in the asic

Although this incurred a penalty in receiver sensitivity, a GaAs LNA has extremely low inherent noise and that factor could be traded-back to produce acceptable overall receiver performance.



personal communications networks such as paging and wireless lans.

Satellite receivers for Inmarsat and GPS operate around 1.6GHz while high speed (1Mbit/s) spread-spectrum wireless lans are becoming established at 2.4-2.5GHz.

Regardless of the transmission and encoding methods, each of these developing and future networks will use essentially similar UHF technology at transmission signal frequency. As the potential markets expand, the benefits of high-performance, low-cost RF ICs will become increasingly apparent.

### Receiving systems

Most UHF receiving systems are based on double-conversion superhet architecture, with a first IF in the VHF region, typically about

50MHz in an 800-900MHz receiver but generally higher in 1.8-1.9GHz systems. Fig. 1 shows a typical block diagram of the front-end which includes the UHF signal frequency circuits and the first mixer. After the first mixer is an IF filter which provides sufficient selectivity to eliminate spurious responses in the second conversion to the final IF.

Although it is primarily the second IF filter which defines the overall shape of the receiver passband, the first IF filter plays an important role in protecting the subsequent stages from overload due to strong off-channel signals. Typically, all receiver functions from the second mixer onwards are carried out in a single-chip FM receiver which produces analogue or digital baseband signals for further processing. The UHF local oscillator operates

at either (signal frequency + IF) or (signal frequency - IF); it is frequency-synthesized using a chip-set which integrates all functions except the voltage controlled oscillator and is linked by a local bus to the control processor. Other receiver architectures such as direct conversion have similar features to the conventional double superhet, and have similar front-end design problems.

Until quite recently, signal-frequency amplification and mixing was the domain of discrete components, but this is now changing rapidly. The new generation of RF ICs and packaged filters are close analogues of the building blocks used in system design (Fig. 1) with defined interfaces between modules, often at a system impedance of 50Ω. This greatly eases the transition from design into

production, allowing simple no-tune assembly and testing. While this has made UHF applications much easier for non-specialists, it is still necessary to understand the underlying principles of UHF design to apply these devices effectively.

A receiver for personal communications must meet demanding specifications. Signal levels range from fractions of a microvolt at the limits of range, up to several millivolts when operating close to the base station. In multi-channel systems such as mobile phones there will often be strong signals on adjacent channels which the receiver must ignore. In order to receive very weak signals in the presence of very strong ones, the receiver needs a wide dynamic range between the power level of the weakest discernible signal and the much higher levels at which strong-signal overload effects begin to appear.

The receiver's noise floor is determined partly by noise picked up by the antenna and partly by internal receiver noise.

However, in spite of modern advances in low-noise RF devices, it is not possible to aim exclusively for low receiver noise without incurring major penalties in strong-signal handling.

There are two distinct types of strong-signal problems: those caused by the wanted signal being extremely strong, and those caused by strong signals on adjacent channels. A strong wanted signal is easily dealt with by conven-

tional automatic gain control, but the off-frequency signals can only be sensed in terms of the interference they cause, generally through intermodulation products created in the early stages of the receiver before the first IF filter (Fig. 1). The key to maintaining a high dynamic range is to keep the cumulative power gain as low as possible throughout the front-end, to minimize RF voltage and current swings up to and including the output of the first mixer. Stages after the first IF filter are effectively protected against overload by strong off-channel signals.

A further cure for strong-signal overload in active devices is to increase the DC power levels, so that even the largest RF signals remain negligible compared with the DC voltages and currents within the semiconductor devices. This approach is applicable to base stations – although it can be expensive – but is entirely ruled out for hand-portable units which operate on a stringent power budget. The new generation of RF devices are specified for a nominal 3V DC supply, and every device must draw the lowest possible current.

Given these restrictions, the optimum balance between sensitivity and dynamic range can only be achieved through very careful design tradeoff. A further requirement in some instances is for tight production control of front-end gain; this applies particularly to second generation digital cellular systems where the task of measuring the signal strengths of

neighbouring base stations is devolved to the mobile units. By the time the ICs reach the equipment designer, most of the critical decisions about receiver front-end design will already have been cast irrevocably in silicon or gallium arsenide.

**LNAs and mixers**

Low-noise RF amplifiers (LNAs) are routine technology nowadays. At frequencies around 1GHz, silicon devices can produce noise figures of about 1dB and GaAs MESFETs can manage under 0.5dB. However, the noise figures on the data-sheet are increased in practical systems by the noise contributions from elements both upstream and downstream of the LNA device. Thus a low noise figure from the LNA device becomes just another item in the overall tradeoff between sensitivity and dynamic range.

Upstream of the LNA it is necessary to allow for losses in the transmit/receive diplexer or RF switch (Fig. 1), and for losses in the input network to the device itself, although all of these losses should not total more than 1-2dB. The more serious problem is the noise contribution from the first mixer. For reasons I will explain later, the noise figures of mixers run considerably higher than those of LNAs; a typical SSB noise figure for a UHF mixer IC would be 15dB, and even the lowest-noise LNA devices cannot render the mixer noise negligible without using a very large amount

**Receiver Noise and Dynamic Range**

The fundamental quantity determining noise power is the noise temperature of the device ( $T$ , measured in kelvins). Referred to the input, the noise power  $P_N$  is given by:

$$P_N = kTB \text{ watts}$$

where  $k$  is Boltzmann's constant ( $1.38 \times 10^{-23} \text{ J/K}$ ) and  $B$  is the noise bandwidth in hertz. Note that  $T$  is an equivalent noise temperature, and generally has little connection with any physical temperature.

An alternative quantity for measuring noise in a two-port device such as an RF amplifier, a mixer or a complete receiver is the noise figure (NF), given by:

$$NF = 10 \log_{10}(1 + T/290) \text{ dB}$$

where  $T$  is the noise temperature. Note that  $NF$  is independent of bandwidth, unlike  $P_N$ . Another useful property of  $NF$  is that dissipative losses ahead of the device add directly to  $NF$  in dB, eg a receiver with an  $NF$  of 4dB preceded by an RF switch with a loss of 1dB will have a system  $NF$  of 5dB.

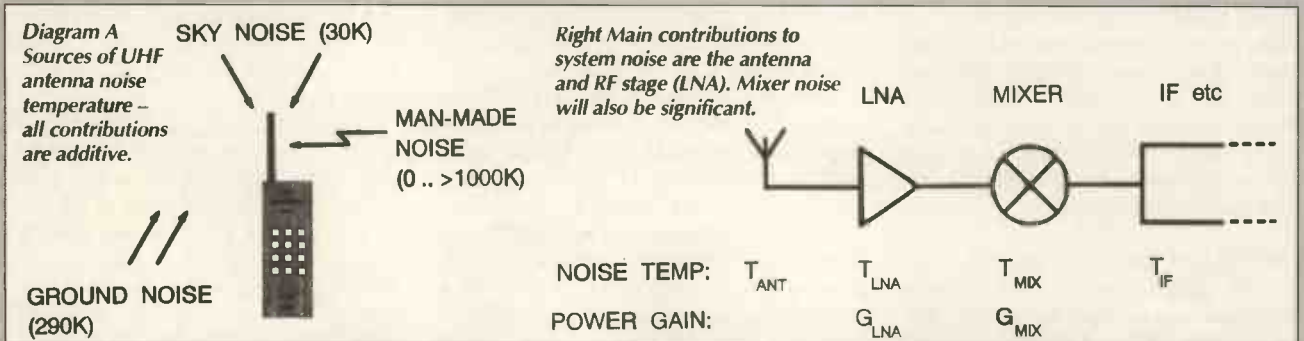
**Antenna noise**

A disadvantage of the  $NF$  concept is that it neglects the contribution of antenna noise pickup to the overall system noise level. This is highly significant in modern low-noise receivers and is best included as an equivalent noise temperature.

The equivalent noise temperature of an antenna has nothing to do with its physical temperature, but is determined by its RF

environment. In the absence of man-made noise, an isotropic antenna (receiving equally from all directions) might receive half of its noise power from the sky above, and half from the ground below (see diagram A). Since the noise temperature of the sky is very low (perhaps 30K at 1GHz) while the ground acts more as a black-body radiator at its physical temperature of about 290K, the antenna noise temperature in this highly simplified example would be about 160K. More typically, there is major contribution to antenna noise temperature from man-made noise (maybe very low for a rural base station, but often well over 1000K in urban, domestic, office or factory environments).

Thus the antenna noise temperature of a



of RF gain – but that would ruin the dynamic range because mixers are extremely vulnerable to overload by strong signals.

Mixers are inherently non-linear devices; two input frequencies (signal and LO) cannot produce a different output frequency (the IF) without second order nonlinearity in the transfer characteristic. Unfortunately this opens the door to non-linearities of higher orders – particularly the odd orders, which permit intermodulation between signals on adjacent channels to produce an interfering signal on the wanted channel. If cost and power consumption were no object, the best solution would probably be a passive diode ring mixer, which has a noise figure of about 6dB (consisting largely of conversion loss) combined with excellent strong-signal handling. Unfortunately such mixers require several milliwatts of local-oscillator power, which in most cases, imposes unacceptable penalties in cost and battery life.

The normal solution for low-power units is an active mixer, generally based on the Gilbert cell (Fig. 2). With accurate matching of the transistors, which can easily be achieved within an IC, the Gilbert cell offers good isolation between the input, LO and output ports.

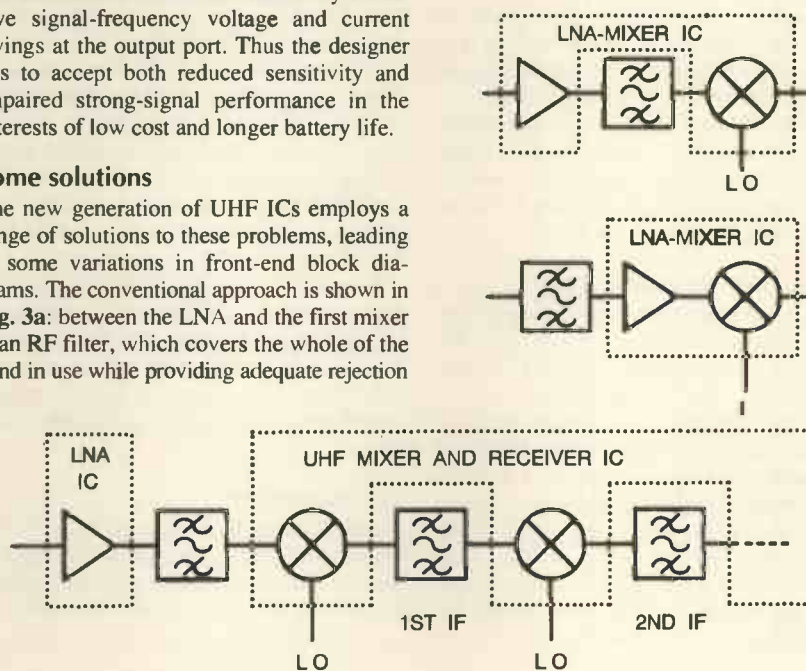
The problem for receiver designers is that the Gilbert-cell mixer has a typical SSB NF of 15dB at UHF, representing a noise temperature of over 8000K, and this can severely degrade the system NF. In a typical example,

the NF of a receiver with a sub-3dB LNA can be degraded to 6dB or more by mixer noise. It is not feasible to add more RF gain to overcome the mixer noise, because the excessive gain would degrade the dynamic range. Moreover, the inherent gain of an active mixer can lead to intermodulation caused by excessive signal-frequency voltage and current swings at the output port. Thus the designer has to accept both reduced sensitivity and impaired strong-signal performance in the interests of low cost and longer battery life.

**Some solutions**

The new generation of UHF ICs employs a range of solutions to these problems, leading to some variations in front-end block diagrams. The conventional approach is shown in Fig. 3a: between the LNA and the first mixer is an RF filter, which covers the whole of the band in use while providing adequate rejection

Fig. 3. Alternative receiver front-ends:  
 a) Best in principle, but less convenient for integrated LNA-mixer packages;  
 b) RF filter at input only – compromises noise figure;  
 c) First mixer included in main radio IC package



portable UHF receiver will vary considerably according to its environment. A design value of 290K is often assumed, this being the near-ambient reference temperature used in the definition of NF. A two-port device with a noise temperature of 290K would have a noise figure of 3dB, and many designers simply add 3dB to the receiver NF to allow for antenna noise. Although this short-cut leads to errors in low noise systems, in this particular case the error is well within the uncertainties in the assumed antenna noise temperature.

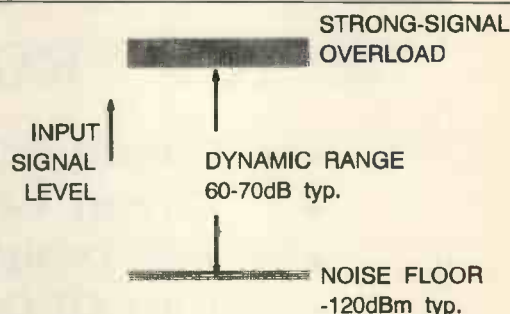
**Mixer noise**

Receiver noise includes contributions from all stages, active or passive, though these generally dwindle away after the first mixer. Taking a simple case as shown in diagram B:

$$T_{SYSTEM} = T_{ANT} + T_{LNA} + T_{MIX}/G_{LNA} + T_{IF}/(G_{LNA} \times G_{MIX})$$

where *T* represents noise temperature and *G<sub>LNA</sub>* and *G<sub>MIX</sub>* are the power gains of the RF stage and mixer, each expressed as a ratio. Note that cumulative gain acts as a divisor in this formula: although the LNA may not have sufficient gain to make mixer noise negligible, the cumulative gain of both the LNA and an active mixer generally means

**Dynamic range**  
 The dynamic range (sometimes called spurious-free dynamic range) is the span in decibels between the noise floor and the signal level at which intermodulation or other strong-signal overload effects begin. In typical power-conscious mobile receivers the dynamic range might be 65-70dB, though considerably better performance can be obtained in base stations.



that noise contributions from later stages can be ignored.

The mixer is fed with a local oscillator signal at *F<sub>LO</sub>* and is sensitive to two input frequencies, (*F<sub>LO</sub>*+*IF*) and (*F<sub>LO</sub>*-*IF*). However, only one of these contributes a wanted signal – the other contributes noise and/or interference. Hence it is necessary to add a filter at signal frequency, which is conventionally placed between the LNA stage and the mixer, and the “SSB” noise figure given in data-sheets for mixers assumes that this filtering is present.

**Noise floor**

Sometimes called the minimum discernible signal or MDS, the receiver noise floor is the equivalent noise power at the input to the system. A signal at this level would give a

signal/noise ratio of 0dB or a (signal+noise)/noise ratio of +3dB. In other words:

Noise floor = *kT<sub>SYSTEM</sub>B* watts where *B* is the noise bandwidth of the receiving system and is generally approximated as the nominal IF bandwidth. A typical UHF receiver might have a noise floor in the region of -120dBm. Clearly the term discernible signal should not be taken too literally; for example, spread-spectrum techniques allow signal recovery from below the noise level (though at the expense of increased bandwidth) while conventional FM has a threshold signal/noise ratio below which the modulation remains essentially unreadable.

of noise and any unwanted signals at the RF image frequency. A major benefit of this arrangement is that the losses associated with the RF filter appear after the LNA, where their contribution to the system noise figure is less significant.

Once again I must emphasise that the aim of using a low-noise RF amplifier is not to achieve an extremely low system NF; it is to increase the scope for optimizing the balance between system NF and dynamic range.

A possible drawback of the arrangement in Fig. 3a is that the LNA and mixer must either be separate ICs, or else a breakout between the two subsystems in a single package must be provided for insertion of the RF filter.

**Ready made solutions**

An alternative is to place all the signal frequency filtering close to the antenna (Fig. 3B). This is the approach used in the GEC Plessey DE6003 data transceiver (see panel).

Motorola also offers a down-converter IC using the same architecture. The MRFIC2001 was designed for operation at 800-1000MHz using a minimum of external components and makes no provision for an image filter between the LNA and the mixer. One might therefore expect a loss of up to 3dB in system noise figure due to LNA noise at the RF

image frequency. However Motorola has found that this degradation can be held down to only 1dB by controlling the magnitude and phase angle of the mismatch offered by the bandpass filter to the input of the LNA. In practice this involves only the insertion of a particular length of 50Ω transmission line between the filter and the LNA. Although the NF of the MRFIC2001 can be quite passable (5dB), the losses in a high-performance signal-frequency filter at the location shown in Fig. 3b would produce an unacceptable degradation of both receiver and transmitter performance. This simplified approach is therefore limited to applications such as cordless telephones, other short-range links and the low-cost end of the cellular radio market.

A more recent development for applications below 1GHz is to include the first mixer on the main radio chip (Fig. 3c). This requires a break-out for both the first and the second IF filters, but offers a more convenient arrangement for the separate LNA and RF filter packages.

**On the market**

The semiconductor manufacturers have adopted quite different approaches to the degree of on-chip integration and the physical interfaces on the front-end. This is partly determined by

the fabrication technologies available to each company, because at some point there must be a transition between the high-performance higher-cost UHF technologies and the high-density low-power bipolar silicon technologies required for second-IF and baseband signal processing. Gallium arsenide devices offer significantly better front-end performance at frequencies above 1GHz, so once again a transition to high-density bipolar silicon must be made at some stage in the receiver architecture.

There are far too many single-stage LNA and mixer ICs to be reviewed here in detail. In some respects their role is diminishing as complete single-chip front-ends become increasingly attractive. However, integration of the first mixer into the main radio chip may ensure a continuing role for single-stage LNAs, particularly in GaAs.

*Continued next month*

**Further information**

W A Hayward, *Introduction to Radio Frequency Design*, Prentice-Hall, 1982. ISBN 0-13-494021-0  
 The *VHF/UHF DX Book*, DIR Publishing, 1992. ISBN 0-9520468-0-6.

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# SOUNDS GOOD –

How can low cost, high performance and a simple operating philosophy all be combined in one audio power amp. Marco Corsi\* has the answer.

# LOOKS SIMPLE

Numerous articles have been written about using esoteric power transistors to improve distortion/bandwidth in high speed audio power amplifiers. While most of these undoubtedly achieve excellent performance, the parts used are often hard to source and construction of such beasts is time-consuming.

In this design we use as few components as possible without compromising performance. The aim is to produce 50W RMS into a 4 $\Omega$  power amplifier with a slew rate greater than 20V/ $\mu$ s and a -3dB bandwidth of >100kHz.

In the past, this kind of performance was not

feasible if the design were built using op-amps as the gain block. For instance, *TLO71* is limited to 13V/ $\mu$ s and the *NE5534* can only produce 6V/ $\mu$ s with 20pF load. So high speed power amplifier designers frequently turned to discrete design – gaining performance but making projects daunting to all but the most determined.

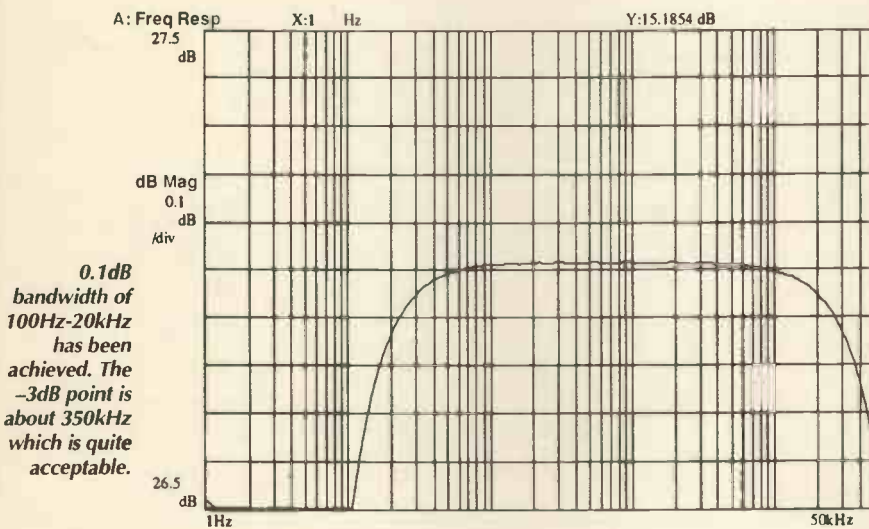
Many of the problems involved in designing a high speed precision op-amp stem from the fact that only a limited list of components are available to the IC designer. In a typical NPN bipolar process there are good NPNs, reasonable resistors, capacitors of less than 40pF and very poor, very slow PNP transistors. Poor PNPs limit the performance that can be achieved in an op-amp and in the last few years many of the major IC manufacturers have introduced complementary bipolar processes integrating both a high quality NPN and PNP. The result has been development of several high performance op-amps. Most tend to be very expensive but the range produced by Texas Instruments is reasonably priced considering its performance advantages.

The op-amp selected for this power amplifier has many characteristics which single it out. It has a typical slew rate of 40V/ $\mu$ s into a 500pF load, and its output circuitry has been specially designed with a fast saturation recovery so that if the amplifier is overdriven there are no long term storage effects – which could be very audible. The device also has better than 2mV input offset voltage, meaning that the speaker can be DC coupled with no adjustment for DC offset.

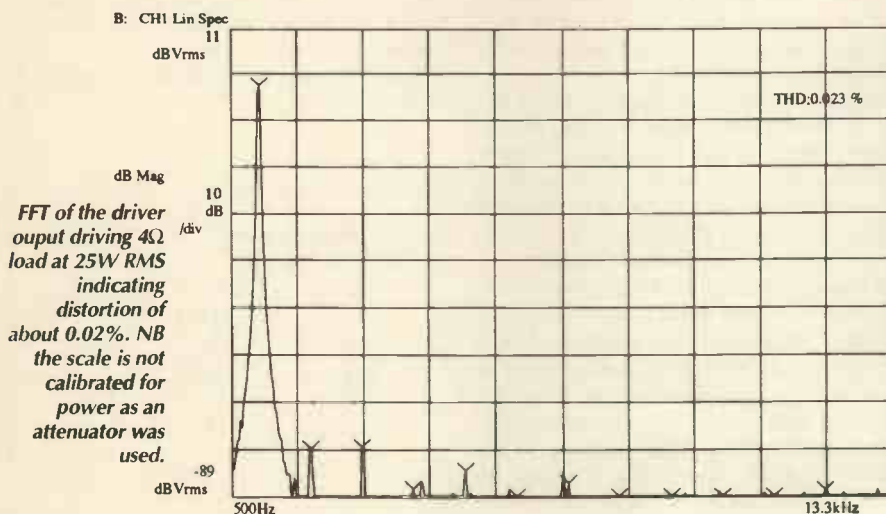
## Simple operation

Operation of the circuit is very simple.  $Tr_1$  and  $Tr_3$  are the Darlington output transistors and the class AB biasing is provided by  $Tr_2$ ,  $R_2$  and  $R_6$ .  $VR_1$  and  $Tr_4$ .  $Tr_4$  is a constant current diode and it can be thought of as a 4.7mA current sink. Current passes through the biasing network formed by  $Tr_2$ ,  $R_2$  and  $R_6$ .  $VR_1$  and a voltage is generated between the collector and emitter of  $Tr_2$  to set up a constant current through  $Tr_1$  and  $Tr_3$ . As  $Tr_2$  is in close thermal contact with the heat sink to which  $Tr_1$  and  $Tr_3$  are bolted, the biasing network is temperature independent and the circuit is free from thermal runaway. The top of the biasing network is tied to the output of the op-amp and the op-amp is connected in non-inverting gain mode by feedback. Resistors  $R_{4,5}$  and  $R_3$ ,

\*Marco Corsi is an applications engineer working with Texas Instruments.



0.1dB bandwidth of 100Hz-20kHz has been achieved. The -3dB point is about 350kHz which is quite acceptable.



FFT of the driver output driving 4 $\Omega$  load at 25W RMS indicating distortion of about 0.02%. NB the scale is not calibrated for power as an attenuator was used.

## DESIGN

and  $C_7$  form a Zobel network to ensure that the amplifier always has a load at high frequency, and  $L_1$  and  $R_9$  ensure stability into capacitive loads.

Capacitor  $C_1$  provides isolation to DC: it can be omitted if you are confident your preamp has no DC offset! As  $C_1$  is directly in the signal path, best performance is obtained with a high quality polypropylene type.

### Construction tips

Construction of the amplifier is relatively straight-forward.  $Tr_1$  and  $Tr_3$  need to be mounted on a suitable heat sink of about 0.6 C/W or better (for a stereo amp) and should be insulated from the heat sink by a suitable mounting kit. The parts list includes several different types of power transistor which are suitable, but note the package that is being used when choosing a heat sink. Plenty of thermally-conductive grease should be used when mounting the transistors and the bolts must be properly tightened. A wise move is to tighten the bolts again after the amplifier has warmed up as things tend to expand a little.  $Tr_2$  must be in good contact with the heat sink and a good way of ensuring this is to glue the transistor to the heat sink with a little epoxy resin.  $Tr_2$ 's job in life is to monitor the temperature of the output transistors and so only needs to be glued in place.

Try to star-earth the amplifier and ensure that capacitors  $C_{2,5}$  are as close to the op-amp as possible. Resistors in the emitters of  $Tr_1$  and  $Tr_3$  are there to help stabilise the bias of the circuit but they also serve to protect the output transistors in case of a short circuit load. Use four small resistors in parallel, as

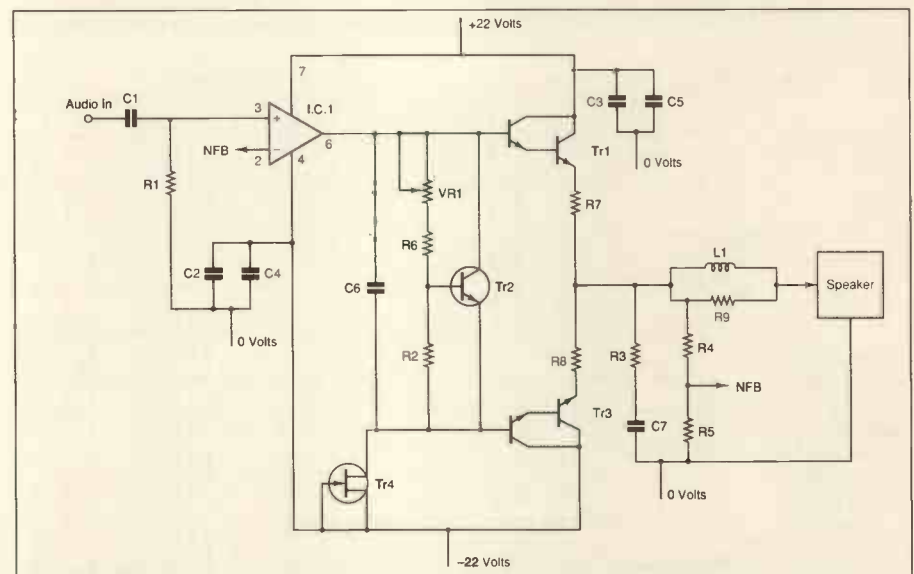
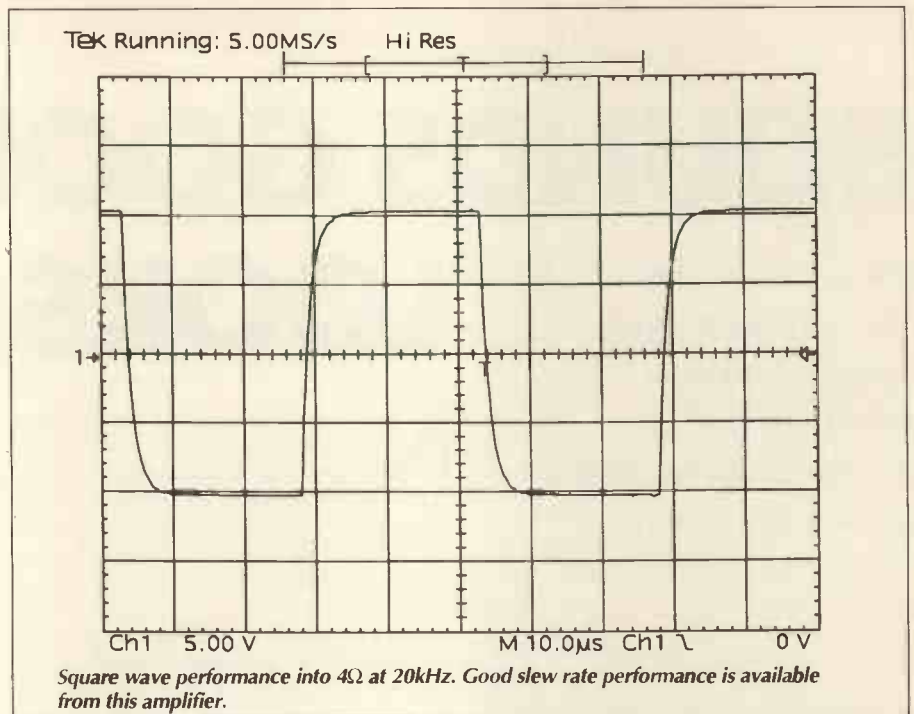
### Parts List.

Amplifier: two needed for stereo.

$IC_1$	TLE2141
$C_1$	2 $\mu$ F polypropylene
$C_{2,3}$	220 $\mu$ F 25V electrolytic
$C_{4,5,6,7}$	330nF 63V
$R_{1,5}$	22K 1/2W
$R_2$	680R 1/2W
$R_3$	10R 2W non-inductive
$R_4$	470K 1/2W
$R_6$	1k8 1/2W
$R_{7,8}$	0.25R comprised of 4 x 1R carbon 1/2W resistors in parallel.
$R_9$	10R 5W
$VR_1$	1K
$Tr_1$	TIP642/TIP641/TIP142/TIP141
$Tr_2$	ZTX753 or similar not important as long as a silicon NPN in an insulated package
$Tr_3$	TIP647/TIP646/TIP147/TIP146
$Tr_4$	J511 two terminal current diode
$L_1$	25turns of 12SWG enamelled copper wire around R9

PSU: for stereo use.

$T_1$	100VA toroidal transformer with 2 x 15V secondaries and 1 x 240V primary
$C_{1,2}$	22,000 $\mu$ F 25V
$B_1$	4A >50V bridge rectifier



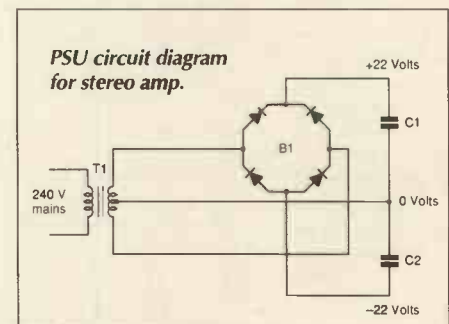
indicated in the parts list, and if you short circuit the output these resistors will fuse. Resistors are very low cost and probably cheaper than using a real fuse.

Before powering up the amplifier check that  $VR_1$  is set to its lowest value, ensuring that the output stage is biased up into class B. Apply the mains and check that the power supply is providing the correct voltages as indicated on the circuit diagram. There should be less than 50mV between the output and ground.

Assuming everything is OK, connect a voltmeter across  $R_7$  and adjust  $VR_1$  until a voltage of 50mV is measured. This sets up the bias in the output transistors for a small amount of class A reducing the crossover distortion considerably. Monitor this voltage as the amplifier warms up and check that it does not change wildly. Once it has warmed up, re-adjust  $VR_1$  to set 50mV across  $R_7$ . If it does not stabilise

check that all the transistors are bolted down firmly and ensure that  $Tr_2$  is in good thermal contact with the heat sink.

Now simply put the lid on the box and listen to lots of music. ■



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# Quickroute plays Windows joker

*Quickroute design software has always included schematic capture and an autorouter. The latest version has netlisting and a Windows interface. Martin Cummings finds it a useful upgrade – if you like Windows.*

## Key features

8 copper layers plus 2 silk screens  
Designs up to 30in square  
Minimum track size  
1thouAutorouter  
Interface to spice  
On line help  
Area fill

*Schematics can be converted to netlists, with a netlist report.*

**W**indows fans will immediately feel at home with the screen layout of *Quickroute 2* – the upgraded low-cost PCB design package now given a *Windows* interface and a netlisting capability. Under the drop down menu headings, a button bar allows selection of all main features and displays XY position, the current object type and layer. Placing of symbols and tracks is intuitive, involving selecting the category of item to place, choosing the exact one from a further box, then placing it.

In PCB mode, the choice spans tracks, pads, integrated circuits and other components, and in schematic capture these become connections, nodes, and symbols.

PCBs or schematics can be up to 30in square. Panning around a design is easy, and as an alternative to the normal windows scroll bars, a right mouse button click will cause a redraw around the current cursor position.

Of the three different ways of achieving zoom, probably the most popular is to define a zoom box with the mouse. But the menu also provides zoom factors from 0.1 to 10-times in seven steps – which can be directly implemented from the

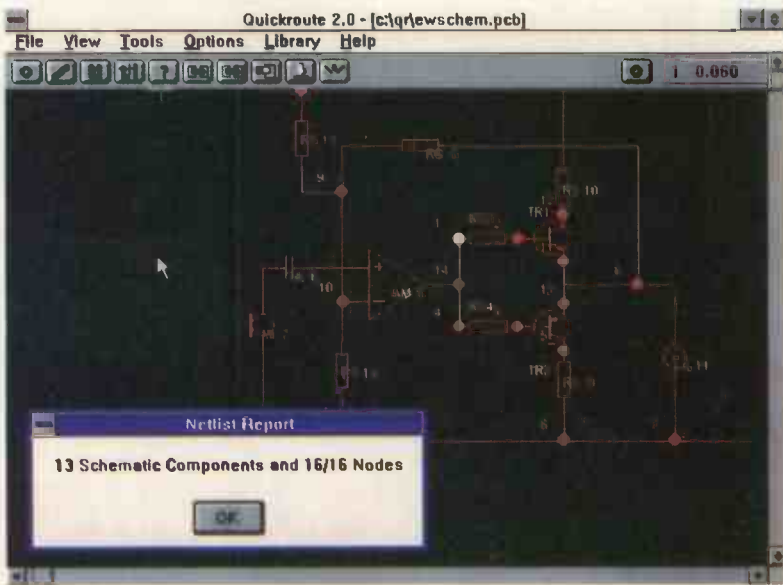
function keys – or a custom zoom factor can be typed in to four significant figures.

Redraw time could be described as adequate rather than impressive. Turbo redraw leaves tracks and pads as outlines, and though it undoubtedly saves time, in the example I chose, it only reduced redraw from 6s down to 4.

A grid can be displayed though there is no control over its pitch. Instead, it adjusts itself according to the current zoom level and looks roughly the same density on the screen with all settings. At first, this feels like a limitation, but it is a surprisingly sensible arrangement and easy to accept.

For the more important snap, or cursor step, there is full control, giving adjustment from 1in down to 1thou in eight steps. The grid can be reconfigured to operate in metric, giving eight steps from 2cm down to 0.02mm, and in a rather thoughtful way, *Quickroute* warns that you should not place integrated circuits using a metric grid.

Earlier versions suffered from unhelpful place and move commands, which kept the location of the component a secret until it was fixed in position. Placement had to be



## General note about Windows

**W**indows provides a graphical user interface where almost everything can be done with the mouse and icons or button bars. The new generation of *Windows* compatible programs all have the same look and feel and this makes them quick and easy to learn to use. It is possible to have several windows open simultaneously and quickly switch between them transferring text and graphics from one to the other if required. Several windows can be open simultaneously, into the same application or several completely different applications.

Cost of this flexibility is that to maintain performance, a reasonable processor is needed with plenty of memory. Although not strictly necessary, a 25MHz 386SX with 2Mbytes of ram should be considered a minimum system.



made by a series of iterations and was far from satisfactory.

But in the most recent version this has been cured and now a ghost component follows the cursor as it is moved around so there are no surprises when it is finally placed. A small price must be paid in speed, particularly when a block of circuitry is being moved, but the change is a major advance and brings *Quickroute* into line with similar packages.

Editing – layouts or schematics – is either block-based or pick and place. Block editing involves defining a rectangle to enclose the item, or items, and using the mouse to either move, copy or delete. In pick and place editing, an item is selected by clicking nearby, to highlight it: then the same three options are possible.

With either method there are odd occasions when it is quite difficult to select just the right component to be edited. It is not immediately apparent if selection is successful because *Quickroute* has to pause for thought while picking and highlighting the selected item.

Picking pads alone can be quite quick. But with the PICK ALL switch enabled, the delay is noticeable. No doubt thinking time varies with complexity of design and hardware, but on the occasion I bothered to measure it, the “egg timer” was displayed for around 6s – an eternity when there is nothing else to do.

## Libraries

There is a fair selection of devices provided both for component outlines and schematic symbols. For example clicking on the question mark reveals a choice of 48 different pads. But this in itself is not a limit because each of them can be reconfigured by specifying pad and hole diameters, down to 1thou.

Devices are organised into libraries that can be stored and called up as required, and it is relatively easy to create devices on a miniature gridded window and build up user specific libraries.

For schematics, over 100 circuit symbols are pre defined, ranging from basic logic building blocks, a good selection of transistor types, through to filters, switches and one or two audio components such as microphones.

PCB mode will handle eight copper layers together with top and bottom silk screen layers and an automatically-generated solder mask.

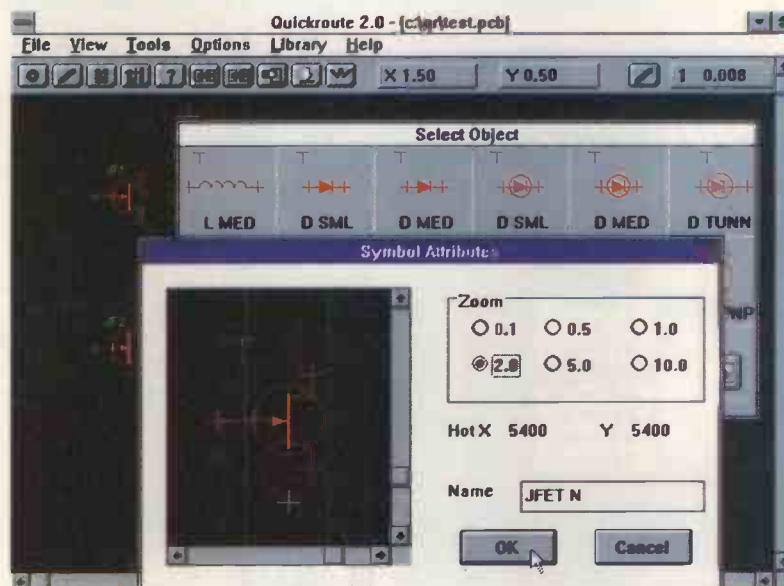
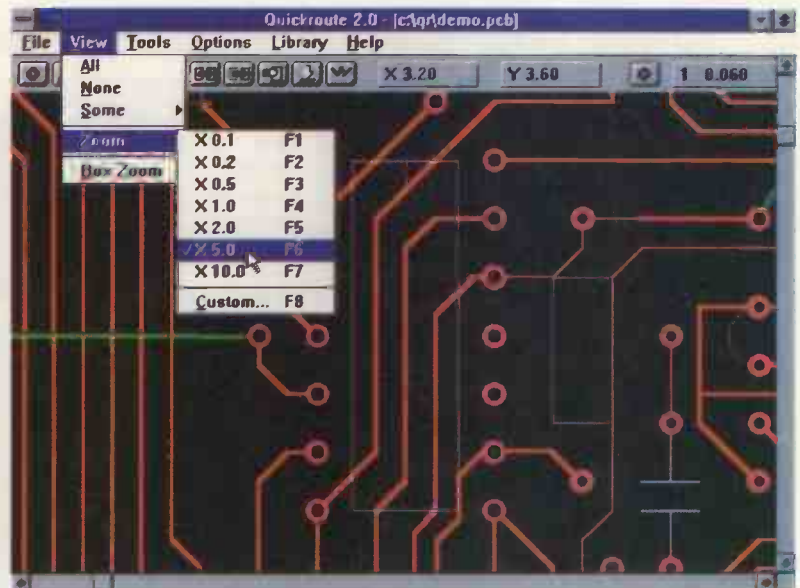
Layers can be turned on or off in any combination, though the solder mask is normally turned off because it obscures everything except the pads.

Up to 32 different track widths can be accommodated in any one design, and each one can be adjusted in thickness from 1thou up to 9in. Areas can be filled with copper using the polygon draw mode to produce an outline that is filled by the programme.

## Netlist capability

A significant improvement over the previous version of *Quickroute* is the ability to produce a netlist from the schematic and feed it into the autorouter. Unfortunately, this appears to impose a restriction on the number of components that can be used in a design and the way the schematic is drawn. As components are placed, one by one, the software suggests a component identification, automatically incrementing each time, and there is the opportunity to modify the proposal before accepting it.

A schematic can be drawn in two ways, depending on



Three different zoom methods.

A small gridded area appears to edit or create circuit symbols.

## Installation

*Quickroute* is installed from within windows and the process is completed in a matter of seconds. Requiring well under a megabyte of disk space this is one of the more modest windows applications around. A double click on the icon and within a minute or two of unpacking the disk it is running in a window occupying about 60% of the screen. There is a great temptation to maximise the window immediately to give plenty of design space, this may be the right thing to do initially but there are benefits, described later, in being able to switch to other windows.

In keeping with most *Windows* packages there is extensive on line help. The help that can be called up on screen is quite comparable in detail and content with that included in the manual. Given that the on screen help can be printed out and even annotated, it begs the question as to whether it is worth bothering with a printed manual at all. The paperwork must be a major component in the cost of supply. Having said that, the manual supplied is well presented. It comes in a ring bound A5 format and includes about 50 pages of well spaced out but attractive details organised into tutorial and reference sections.

Libraries of components are adequate.



point to point connections. Components can then be shuffled around until the desired arrangement is achieved – then the autorouter is unleashed. At least this is the theory.

In practice when I moved the components, the autorouter routed everything to its old position, giving a totally disjointed result. I am sure there is an explanation for this and it was probably something I forgot to do, but when using *Quickroute* you need to keep your wits about you and be prepared for the odd eccentricity.

### Simple autorouter

The autorouter itself is a relatively simple affair that tries to find the shortest route between the ends of each connection without straying outside a rectangle bounded by those end points. Several parameters can be adjusted to influence the performance of the autorouter, the most

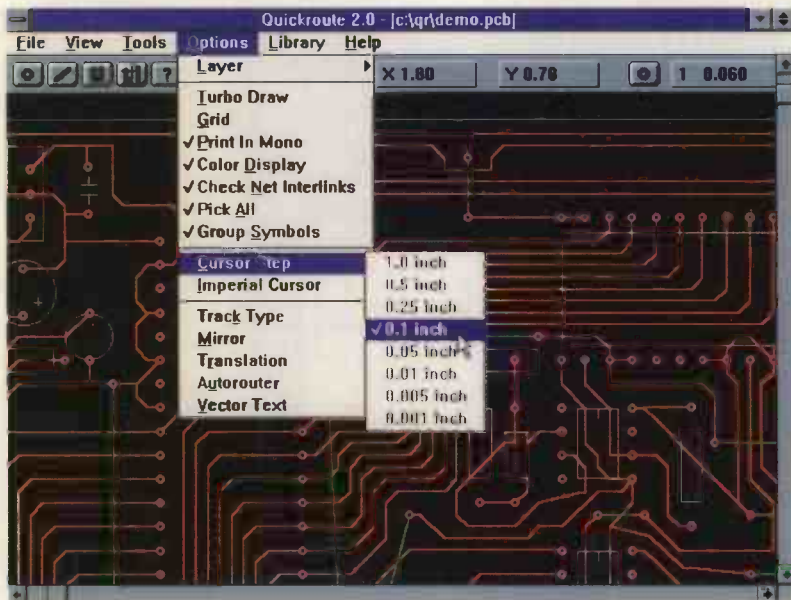
important being grid size for routing which has four settings, from 0.25in up to 0.2in. A route will be attempted on all of the layers currently displayed.

There is no report at the end of the exercise to explain the outcome, so you are left wondering exactly what it has been done and why it has not managed to route some of the connections.

Assuming the layout is beginning to take shape, text might be added to the design.

Two types of text can be created: windows text, providing an attractive font but always horizontal on the design and limited to one size; and the more useful vector text which comes in four different sizes and can be placed in any orientation.

The old version of *Quickroute* included few printer drivers and was limited to Epson or Hewlett Packard compatible devices. One of the benefits of working within *Windows* is that this limitation no longer exists and output is possible on



Cursor step is selectable over a wide range.

whether the system is to be used simply as an electronic drawing board or to generate the netlist.

For the netlist, make interconnections between circuit elements using nodes created by placing what would be a pad in the PCB mode, at the junction of wires and component symbols.

Once the design work is completed, one click on a drop-down menu quickly generates the netlist, and a report window opens to report how many nodes exist.

The process works well – but why bother entering the nodes at all?; and there is a limit of 500 components that can be included in the design.

On the bright side, the netlist can be used to generate a *Spice* file when simulation work is to be undertaken.

The alternative drawing method is not to bother with the nodes and just arrange the symbols and interconnections to look like the circuit. The resulting circuit diagram is as good if not slightly neater than before but will not generate a netlist. But now there is no imposed limit on the number of symbols. Depending on memory available, symbol count can be well into the thousands.

Assuming the netlist has been created, the next step is to start the layout process. *Ratsnest* command will convert the netlist and component details into a provisional layout with

### Personal response to bugs

One or two unusual things happened during use. On one occasion all the transistor outlines turned black (and hence invisible) for no particular reason. On another, panning from a mouse command disabled itself without notice.

But, in the *Windows* environment it may be unfair to lay all the blame on *Quickroute*, and to counter this, the technical support was effective.

The organisation, although growing, is still small, and it is likely to be the author that deals with your query. One or two bugs that I discovered were quickly diagnosed and a corrected version issued in a matter of a couple of days.]

### Supplier Details

*Quickroute 2.0* for *Windows* £59, *Quickroute 1.5* for dos £39. Bought together £79.

Powerware, 14 Ley Lane, Marple Bridge, Stockport, SK6 5DD.

Tel or fax: 061 449 7101

any Windows-supported device or that comes with its own Windows driver. Indeed there is an element of future proofing, in that devices not yet in existence will be compatible so long as they come with a windows driver.

Exact content of the output is determined by what is displayed on the screen at the time the printout is requested. Hard copy will be scaled according to the screen zoom factor selected and will include the layers currently chosen for display. There is no scope to fine tune the scaling of the print or plot.

#### Assess the Windows importance

In general terms *Quickroute* is unremarkable, whether measured against features, performance or even value for money. But there is no doubt that running under *Windows* puts it ahead of the field and makes it a visually attractive package.

The *Windows* environment brings several recognised advantages. Perhaps most evident is the ability to have several windows open simultaneously, eg the schematic and layout open alongside each other. Designs can also be cut from *Quickroute* and pasted into other *Windows* software such as word processors (although applications for this are difficult to imagine).

On most machines, *Windows* gives access to more memory – both real and virtual. There is also the attractive learning curve to consider. The look and feel of all *Windows* software is deliberately identical so that it takes, literally, minutes to start exploiting *Quickroute*, where traditionally cad packages are an acquired taste. While this is unlikely to be relevant in a professional application where users are working with a

package day in, day out, in a teaching environment students can concentrate on the engineering rather than wasting time learning the key presses.

The price to be paid is in overall speed of operation – though as hardware continues to improve, this becomes less of a problem, and anyone running a 386DX or above is unlikely to be bothered by time delays.

Although *Quickroute* comes into the low cost bracket, Powerware is deliberately distinguishing it from shareware, as opposed to *Quickroute 1* which was distributed as shareware. It should also be recognised that there is an effective technical support service and, I am told, free upgrades until the next major release.

Users committed to *Windows* and wanting to run design software under it, currently have a limited choice. In these circumstances, where the benefits of a *Windows* interface could be the overriding factor, *Quickroute* stands out.

But if *Windows* is a secondary consideration, the package is likely to have some stiff competition from other existing software as prices come down. ■

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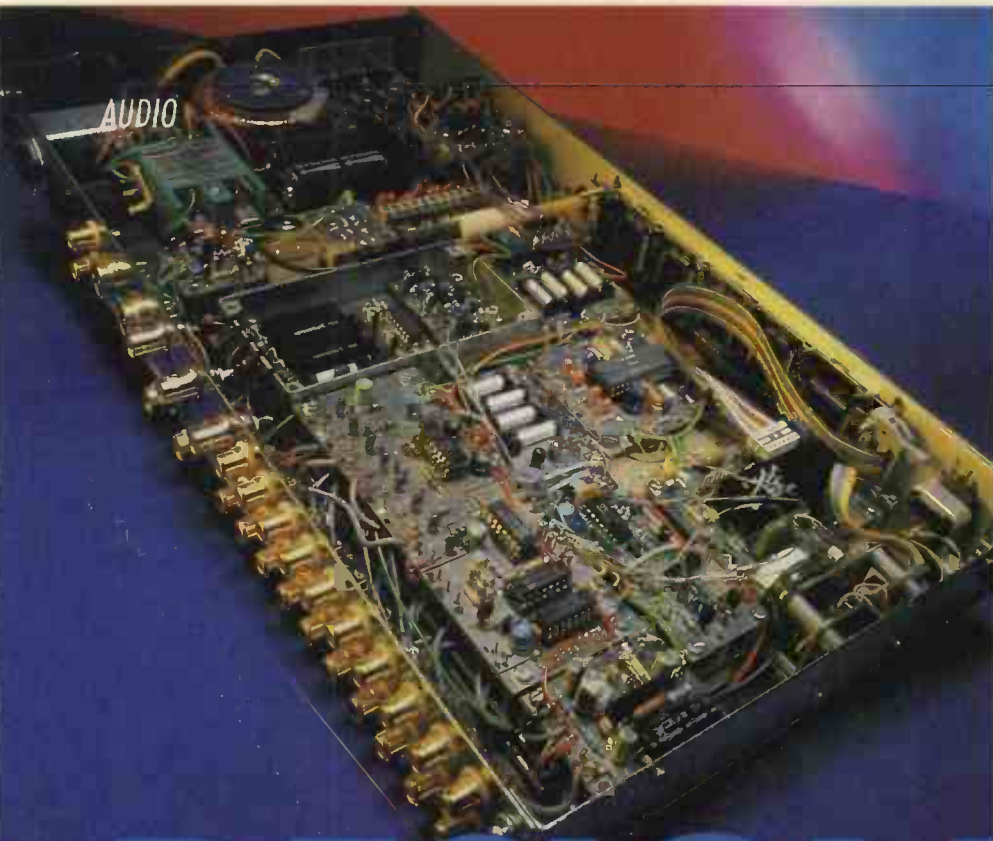
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*Reducing the effects of switching noise from a microprocessor on quality audio circuits is a necessity. This is just one aspect of breathing intelligence into dumb audio equipment. Martin Eccles discusses the zen and art of audio control by digits.*

# DESIGNING

## a microprocessor-controlled audio preamplifier

Seeing Chris Miller's digitally-controlled audio preamplifier in the September 1992 issue has tempted me to share my problems and solutions on the same subject. Our designs both revolve around a microcontroller driving an I<sup>2</sup>C sound processor but that is where the similarities end.

Most noticeably my design has only one control on its front panel, redundant I might add, and all indicator lamps are replaced by a two-row, 40-character LCD. Functionally, an LCD is excellent but don't ignore the viewing angle specification. Most, like mine, are designed for mounting in keyboards and are unsuitable for front-panel mounting.

I placed more emphasis on low distortion than perhaps Chris did since he doesn't mention it. I was concerned that the I<sup>2</sup>C sound processor I chose, with its 0.05% THD figure, would not suffice for the best quality sources. As a result, I built in a by-pass option using reed relays, Fig. 1. This means that all hi-fi inputs can be directed to the power amp via just three reed relays in series, a potentiometer and a high-performance unity-gain buffer.

For two years now, this by-pass function has served only to reassure me that the I<sup>2</sup>C chip introduces no degradation that I can hear.

Since the microcontroller has an abundance

of spare processing power, it seems logical to make it do as much work as possible. It switches mains to both power amplifiers and the TV monitor from the remote control pad via electronic relays. Mains switching is an important feature if you include a real-time clock for automatic recording or burglar frightening. In the same 40mm-high rack enclosure there is video switching and buffering to select cross recording from two video recorders and for directing video to the monitor.

My choice of controller includes an RTC and avoids Chris's problem with battery-backed CMOS RAM. The use of LCD avoids the switching transients associated with LEDs since parallel data is passed to the LCD from the controller in very brief low-current bursts. But reducing the effects of processor noise is not the ultimate solution – nor even the simplest.

### Eliminating processor noise

Averaged out, the amount of processing power needed to control a preamplifier is tiny. All the work is done in the instant when you alter a setting, usually once every ten or twenty minutes.

In common with many CMOS microcontrollers, the Dallas DS5000 has a software-

inducible sleep mode that completely stops its oscillator, eliminating all switching noise. In my design, the controller only bursts into action for an instant when I press a key on the remote-control pad. Of course the LCD and remote-control sensor include oscillators but these are low-frequency and low power, producing tiny amounts of RF and EMI relative to the microcontroller.

During sleep mode, all of the i/o lines retain their pre-sleep states. Following the hardware reset, all the i/o lines are configured as inputs and need reinstating. Since this can be done within microseconds, it is of little consequence. In the software however, you need to insure that any lines used to feed clock inputs need to left high in their idle state. If this is not possible, a series resistor followed by a capacitor could be used to filter out the reset low-to-high pulse. You will need to study the controller data sheets since, as with the 8051, the four i/o ports are not identically structured.

Because the controller consumes virtually no power in sleep mode, the preamplifier can be left permanently switched on; the microcontroller, LCD and remote control sensing circuits have their own permanently-on 5V supply. Power to the remaining preamplifier circuits is provided by a  $\pm 15V$  regulator with

slow ramp up/down characteristics to avoid thumps, Fig. 2. This regulator is turned on and off by the microcontroller.

Any output from the remote control sensor, Fig. 3, incites a reset to the controller via the pulse circuit of Fig. 4, causing it to start up and then determine the source of the reset. This can be from the remote-control pad, from an external RTC, Fig. 5, or as a result of an ordinary or post-mains-fail power up. Even when its oscillator is stopped, the controller can detect whether external power has been removed since it has internal battery backup.

I originally attempted to use the controller's two individual interrupts to indicate to the controller whether the reset source was from the remote control pad or from the RTC but for some reason I failed in this. It could be that an interrupt level change simultaneous with the reset pulse is illegal but since I decided not to add the RTC, I did no further investigations.

**The microprocessor**

The DS5000 controller is a 40-pin device with a similar instruction set to the 8051. In the same package there is 32K of ram, software security circuits, watchdog timer, memory management, battery backup and power-up/down circuits. An 8K ram version is also available, and is certainly more appropriate for use in a preamplifier. Needing no external memory and just a crystal and reset capacitor, all of its 32 i/o lines are free to use as you please. Of course if you adopt the microprocessor idling technique then the watchdog timer is redundant.

One of the development advantages of the DS5000 is that, since it is battery backed internally, programming it involves no ROM. There are two ways of developing its software. For the simplest method, you dedicate two i/o lines to RS232 communication. Write the software, configure a couple of pins and dump code via the RS232 pins. A loader routine is built in. Once the device is programmed, you can use the RS232 lines as normal. Alternatively there exists a very simple emulator kit that connects to the PC serial port, allowing complete freedom in circuit configuration.

In one-off applications like this, the high ini-

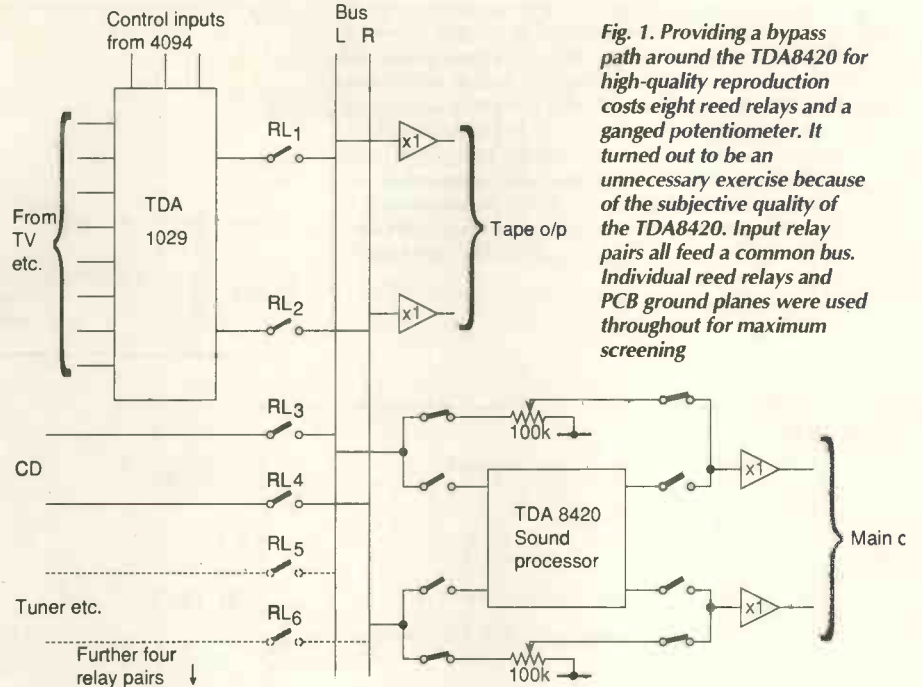


Fig. 1. Providing a bypass path around the TDA8420 for high-quality reproduction costs eight reed relays and a ganged potentiometer. It turned out to be an unnecessary exercise because of the subjective quality of the TDA8420. Input relay pairs all feed a common bus. Individual reed relays and PCB ground planes were used throughout for maximum screening

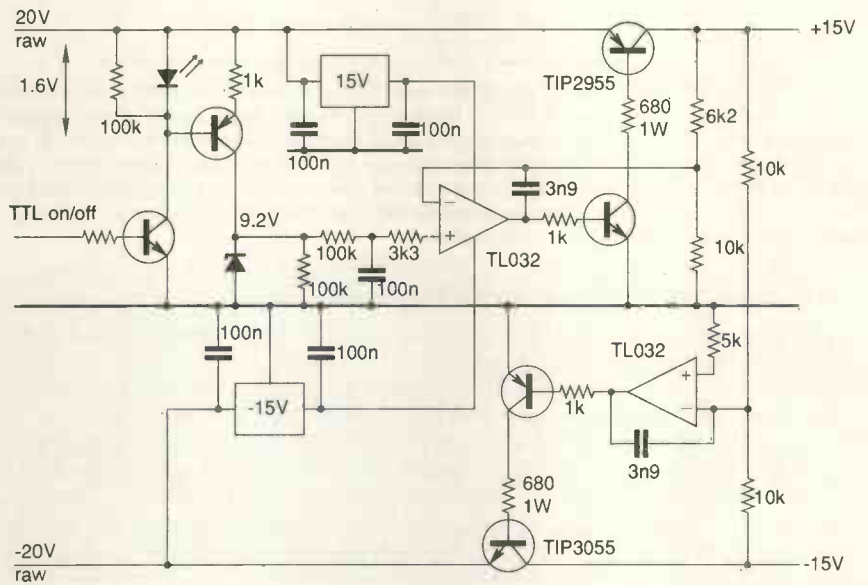


Fig. 2. To avoid thumps, this ±15V tracking power supply has a slow and predictable ramp-up, ramp-down characteristic. Input power to the regulator remains permanently on since the circuit is turned on and off by the microcontroller. The TL032 is a low power consumption fet device. Besides providing a reference voltage for the zener's constant-current source, the led provides a convenient power-on indicator. Although the circuit has no current limiting, the 680Ω power transistor base resistors restrict current through the output transistors allowing brief shorts to be survived. Generally, this configuration of power transistor is more rugged than emitter-follower alternatives. The circuit was designed to provide about half an amp. It should provide more but you will need to reduce the 680Ω resistors.

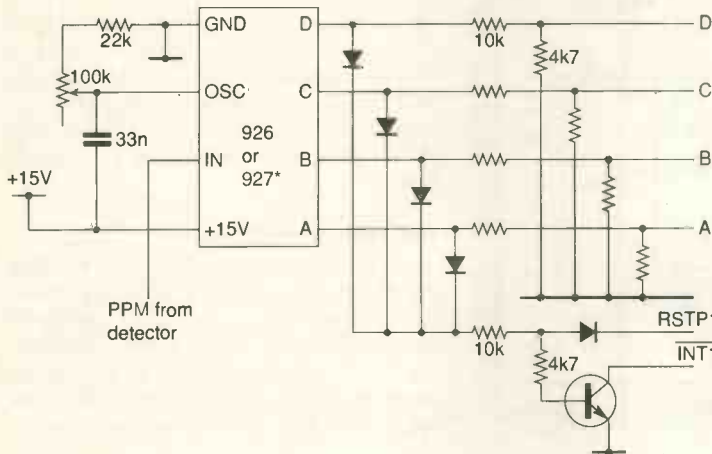


Fig. 3. Remote-control decoder providing a reset to start up the controller. With no pulse-position modulation from the detector amplifier, all outputs are low. Any incoming code other than zero causes RSTP1 to go high and the interrupt low. To avoid latch-up, output signal levels must never exceed the controller supply voltage and potential-divider values will need altering depending on which port of the controller you use. Bear in mind that the final reset pulse (Fig. 4) should reach a level of 3.5V or higher. If you need more data, two or more of these devices running at different oscillator frequencies can be used together.

Fig. 4. Although simple, this circuit allows processor noise to be virtually eliminated from audio and RF circuits. When the processor has finished its task, which in a preamplifier will rarely take more than a few milliseconds, it shuts itself down, removing all switching noise. A high as a result of action from the remote-control circuit or RTC results in a brief reset pulse, firing up the processor. Because of the wide range of the controller's internal resistance, unmarked components will need to be chosen empirically. While the processor is in action, the transistor inhibits any external resets other than from the reset switch.

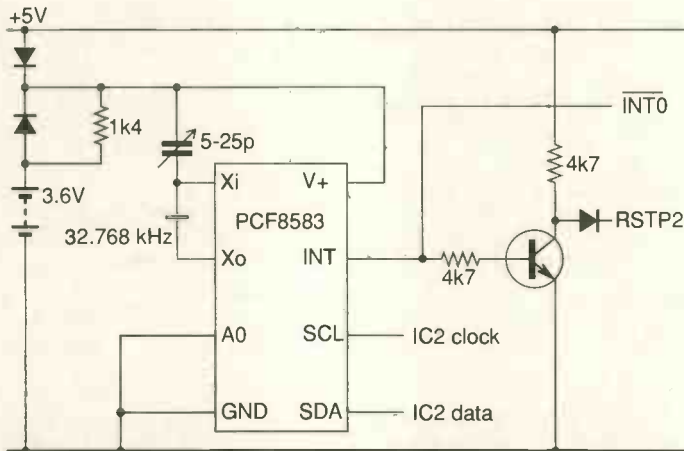
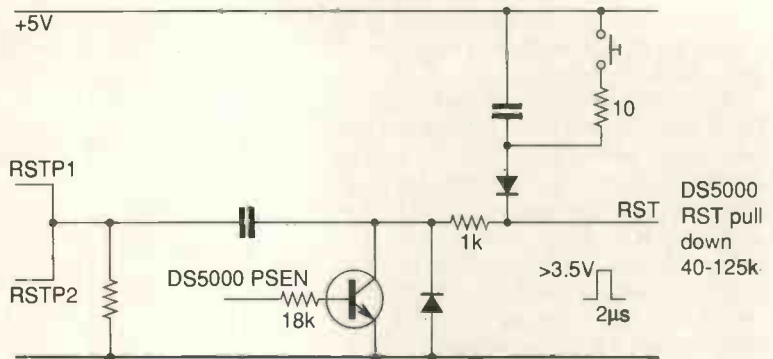
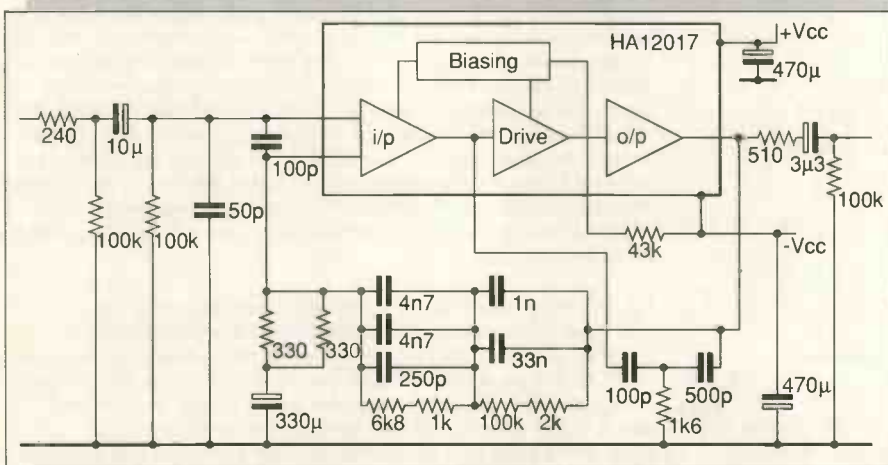


Fig. 5. I designed this real-time-clock circuit but never applied it. There's not much to the circuit but the chip is quite interesting. Firstly it has 256 bytes of ram. Its clock keeps oscillating with supplies down to 1V while the I<sup>2</sup>C bus operates down to 2.5V. A four year calendar function is built in and the device is programmable for alarm, timer or interrupt functions. It is also configurable as an RTC with either 50Hz or 32kHz crystal clock, or as an event counter, in which case, the oscillator input becomes a count input. Operating power consumption is just 50µA. Trickle charge for any small memory back-up type battery is easy to calculate.

### Tribute to an underestimated op-amp

Just for the record, this vinyl disc replay amplifier is not my design. It forms part of my preamplifier and I think it deserves to be documented in the pages of *EW & WW* because of its impressive performance. At under £1, the HA12017 is quite remarkable and I ask myself why people still bother with discrete designs?

Distortion, quoted at 0.002%, is specified for 10V output. Curves show that at 200mV output, distortion rises to just under 0.01% for 20kHz and just under 0.02% at 20Hz but looked at relative to the rest of vinyl replay system, these figures are of little consequence. Input noise voltage is 185nV while output noise for a 3.3kΩ source is typically 5.3mV. Supply ripple rejection figures for the positive and negative rails are 56dB and 45dB respectively. For an overload of 235mV, distortion is 0.1%, and total gain is typically 105dB.



tial price of the DS5000 far outweighs the extra circuitry and programming facilities needed for other solutions.

Despite the fact that the microcontroller has 32 i/o lines, more were needed. I added two cmos serial-in shift registers, each with eight outputs. One of these provides mains switching while the other, Fig. 6, controls input switching. Switches with I<sup>2</sup>C control would have been a more elegant solution but the cheap cmos registers were more readily available and include a strobe input that may be used for zero-crossing mains switching.

Since 12V electronic mains relays are easier to obtain, the mains-switching cmos IC runs at 12V. Converting from TTL to 12V cmos level is done on the serial side using four transistors – two for the clock and two for data – to maintain logic sense. Had level conversion been carried out on the output side, each of the eight outputs would have needed one transistor and the logic sense would have been inverted.

### Zero-crossing mains switching

Unlike I<sup>2</sup>C alternatives, the 4894 shift register has a strobe input that can be used to transfer all eight bytes of serially input data to the output in one go. In audio applications, mains-switching transients are a nuisance, avoided completely by using zero-crossing switching. Zero-crossing electronic relays are available but tend to be more expensive.

Positive zero-crossing pulses, obtaining by simply applying rectified but unsmoothed mains half cycles to the base of a transistor via a resistor, are fed to the shift register strobe input. As a result, the outputs switching the electronic relays only change state on mains zero-crossing instants.

Even though the microprocessor can deliver either logic level as true, it is useful to have all devices controlled by the same byte turn on with the same logic level. It makes programming and debugging easier and allows the shift register to be reset in one go to a safe state.

### Electronic or mechanical?

There are two types of audio source switch in my design, one comprising reed relays for hi-fi sources and the second for TV and 'lo-fi' signals provided by a dedicated audio switching IC. I studied specifications for various cmos analogue switches for the non hi-fi side but deemed them probably unsuitable, anti-

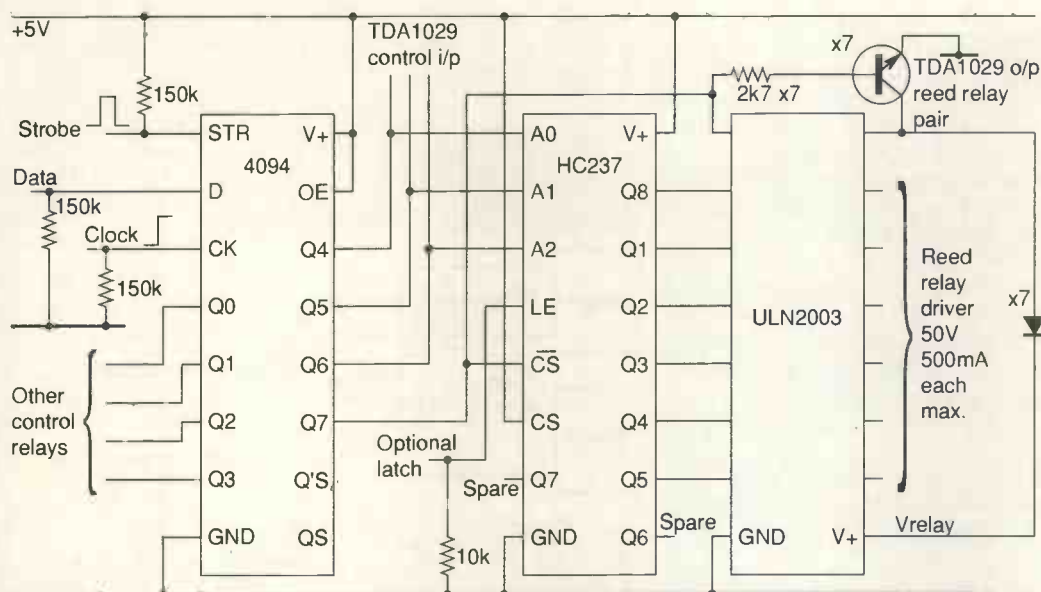


Fig. 6. This logic-efficient circuit controls the relays shown in Fig. 1. All seven pairs of input selector relays are driven by the 2003 while the 4094 controls the bypass relays and other functions either directly or via discrete drivers. If you adopt the TDA1029, it is important that its selector relay is driven only from the output shown. When this output is on, the 237 one-of-eight decoder is disabled, allowing the three TDA1029 control lines to produce any combination. This makes very efficient use of the selectors. Driving the relays directly from the 4094 would have saved an IC but introduced the risk that more than one relay could turn on at a time.

pating the possibility of 13-bit Nicam TV. Discrete medium-power mosfets seemed like a more attractive alternative but having neither the time nor the inclination for experimenting, I opted for a safe alternative.

Voltage-dependent resistance worried me most about cmos analogue switches. Even for today's more advanced chip designs, cmos switch specifications are rarely useful to audio designers – perhaps because analogue switch data sheets are compiled by digital engineers with little knowledge of the problems facing analogue designers. (For further information on analogue switch design, see Mike Meechan's feature commencing page 562 of this issue – Ed).

The dedicated audio switch that I opted for, the Philips TDA1029, has a performance that the I<sup>2</sup>C alternatives did not match at the time although it would be worth investigating what is on the market today. Needing only three passive components for each input and a couple of extra capacitors, the 1029 selects one of four stereo inputs depending on the states of three control inputs. It handles up to 5V rms input, buffering it down to 400Ω output via a unity-gain amplifier with a current gain of 10<sup>5</sup>. Distortion is typically 0.01% rising to 0.03% over a range of 20Hz to 20kHz, while typical noise voltage is quoted as 5μV unweighted, again over a 20 to 20kHz range.

Not that it matters much even for Nicam telly sound but the speed of the 1029 is 1.3MHz and its slew rate 2V/μs. Crosstalk is good too, rated at typically 70dB and largely

dependent on external components. Now I've got to defend my use of reed relays for the hi-fi. Well, they give you that little click that lets you know that they have switched in the absence of a signal...

### A versatile I<sup>2</sup>C audio IC

I don't have any data on the TDA7300 control IC that Chris used but he says that it was intended for automotive applications which would have automatically excluded it from my list of choices however good it was. I opted for an IC described as suitable for hi-fi audio – the TDA8420.

As Fig. 7 shows, the 8420 only has two stereo inputs as opposed to the 7300's five but in other respects it seems to be more suitable for non-car preamplifier applications. For example, it has two attenuated output channels but unlike the 7300, one of the channels is adulterated by nothing other than an attenuator, making it suitable as an auxiliary output

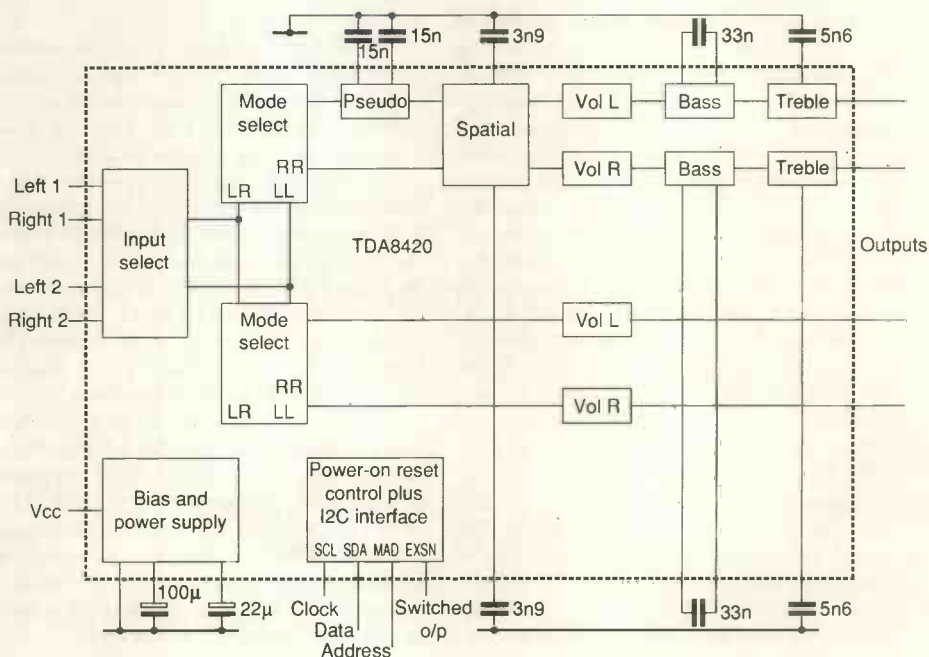
for recording, say, or as a headphone output.

Besides having bass and treble controls, the 8420 also incorporates spatial and pseudo-stereo processors that must have a use or they wouldn't be there. Distortion is quoted as 0.05% typically for a 500mV rms input between 20Hz and 12.5kHz, although the chip's response covers the entire audio range. Even down at 12.5kHz though, any harmonics are outside the audible range of course. Noise is 90dB while channel separation is 75dB.

As I said earlier, the IC can be by-passed completely in my design. When its gain characteristic is set flat at 0dB and the by-pass potentiometer wound up fully, switching between processed and by-passed sound is inaudible except for the tiny click of the relays. Many, including me, have unsuccessfully tried to differentiate between the two modes of operation, despite the fact that one path is AC coupled, the other entirely DC.

The only drawback I have found to the IC is

Fig. 7. This sound controller surpassed my expectations. With very few components, it is capable of phase shifting for pseudo stereo, image widening, gain from -46dB to 16dB with mute, treble control from -12 to 12dB and bass control from -12 to 15dB. A second channel with just a -62 to 0dB attenuator is available for headphones and the like. The address line allows two devices to be addressed on the same bus while EXSN provides a spare I<sup>2</sup>C-controlled logic output.



## Switching for video cross recording

Many pre-SCART video recorders had no manual switching between signals from their video input and signals from their integral TV tuner. Instead they incorporated automatic switching that meant that if you connected anything to the video-recording input, all TV channel reception was inhibited. As a result, if you connected the output of one recorder to the input of a second, the latter had to be unplugged in order to access its TV tuner.

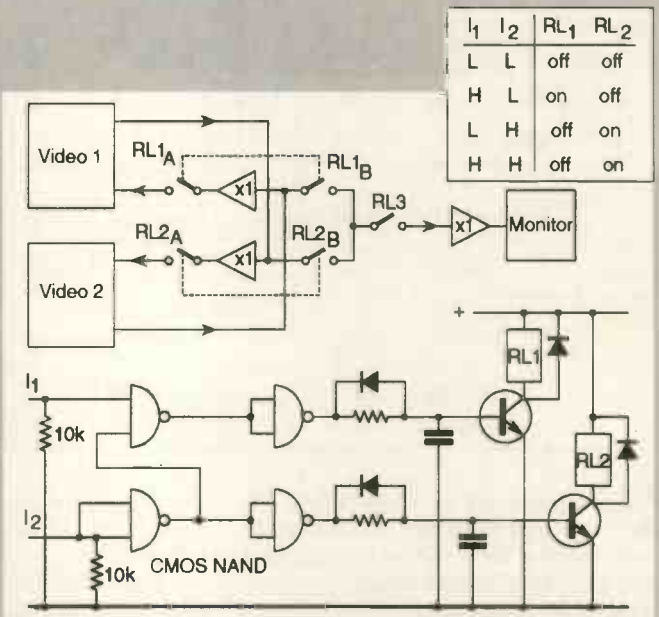
Designed for convenient cross recording between two video recorders, this circuit only connects output from recorder 1 to the input of recorder 2 when recorder 1 is selected for displaying on the monitor and *vice versa*. In this way, the selected video recorder will never have anything plugged into its input when you want to watch its output; plugged is use metaphorically of course.

The third relay is there to clear the monitor screen in an instant, just in case a colleague calls when you are watching – or even worse recording – something embarrassing like *Coronation Street*.

The logic makes sure that both relays can never be on at the same time. During changeover, the RC/diode network ensures that one relay is turned off faster than the second can be turned on. Quite why you would want access to TV signals from two video recorders is a mystery to me but if you've read this far, there must be something in it.

I would advise separately enclosing the switches and buffers in their own RF-tight diecast box and to use feed-through decoupling for the power supplies and the three control lines,

one for the single-pole monitor relay and two for the double-pole crossover relays.



that the gap between its lowest volume level of -62dB and its mute facility at -90dB or less is a little too large and it would be advisable to insert extra attenuation if you've got very sensitive ears or loudspeakers. The loss of gain can be compensated for since the IC's main channel only has a maximum gain of 16dB as opposed to a 0dB maximum for the headphone channel. Gain increments on both channels are 2dB.

### Ergonomics and remote control

The display is cryptic to the average domestic user since I wanted to show all information at once. It is useful to have levels specified in dBs; the *TDA8420* is quite accurate allowing the preamplifier doubles as an handy attenuator for making speaker or microphone measurements. If I were to start again though, I would look into having all switching information on one display and all control settings on another since I often forget what the numerous one-letter abbreviations mean.

The keypad format is equally complex but more successful design-wise. It has fifteen keys. Although the remote-control IC responds to 16 codes, the code for zero is the same as the code for no data, which I fail to see the use of. More than 15 codes are needed of course so I used the bottom four keys, all red, as mode switches to alter completely the function of the keypad.

Volume, tone, sound processing and mono/stereo switch are covered in the first mode. The second selects one of six sets of input reed relays or two of the *TDA1029*'s input channels while the third covers mains switching and the *1029*'s remaining two

inputs. Three modes would have sufficed since the fourth is only used for the main on/off switch. It was intended for RTC functions.

Although it seems quite complex, especially when you consider that the home made remote controller has no key legends, finding out where the keys are can be learnt quite quickly. Professional-looking legends that describe all four functions of each key would have been an impossibility so I opted for the compromise of colour-coded keys, carefully grouped so that the coding makes sense in all three modes. A bonus is that anyone wanting to tamper has a pretty difficult task.

My only other suggestion about the remote controller is to use multiple leds, say three, and drive them with as much power as they will take. At the same time, keep the drive pulses as fast and as short as you can.

I incorporated high light output so that I could impress the neighbours by turning my hi-fi up and down from the garden. In theory the penalty should be shorter battery life but the original PP9 has been in use since the controller was first built well over two years ago and it shows no signs of weakening despite intensive use. The same battery even drives a visible-light LED to verify operation.

I don't know why it should be so efficient but it has occurred to me that because every key press results in an action, fewer key presses are needed; this remote control unit is far more effective than any commercial design I have tried. The only other reason I can think of that could conceivably contribute to extending battery life is that I cleaned the PCB thoroughly after soldering and coated it.

### Loose ends

Since this was my first attempt at programming in 8051 code, there's little point in sharing my knowledge on that subject. Besides, it is unlikely that any preamplifier you may make will be identical to mine. But there are one or two observations that might be helpful.

Firstly, I found data-book descriptions of I<sup>2</sup>C operation very muddled (*This will soon be corrected. We have an excellent article in preparation on the subject – Ed*). In fact I found learning 8051 code easier than getting an I<sup>2</sup>C chip to respond properly. It seems to take a lot of code to address an I<sup>2</sup>C device.

Provided you have some prior knowledge of assembly language programming and a good assembler, handling 8051 code should not pose too many problems. If you have only used Z80, 6802 or 6805 type code before, you might find the 8051's data and program memory concept a little hard to grasp at first. Had I had to program an eeprom for each iteration, I would probably have abandoned the project but luckily, the *DS5000* allows you to experiment effortlessly.

As a matter of course, whenever possible, I always design PCBs with tracks underneath and a ground plane on top. Surface-mount 0.1µF capacitors are cheaper than the through-hole equivalent, they are quite easy to solder manually and they do not suffer from lead inductance. As a bonus, if you design a PCB with power rails running alongside each other to accommodate SM decoupling, it is a simple matter to increase the decoupling if the design should turn out to need it.

With hindsight, the potentiometer on the front panel is unnecessary. ■



# APPLICATIONS

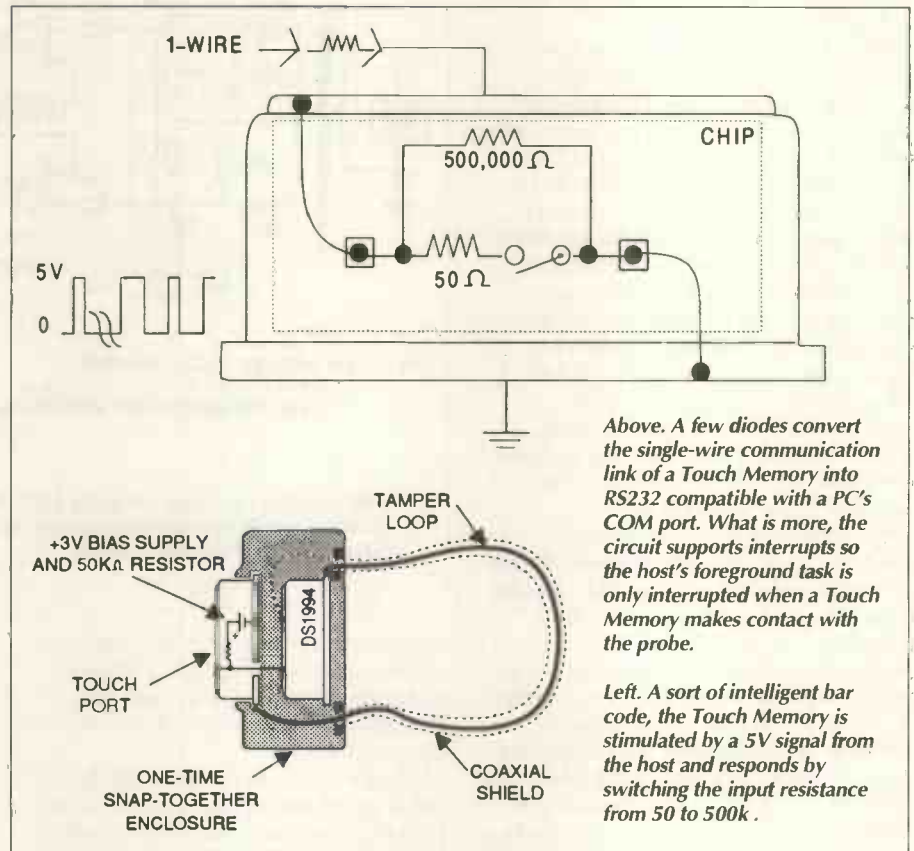
## Two terminal memory for automatic ID

In order to make the touch memory competitive against bar coding and the like, Dallas had to make it user friendly. The company's book *50 Ways to Touch Memory* details how they did it. Most of its 92 pages demonstrate how the device can be implemented, with interesting ideas like making the bumper of a truck one of the memory's two 'electrodes', but there are also circuits illustrating how the memory's data can be inserted and extracted.

Housed in a stainless steel button-cell package, the Touch Memory reads and writes data over a single wire by switching its resistance between 50 and 500k. This 10,000:1 off-to-on ratio minimises the effects of poor contacts and allows data to be transferred over distances up to 300m. Data is transferred rapidly too, and it is verified. Reading the signature takes 5ms so data can be read when contact is intermittent. The book even suggests that the cell can be read while it is rotating.

There are five touch memory versions, all capable of providing a unique 48-bit identification code via a single wire and ground. Because of this signature, it is possible to parallel many touch memories yet still access them individually. Four of the five types have additional ten year retention RAM up to 4Kbit and one even has a built in RTC - a Dallas forte.

A development kit exists for reading and writing Touch Memory via a PC but as you see from the circuit, an interface for a com port on a PC is a very simple affair. Software is a little more complex however



Above. A few diodes convert the single-wire communication link of a Touch Memory into RS232 compatible with a PC's COM port. What is more, the circuit supports interrupts so the host's foreground task is only interrupted when a Touch Memory makes contact with the probe.

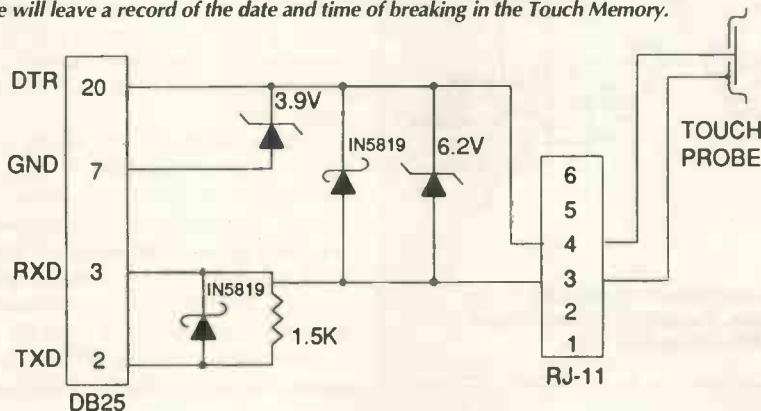
Left. A sort of intelligent bar code, the Touch Memory is stimulated by a 5V signal from the host and responds by switching the input resistance from 50 to 500k.

since the data is not level determined, as it is in RS232, but rather time interval dependent. Logic one is a 15ms low while logic zero is 60ms low level. As a result, the

serial port must support a data transmission rate of 115,200bit/s in order to form the single-wire time slots correctly. Details of how to formulate the data are presented in the book.

Despite its apparent simplicity, the interface has three functions and supports interrupts. It combines RxD and TxD to produce a single-wire signal and it clamps the RS232 voltages to levels compatible with the Touch Memory, zero and 6V. Since the polarity of the signal on the combined RxD and TxD lines is inverted, a power supply is created with diodes and connected to Data while the inverted single-wire signal is connected to ground.

Using a Touch Memory with built-in RTC and a similarly sized lithium cell such as the CR1632, it is possible to make an easy-to-use security device. Breaking the loop in this example will leave a record of the date and time of breaking in the Touch Memory.



Dallas Semiconductor, Unit 26, West Midlands Freeport, Birmingham B26 3QD. Telephone 021 782 2959.

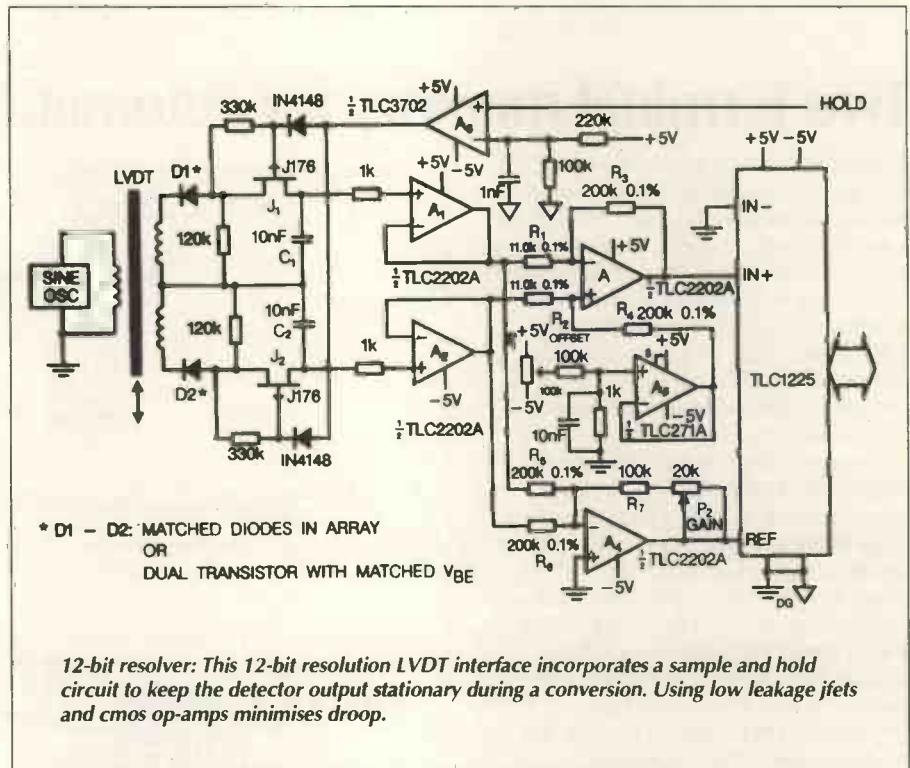
# Signal conditioning for instrumentation

These three circuits are representative of examples used to illustrate advances in op-amp technology in Texas Instruments *Linear Design Seminar Slide Book*. One is an LVDT resolver with 12-bit resolution, one detects charge from a piezo sensor and one amplifies output from a thermocouple with low noise.

**12-bit LVDT resolver.** Besides being accurate, the digital-output resolver for linear variable displacement transformers illustrated operates conveniently from a  $\pm 5V$  supply. Benefits from using the 2022 op-amp are particularly relevant where IC1,2 are concerned. Low input bias current of 100pA maximum regardless of temperature prevents discharging of hold capacitors C1,2. Common mode input and output ranges of the 2022 are high. They even allow common mode input swing to the negative rail. Input offset voltage is low enough to allow trimming for 12bit accuracy. Finally, high common-mode voltage is present on the amplifier inputs so good common-mode rejection prevents excessive offset and offset drift.

**Accelerometer.** In piezo transducer interfaces, such as the accelerometer shown, dynamic range is usually limited by op-amp noise. Designed in advanced *LinCMOS* technology, the TLC2201 and 2202 are claimed to challenge the input noise of the best jfet input op-amps while being capable of operating from low supply voltages.

Voltage-mode operation requires that the op-amp is physically very close to the sensor since parasitic load capacitance caused by cabling will alter its sensitivity. Variations in capacitance due to cable movement also modulate the signal. For these reasons,



**12-bit resolver:** This 12-bit resolution LVDT interface incorporates a sample and hold circuit to keep the detector output stationary during a conversion. Using low leakage jfets and cmos op-amps minimises droop.

charge mode operation is widely used, primarily because the influence of any sensor shunt capacitance is eliminated. Consequently, cable length affects only system bandwidth.

Due to low op-amp noise and rail-to-rail output swing, the circuit provides a wide dynamic range. Noise bandwidth is limited by the bandpass filter. Using an accelerometer with  $1\text{pC/ms}^{-2}$ , maximum

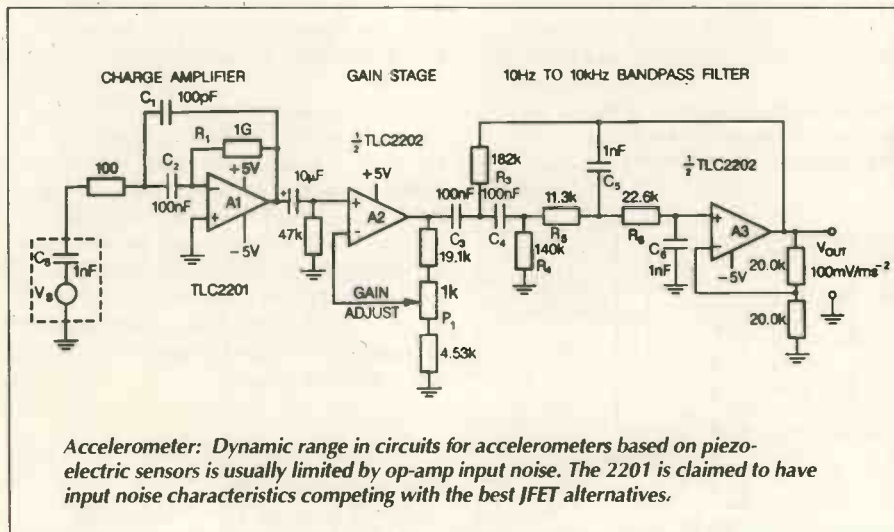
full-scale rms acceleration of  $35\text{ms}^{-2}$ , or around 36g, can be measured. Minimum reading is limited by the charge amplifier's noise. Assuming a typical system with a 5dB minimum s-to-n ratio vibration levels down to  $1.7\text{mms}^{-2}$ , corresponding to 0.17mg, are theoretically measurable.

**Precision thermocouple amplifier.** For a typical S-type thermocouple, average output voltage between 0 to  $1500^\circ\text{C}$  varies by only  $10.38\text{mV}/^\circ\text{C}$ . Although linearity is poor, temperature and voltage relationships are predictable and repeatable so digital post processing can be used to enhance linearisation.

Because of the small slowly varying signals involved, a chopper stabilised op-amp is a good choice since it exhibits high open-loop gain combined with low offset and low drift. Drift of the TLC2652A is at worst  $-30\text{nV}/^\circ\text{C}$ .

In the cold-junction compensation section of the circuit, drift of  $2\text{mV}/^\circ\text{C}$  from a low-cost diode is divided down resistively to  $6\text{mV}/^\circ\text{C}$  to compensate for changes in reference junction temperature. Output is 4.5V full scale. Ideally, minimum output would be  $0^\circ\text{C}$  but in practice its about  $25^\circ\text{C}$  since the amplifier cannot reach 0V.

These three circuits are all from the book's signal conditioning section. Further sections

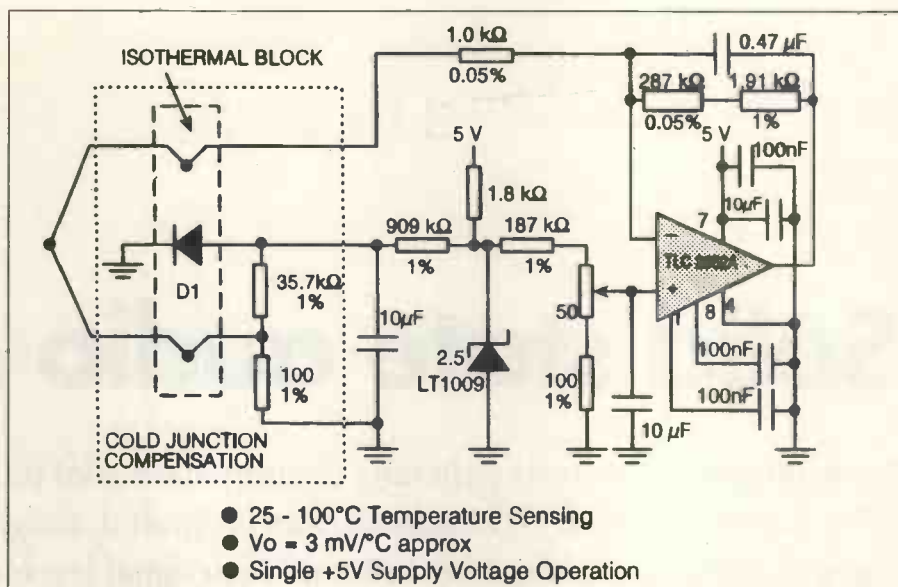


**Accelerometer:** Dynamic range in circuits for accelerometers based on piezo-electric sensors is usually limited by op-amp input noise. The 2201 is claimed to have input noise characteristics competing with the best JFET alternatives.

cover data conversion, sensors, data transmission, opto, lighting and telecomms protection circuits.

Texas Instruments, Manton Lane, Bedford, MK41 7PA. Telephone 0234 270111.

**Thermocouple amplifier:** Standard S-type thermocouples change by just over 10mV/°C so demands on the amplifier are high all round. To get full benefit from the 2652's chopper, with its offset voltage drift of -30nV/°C maximum, be careful with dissimilar metal junctions - including leads soldered to PCBs which can cause several microvolts per degree Celsius.



- 25 - 100°C Temperature Sensing
- Vo = 3 mV/°C approx
- Single +5V Supply Voltage Operation

## Adjustable bandpass filter with constant bandwidth

Switched-capacitor bandpass filters allow centre frequency to be varied simply by altering clocking frequency. To increase bandwidth while lowering noise and distortion however, high performance bandpass filters often have continuous-time filter circuits comprising fixed resistors, capacitors, op-amps and filter ICs. Because the poles and Qs are set by fixed resistors, it is almost impossible to provide centre-frequency tuning.

Adding multiplying D-to-A converters provides digital tuning capability for switched capacitor based continuous-time filters, as this design example for 5 to 20kHz shows. It is part of Maxim's ninth *Engineering Journal* and is accompanied by in-depth discussions of circuits for portable computer power management, fast charging for NiCd cells, power monitoring, constant-current loading and a battery back-up for pseudo-static rams.

Bandwidth of the fourth-order filter circuit shown is fixed at 500Hz. Centre frequency of the filter is proportional to the normalised digital code applied in parallel to the D-to-A converters. Code FF16 for example centres both second order filter sections at 20kHz with Qs of 25.8, resulting in a

net cascaded Q of 40 and a bandwidth of 500Hz. Lower codes attenuate the feedback signal between low-pass output and the input of that section, reducing centre frequency and Q across the range 5kHz to 20kHz. Pass band remains constant at 500Hz.

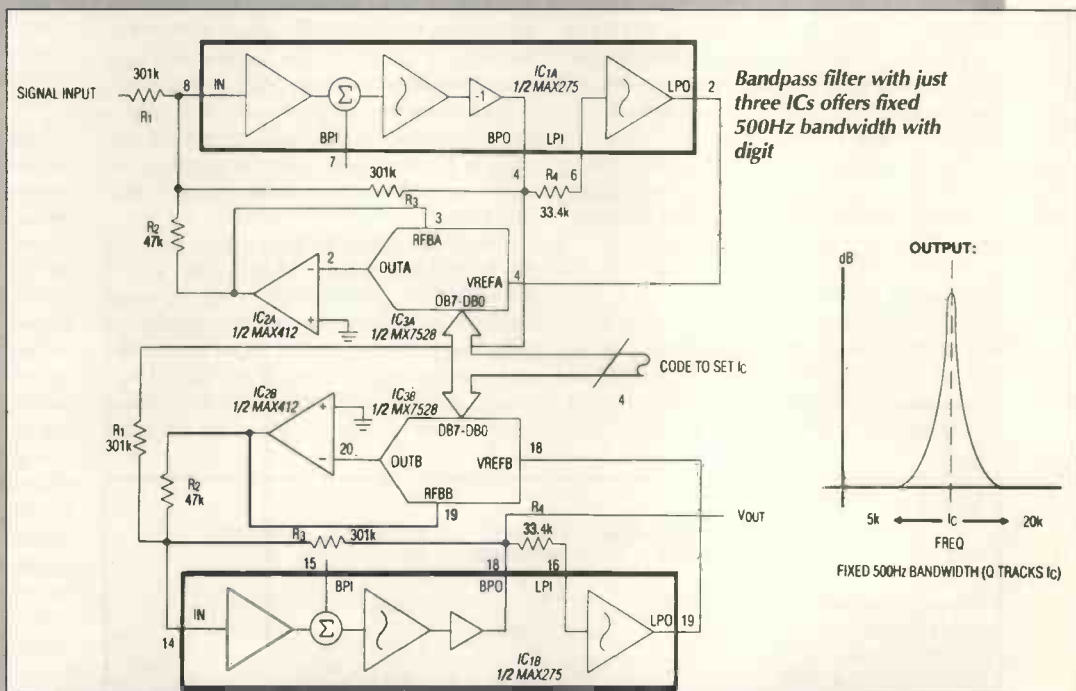
To provide feedback for determining the filter's pole frequency and Q, a non-tunable circuit would have the bottom of its R<sub>2</sub> connected to low-pass

output LPO. In this circuit, a D-to-A converter attenuates each signal before it gets to R<sub>2</sub>, providing software control of frequency and Q. Because the output amplifier associated with each converter inverts the low-pass signal, R<sub>2</sub> must connect to IN rather than BPI to maintain the correct signal polarity.

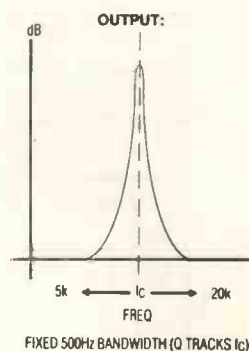
Other feedback signals within the filter can be altered using multiplying D-to-A converters to provide digital control of Q

alone, via R<sub>3</sub>, and gain, set by R<sub>1</sub>, in addition to frequency. The technique can also be applied to adjustable low-pass anti-aliasing filters that accommodate A-to-D converters with multiple sampling rates.

Maxim Integrated Products, 21C Horseshoe Park, Pangbourne, Reading, Berkshire RG8 7JW. Telephone 0734 845255. ■



Bandpass filter with just three ICs offers fixed 500Hz bandwidth with digit



# Solid state audio switching

*Semiconductors in audio switching circuitry have a lot to offer, but are not perfect. Headroom can be limited, strays can give rise to switching transients and high signal levels can cause distortion. Mike Meechan describes methods of avoiding their drawbacks in professional audio applications.*

Analogue switching probably first posed a problem in the early telephone exchanges, where huge multi-bank, multi-way rotary relays – uniselectors – were used to route calls. Since then, designers of audio equipment have battled with the problem of switching particular inputs to particular outputs at a given time.

Traditionally, switching has been mechanical, sometimes involving extraordinary geared switching mechanisms, actuated by cable or extended control rods from a front-panel knob; cam-operated slide switches find uses in cassette or open reel tape machines. All have been used in an effort to minimise the amount of interboard wiring with a view to reducing hum, noise, RF injection, stray capacitance, finite resistance and crosstalk.

A further solution – the solid-state switch – is now common. In this article it is my object to describe both the advantages and the problems of this approach to switching.

## Pro-audio applications

In studio desks, real automation became possible in the middle 1970s. Substituting solid-state or relay switching for the mechanical types meant that desk set-ups and channel configurations could quickly be stored and

recalled from a master control, perhaps from a computer or other storage medium. Figure 1 shows the main elements of a typical multi-track desk, in which the main causes for concern are distortion, headroom, noise and cost. Distortion and headroom come top of the author's list; a comparison of the headroom and performance expectations of a quality domestic amplifier against those of a studio-quality switch is worthwhile pursuing as an example.

Signal levels of  $-70\text{dBu}$  are often handled in a mixing desk, in contrast to those in domestic equipment where  $-48\text{dBu}$  from a magnetic cartridge is the minimum, so that switching noise must be of the same order of magnitude as noise from the source if system S:R ratio is not to be compromised. Any switching element in the audio chain must be transparent in use<sup>1</sup>, since damage done at the source is irretrievable.

Conversely, transients from a drum kit reach up to  $+24\text{dBu}$  (about  $+8\text{dBu}$  from a CD domestically), driving following op-amps almost to saturation and greatly exacerbating switching problems. Before signal reaches the mixer, audio levels are, to all intents and purposes, uncontrolled, and any intervening switch must be able to cope with the same

maximum signal level as the rest of the channel strip electronics.

## Switching devices

A brief wish list for a pro-audio active switch is shown below, and corresponds closely to that for its mechanical counterpart:

minimum feedthrough in off position (infinite  $R_{\text{OFF}}$ ); minimum insertion loss in on position (zero  $R_{\text{ON}}$ ); minimum crosstalk;

transparent in use (no noise or distortion added);

zero offset voltage;

zero power dissipation;

analogue signals are well isolated from the switch-control signals;

zero cost.

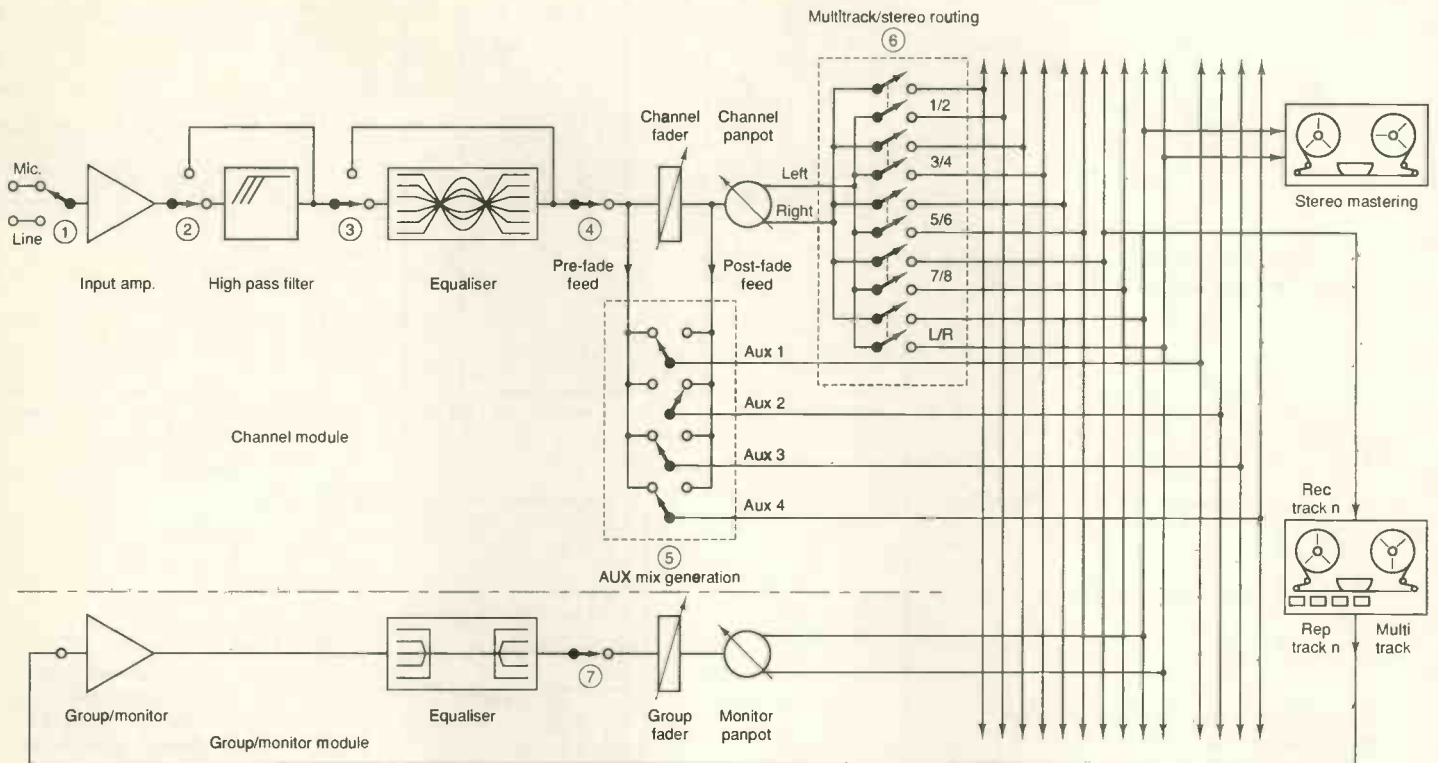
Table 1 shows a comparison of the various competing devices used for switching<sup>2</sup>. Mechanical switches come close to the ideal, since the  $R_{\text{ON}}:R_{\text{OFF}}$  ratio is highest and the analogue signal is completely isolated from the switch control function. Despite this, its mechanical nature makes it unsuitable, since there are contacts to bounce or pit, a physical mass must be moved to actuate the switch, and its susceptibility to vibration. Finally, it cannot change states very quickly, and consumes more power than a solid-state switch.

Fets, bipolar transistors, diodes, and triacs or thyristors can all be used as switches, but the last two are for power applications and diodes need DC bias – feasible for RF, but out of the question for quality audio; bipolar transistors are unidirectional and have a DC offset.

This leaves the field-effect transistor as the only viable discrete semiconductor option. Like the bipolar transistor, on and off impedance ratio is high, although the fet's is

TABLE 1

	mechanical switch	bipolar transistor	n-channel fet	pmos fet
On resistance ( $R_{\text{on}}$ )	$10^{-12}\Omega$	$10\Omega$	$30\Omega$	$100\Omega$
Off leakage	$10\text{pA}$	$100\text{pA}$	$100\text{pA}$	$100\text{pA}$
Offset voltage	0	$10\text{mV}$	0	0
Max. switching rate	$1\text{kHz}$	$100\text{kHz}$	$10\text{MHz}$	$50\text{MHz}$

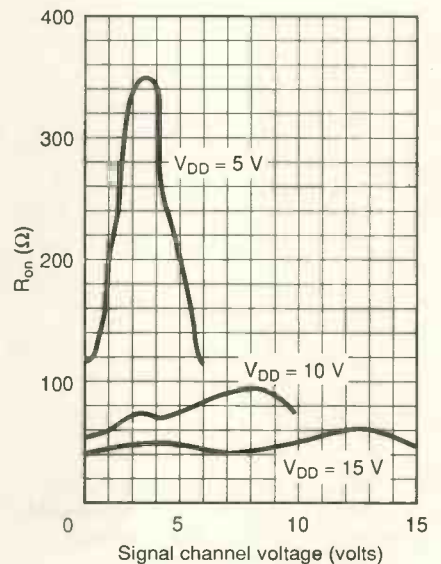


Key to switches and likelihood for use of solid state switches/inclusion in automated system

- ① Input source (mic/line) source selection<sub>2</sub>
  - ② High pass filter in/out<sub>3</sub>
  - ③ Eq. in/out<sub>2</sub>
  - ④ Channel on/mute<sub>1</sub>
  - ⑤ Aux mix pre/post fade selection and muting<sub>1</sub>
  - ⑥ Multitrack/stereo routing matrix<sub>2</sub>
  - ⑦ Group/monitor on<sub>1</sub>
- 1 - Very likely  
 2 - Likely only on expensive, large scale automated desk  
 3 - Relatively unlikely

**Fig. 1. The main elements of a typical multitrack desk. Not all the switch points are susceptible to solid state routing.**

**Fig. 2. On resistance of one channel of a 4066 varies with voltage, causing distortion known as Ron modulation distortion. There is no straightforward way to maintain constant on resistance in simple circuit arrangements.**



higher by a huge order of magnitude. Further, the channel of a fet contains no p-n junctions and consequently no offset, so that symmetrical switching is possible. There are also no base-bias current errors,  $R_{ON}$  is low, and power consumption is minuscule. Varying the gate voltage has the effect of varying the resistance of the drain/source channel and means that the device can be used as a voltage-controlled resistor or attenuator. The gate is very high impedance and so almost completely isolated from the signal path. Further, the admittance-to-input capacitance is the highest of any contemporary device.

Although some n-channel junction fets come close to being ideal switches, they are not perfect because the awkward range of the control voltage makes interfacing with the popular logic families a difficult and sometimes expensive task. A large control voltage swing is necessary because it also determines the voltage range through which the output signal is able to swing without clipping. This signal-handling capability ultimately determines operating headroom through the switch.

A further problem<sup>3</sup>, illustrated in Fig. 2, is the way in which the "on" resistance of the fet is altered by the signal level across it, which cannot be readily compensated for. This variable error term is known as  $R_{ON}$  modulation

and in real terms means some amplitude modulation of the input waveform as it passes through the fet.

The mosfet presents itself as a serious contender for active pro-audio switching purposes. Despite differences in chemical structure and physical construction, mosfet characteristics are basically the same as a fet's, although, the mosfet gate is of even higher impedance than the basic fet and so better isolated. Drive-voltage range is rather easier to handle than that of the fet.

**Integrated devices**

In IC analogue switches, mosfets are connected back-to-back to provide an almost ideal bidirectional analogue transmission gate<sup>4</sup>; 4000 series cmos analogue switches, the 4016 and its more recent successor the 4066, are the best known types.

Early versions of cmos analogue switches presented raw mos elements at the input and output ports; the high impedance "off" state inherent in any cmos design meant that destruction of the switching elements was possible if static was allowed to infiltrate the circuitry. Moreover, if the input signal magnitude even momentarily exceeded the supply voltage of the device, the mos junctions became reverse-biased. This was the cause of latch-ups

and could, in some instances, lead to the premature expiry of the IC. Subsequent generations of the chip provided some protection in the form of diodes on the gates.

This remedied some of the more disastrous faults inherent in the earlier generation ICs, but input signals in excess of the chip supply rails are still able to cause momentary break-over of the switching elements, although the symptom is no longer as terminal as it once was. The 4016 and 4066 are 16-pin dil IC packages containing four identical cmos transmission gates. The maximum supply voltage between  $V_{DD}$  and  $V_{SS}$  is 18V, corresponding to a maximum signal level through the switch of +18dB referred to 0.775V RMS. Such a low absolute voltage swing seriously restricts headroom.

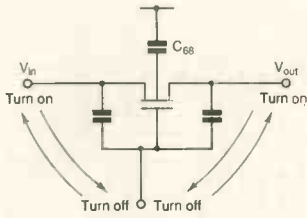


Fig. 3. Equivalent circuit of a mosfet, showing on and off resistances and parasitic capacitances.

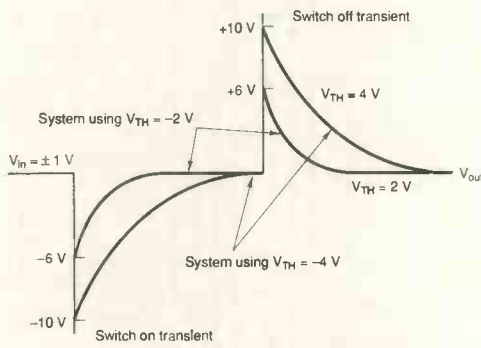


Fig. 4. Parasitic capacitances produce the switching transients shown for threshold voltages of 2V and 4V, with an input voltage of  $\pm 1$ V.

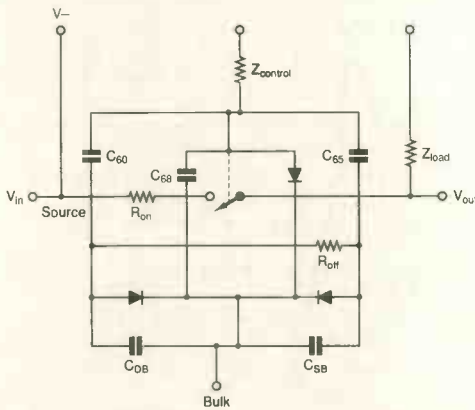


Fig. 5. All the capacitances associated with a mosfet switch cause problems. Putting several devices within a single package inevitably creates cross talk between devices.

The more modern derivatives of the B series, the HC/HCT types, although faster and with smaller  $R_{ON}$ , use much lower supply rails of the order of 10V. Distortion, although quoted as 0.02% for a 1V 1kHz input signal, becomes a woeful 0.4% in rudimentary switching arrangements, such as those shown.

Since integrated fet switches are usually structured as series elements, additional switches in the signal pathway worsen both the amount and variation of  $R_{ON}$  in conducting mode. Also, variations in the control voltage vary the error ratio  $V_{OUT}:V_{IN}$  because  $R_{ON}$  is a function of the effective switching threshold which alters with  $V_{CONTROL}$ . In simple circuit arrangements, there is no straightforward way of maintaining a constant  $R_{ON}$ .

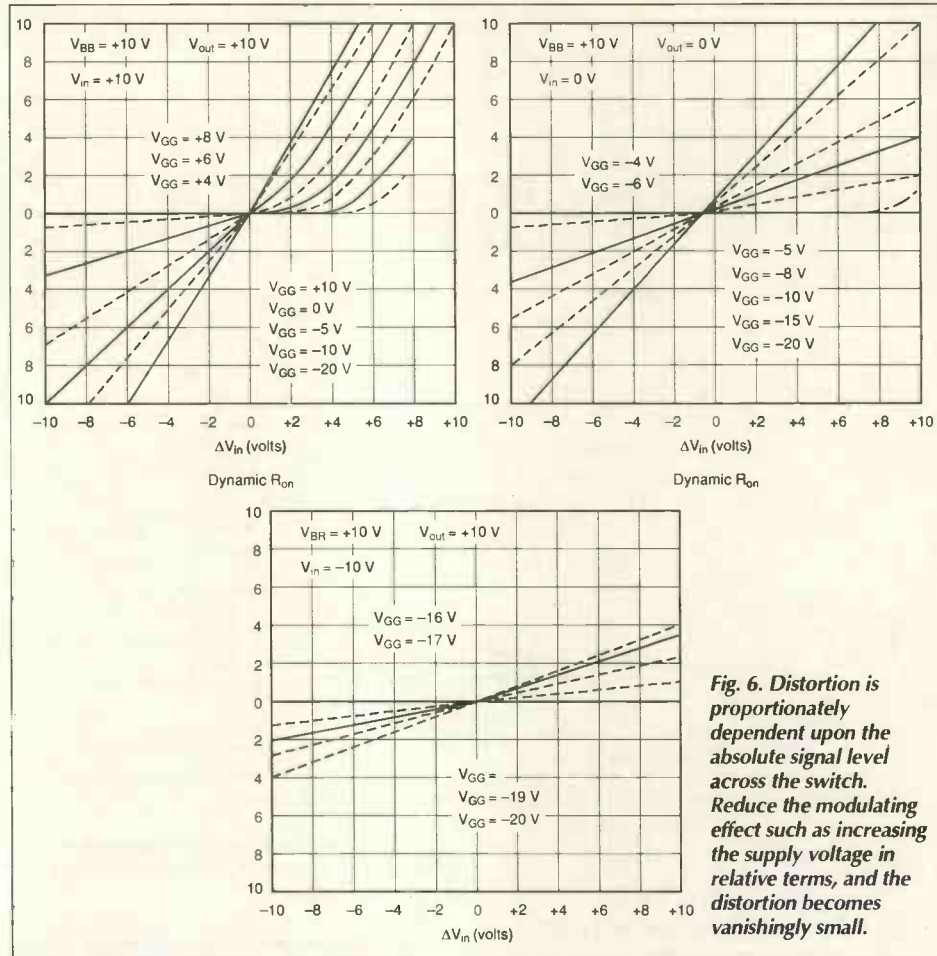


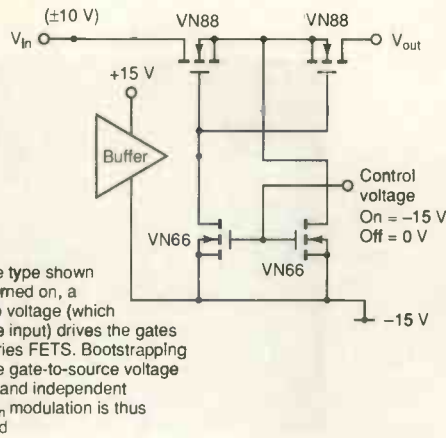
Fig. 6. Distortion is proportionately dependent upon the absolute signal level across the switch. Reduce the modulating effect such as increasing the supply voltage in relative terms, and the distortion becomes vanishingly small.

Various methods of alleviating this problem, such as increasing all surrounding impedances so that variation is reduced, are often used. This produces a voltage divider effect, and so it has been customary to make the load,  $R_L$ , much larger than the combination of  $R_{ON}$  and  $R_S$ . Also, the source impedance must be of the same order of magnitude as  $R_{ON}$  so that when turned off, leakage currents of the fets return to a low-impedance channel signal source. Another problem inherent in switches of this type is the way in which impedance (and hence isolation) diminishes with increasing frequency.

### Transients

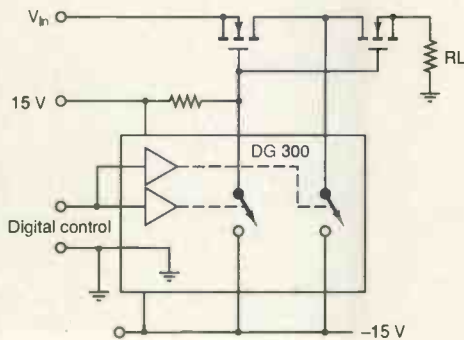
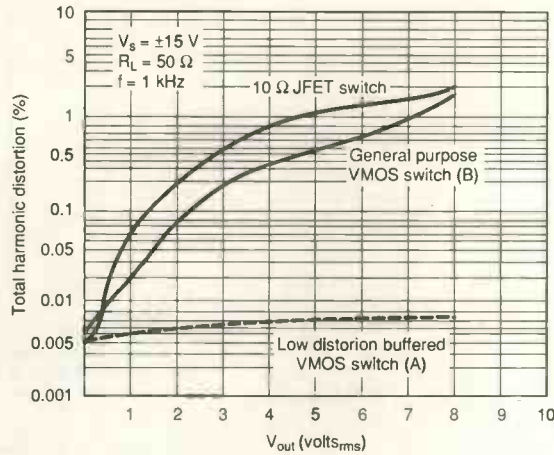
Fets, because of the capacitive coupling<sup>5</sup> shown in Fig. 3, can introduce switching transients of the type seen in Fig. 4, for threshold voltages of 2V and 4V and a control voltage of  $\pm 1$ V, to the signal being controlled. In all mosfets, transmission of an on or off command is followed by a delay proportional to the magnitude and rate of change of the gate control voltage. At turn-on, the delay is lengthened by the RC time constant of the gate bulk capacitance and the impedance in the control circuit. Impedances in the signal path cause a similar effect at switch-off. As  $V_{GS}$  goes negative, energy is pulled from the source and load impedances through the gate-source and gate-drain capacitances. Conversely, when  $V_{GS}$  goes positive, energy is pushed out through the same paths.

The situation is most serious if the signal is sourced from a high impedance and the switch has a low on impedance. A related bad habit of the 4066 is to momentarily short the input to ground during changes of state. Charge transferred to the summing node through the gate-channel capacitance at the transitions of the gate is  $Q = C_{gc} (V_{OUT(finish)} - V_{OUT(start)})^2$ , where  $C_{gc}$  is the gate channel capacitance, typically in the region of 5pF. Note that the amount of charge transferred depends only upon the total voltage change at the gate, not on its rise time. Slowing down the gate signal gives rise to a smaller amplitude glitch of longer duration, the area under the graph being the same in both cases. Since the gate-channel capacitance is distributed over the length of the channel, some of the charge is coupled back to the switch input. Because of this, the size of the glitch depends on the signal source impedance and so is smallest when driven by a voltage source with an ideal zero output impedance. Also, reducing load impedance reduces the size of the glitch at the expense of loading the source and introducing error and non-linearity due to the finite nature of  $R_{ON}$ . Switch IC designers are able to minimise transients at the summing node by driving adjacent channels with coincident "on" and "off" control signals. With this arrangement, theoretically, negative-going transients from the channels turning on will partially cancel out positive-going transients from those channels which are turning off.



When the type shown right is turned on, a bootstrap voltage (which tracks the input) drives the gates of the series FETs. Bootstrapping keeps the gate-to-source voltage constant and independent of  $V_{in}$ .  $R_{on}$  modulation is thus eliminated

(a) Low distortion type



(b) General purpose type

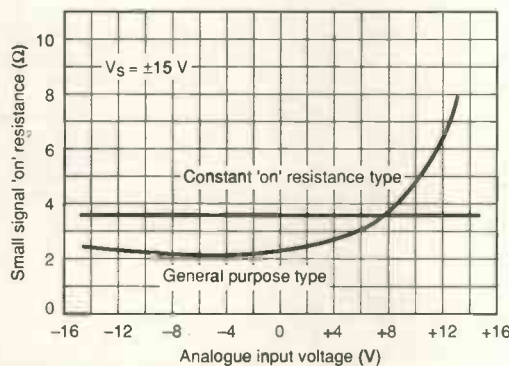


Fig. 7. Bootstrapping signal voltage onto the control voltage reduces distortion in a fet switch. These circuit configurations illustrate two ways of achieving this<sup>6</sup>.

Nevertheless, the glitch problem, or "control signal feedthrough", always remains because the devices are switches, either on or off with no provision for the control of the in-between states. Using a low-impedance gate driver can help, since transients should be inclined to sink into the driver rather than into the output, while the effect would be improved by using a high source impedance, at the expense of larger transients in any channel switched on. In essence, the gate voltage cannot be slowed down and the transition from one logic level to the other must always involve a step with theoretically infinite rise time. Even expensive, video-type multiplexers or switches suffer to some extent from the problem.

With discrete fet switch designs, it can be minimised by using carefully synchronised ramp voltages/appropriate time constants to control the devices. In this way, and as already stated, the upshot is a low amplitude glitch of relatively long duration. If the glitch amplitude is below or approaching the console noise floor, it matters little how long it lasts. The time aspect is, of course, relative and equates to perhaps hundreds of microseconds of low level noise as opposed to tens of microseconds of high level glitch.

All of the above is much worse when the switches are used to route analogue rather than digital signals. AC signals may also vary the effective values of  $V_{SG}$  (as well as  $R_{ON}$  and  $R_{OFF}$ ) which spuriously charges any fet capacitances. These in turn cause voltage offsets at the summing node and, since the channel is

supposed to be off, the condition is known as AC feedthrough or channel feedthrough noise. The main cause is charge transfer through the gate-source and gate-drain capacitances of any channels switched off.

All capacitances inherent and present in mosfet semiconductor architecture cause problems. Putting several analogue switches in one IC causes crosstalk since there is cross-channel capacitance, an effect which increases with frequency and with signal impedance in the channel to which the signal is coupled. Common-sense use of the gates within the IC, with no hostile signals present on adjacent pins of the package and the adoption of RF design rules in the layout of PCBs reduces the crosstalk problem. Using separate packages makes crosstalk a purely mechanical consideration.

### Distortion

Improving the distortion performance requires similar techniques. Since distortion caused by the modulation effect is dependent on the absolute signal voltage across the switch, the obvious solution is to arrange that the signal level is kept as small as possible, Fig. 6.

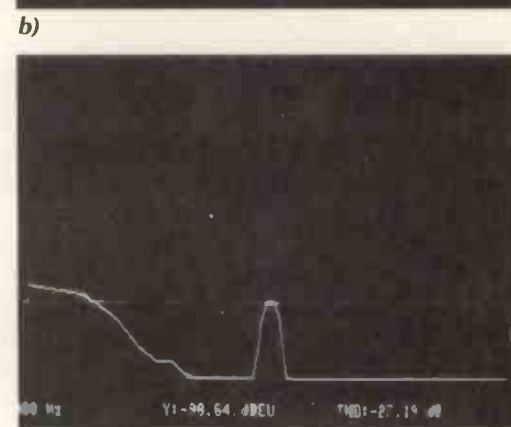
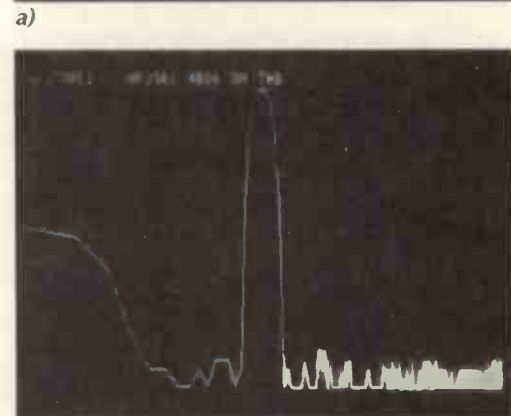
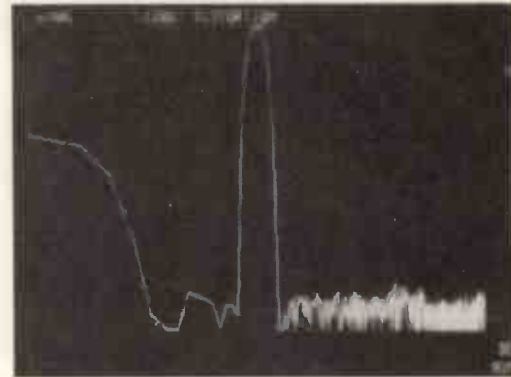
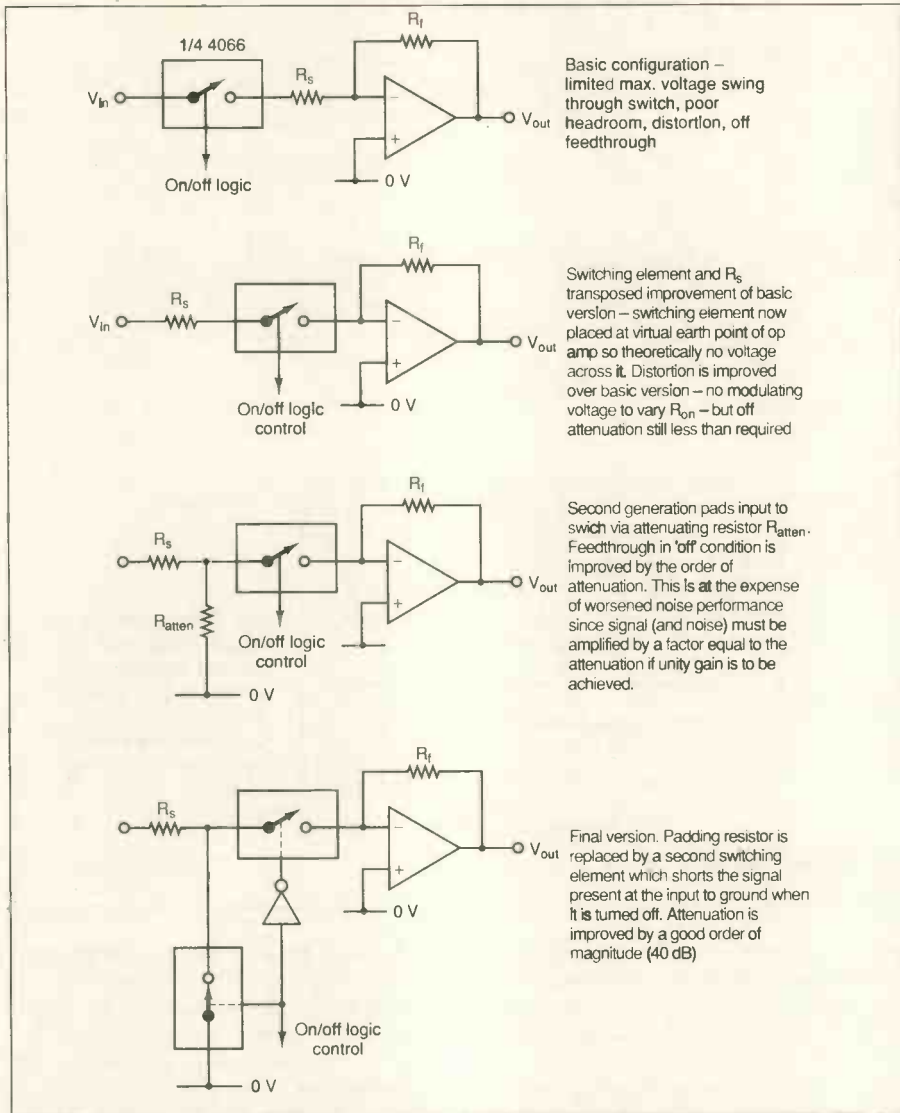
Figure 7 shows a method of maintaining constant channel resistance in the on state through the use of a bootstrapping arrangement. Performance variations between this and the attached graph are also shown.

Placing the mosfet switching element immediately adjacent to the virtual earth point of an op-amp, as in the circuit evolution shown in

Fig. 8, means that the switch is virtually earthed and hence no voltage (theoretically) is developed across it; distortion is consequently reduced by an order of magnitude. It also means that signals up to the maximum level available before clipping in the preceding or following circuitry can be handled by the switch configuration without the previous breakover problem. The mosfet gate is now operating in current mode with no appreciable voltage across the in and out pins.

For less demanding applications, the attenuation ratio – of the order of 55-60dB with the correct choice of device and resistor values – is satisfactory. Better storage/retrieval media such as DAT and CD call for much higher attenuations of unwanted signals within the desk; again, remember the earlier statement about irretrievable damage being perpetrated at the point of origin, the console. Attenuation can be increased by an order of magnitude by arranging that another gate, prior to the original, closes and shorts the input signal to ground when the original gate opens. This arrangement, shown at (c), is an active version of the classic L-type attenuator. With this method, there is theoretically no signal present at the input to the series gate, since it is now grounded. This series/shunt arrangement maximises headroom, isolation and distortion limitations of the configuration.

Feedthrough in the off condition can also be affected by the direction of signal through the switch. Although ostensibly bidirectional in nature, devices such as the HC/HCT 4066



**Fig. 9.** Relative distortion traces with the switch in a variety of positions. See text.

have a definite, preferred signal direction and, for best performance, the out/in pins should always be biased at the higher DC potential when the gate is in the off state.

The choice of resistor values around the switch/op-amp combination is a compromise between good noise performance and good distortion performance. Low resistor values within the driving capabilities of the op-amp mean lower thermal noise but greater distortion because of the smaller relative difference in the magnitudes of  $R_S$ , and  $R_{ON}$  of the switch. Higher values create more noise but less distortion.

Although many audio engineers might scoff at the very suggestion of including a 4066-type package in a high-quality audio signal path, careful choice of op-amp and resistor values, and the series/shunt/virtual earth configuration yield a switch package which is surprisingly transparent. Figure 9(a) shows the distortion trace taken with the switch out of circuit; at (b), the switch is in circuit. The measurement was made with a Hewlett Packard 3561A Dynamic Signal Analyser using a BBC ME2/5 tone source. Both are operating at the limits of their resolution, but nevertheless, the traces show that a cheap IC,

**Fig. 8.** Reducing the voltage across a switch reduces distortion. One way of achieving this is to configure the switching element within a virtual earth point. These circuits illustrate the evolution. However, a virtual earth point is very susceptible to transients coupled from the switch control line.

a couple of resistors and an op-amp (useful, anyway, as a buffer after any switch) can be made to operate with surprising fidelity, with both noise and distortion figures typically of the same order as the op-amp to which they are connected.

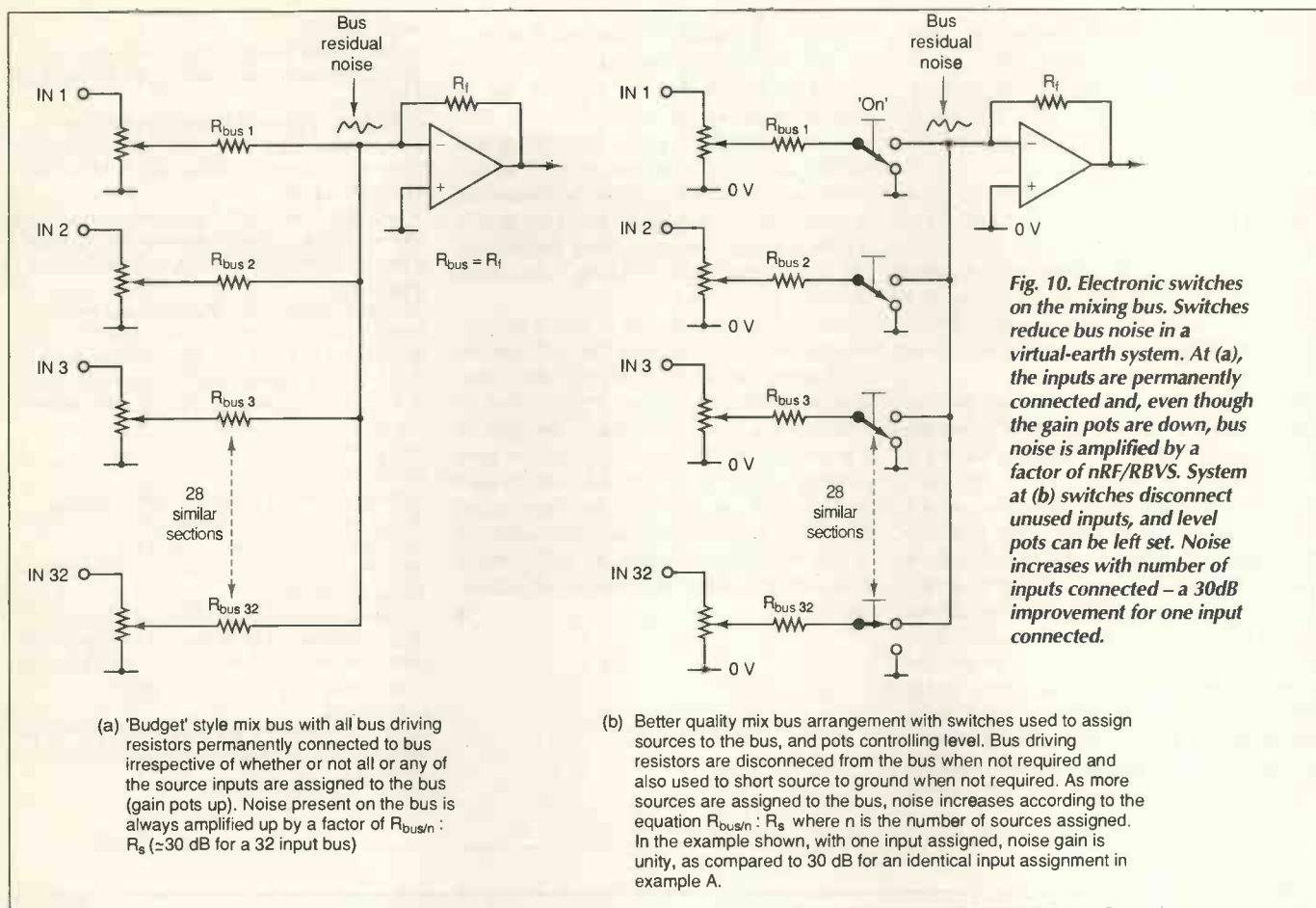
Figure 9(c) shows the op-amp output with the switch in circuit but turned off; breakthrough of tone is commendably low for such a simple topology. This parameter was also tested at a higher audio frequency where, as already mentioned, crosstalk and isolation performance begin to deteriorate.

This virtual-earth arrangement lends itself readily to the bus system of switching shown in Fig. 10, with one virtual-earth amplifier mix amp located in the master section of the mixer, and all analogue switches accessing the bus remotely and directly from the channel strip, inputting signals as and when required.

Analogue switch packages intended for video improve on the basic series/shunt arrangement by including a further series gate before the shunt one<sup>7</sup>. This configuration is the "tee" arrangement and improves isolation in the off condition by a further order of magnitude. This is of great importance at the frequencies involved for video since deterioration here rapidly escalates.

Complementary switching must carefully be arranged; should both elements be on simultaneously, the virtual earth input of the op-amp is tied to deck, causing a burst of high gain from the amplifier. Any noise or DC present at this point is subject to high amplification and transferred across to the output as a burst of noise or a splat. For a pro-audio application, it is obvious that crosstalk and large amplitude glitches on the output are totally undesirable.



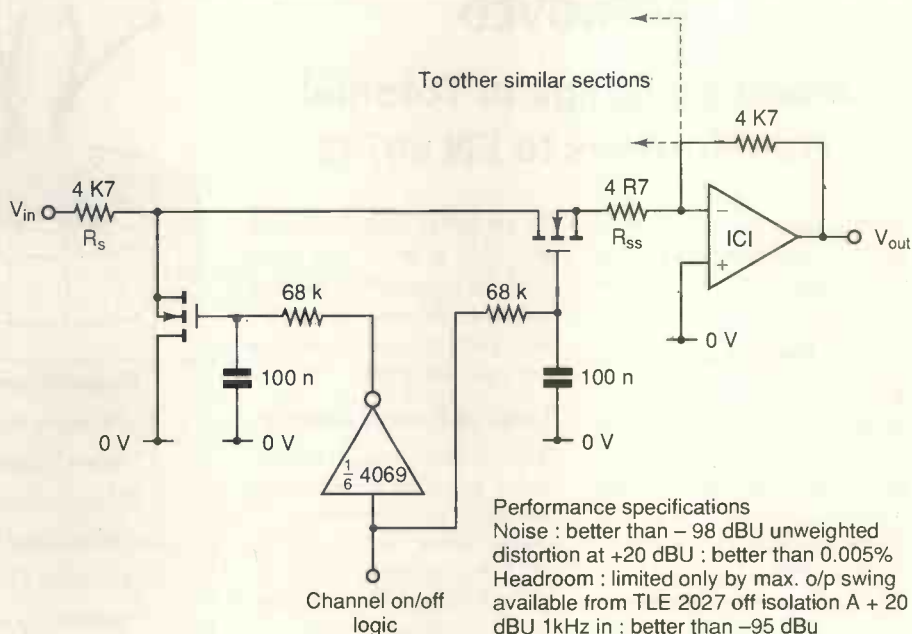


**Fig. 10. Electronic switches on the mixing bus. Switches reduce bus noise in a virtual-earth system. At (a), the inputs are permanently connected and, even though the gain pots are down, bus noise is amplified by a factor of  $nR_f/R_{BUS}$ . System at (b) switches disconnect unused inputs, and level pots can be left set. Noise increases with number of inputs connected – a 30dB improvement for one input connected.**

**Discrete devices**

Within the constraints of noise and distortion performance which they offer, such packages can be used quite successfully for static switching of sources. However, dynamic performance dictates suggest that all but the most expensive integrated switch packages must be abandoned. Even these suffer since, being logic-controlled, the signal is either on or off.

Better to abandon these ICs completely and, at the expense of a slightly larger component count, create one from discrete fets connected in the shunt/series arrangement of Fig. 11. These can be controlled by using a ramp rather than a step waveform. In effect, a complementary pair of voltage-controlled attenuators is created. The control waveforms have the effect of steadily increasing the drain/source resistance of one fet to a very high value while reducing the other's to near-zero, thus causing a fast mute of the signal, with any glitches on the output signal of only very small amplitude. This switching circuit arrangement provides excellent isolation, low noise and low distortion. The only real complaint is in the number of components required to implement the ramp although these are fairly inexpensive. Time constant values can be optimised for a given application – short enough that time precision (to an accuracy of one television frame in some cases) can be achieved whilst avoiding very fast mutes which can cause "poppiness". It goes without saying that for ultimate avoidance of control



**Fig. 11. Switch using discrete fets and ramp waveforms on gates to minimise switching glitches by switching fets relatively slowly. Distortion and headroom also improved.**

signal feedthrough, careful attention must be paid to supply decoupling, the separation of analogue and digital supply lines and grounds, and PCB layout.

**High-quality ICs**

Finally, brief mention should be made of analogue switch packages dedicated to audio switching and intended for pro-audio applications. These are manufactured by semiconductor houses such as PMI, Analogue Devices etc and combine the necessary complementary switches/ramp generators in one IC. The SSM2142, manufactured by PMI, is a good example. Such devices manage some good

specifications (noise, distortion and headroom parameters in line with the rest of the best circuitry of the console, and almost absolute signal isolation in the off condition). Unfortunately, there is a price to pay for this convenience/performance and cost considerations often preclude the use of two or three hundred such devices in a typical mid-range console. Nevertheless, in a good discrete fet design, the cost of the components required quickly escalates, and often the fitting of a completely integrated package works out to be less expensive, as well as freeing space on the often densely packed PCB.

There is a groundswell of opinion, particularly among the subjective fraternity, that any switches, in any audio system, are a bad thing. This is akin, in many ways, to the poor, though often undeserved reputation of op-amps. It is as well to realise that with any recording, unless it's been mastered directly to a digital format – and even with this route, it is open to conjecture – the audio signal has passed through tens and more probably hundreds of such devices, and to all intents and purposes, the inclusion of one more, in the domestic environment, will not harm the signal unduly. It was shown in Ben Duncan's article<sup>8</sup> that as far as distortion is concerned, modern devices such as the AD797 and the

TLE2027 are capable of distortion figures so low as to be virtually unmeasurable. While it cannot be denied that the frivolous use of devices such as op-amps and solid-state switches leaves the designer open to warranted and justifiable criticism, since it wastes both resources and can perhaps be detrimental to overall quality, careful design of the switching element and the surrounding engineering can make transparent switching a cost effective reality.

As a closing thought, it is as well to remember that, no matter how good the performance of an active switch, it will always add – however small – more noise and distortion than its manually-operated mechanical counterpart (or a piece of wire)! VCA's suffer from the same problems. Careful thought and consideration must always be given to the convenience which any switch affords, since the inclusion of any solid-state device in an audio system must always cause some degree of impairment. ■

References

1. Self, Doug. *Inside audio mixers*, pp. 281-286, *Electronics and Wireless World*, April 1991.
2. Wollesen, Donald L., *Analogue-Signal Commutation*, pp. 17-15 to 17-20 (Application Note 33), *National Semiconductor Databook*, Hybrid Products.
3. Mrazek, Dale. *High Speed mos Commutators*, Application Note 28, National Semiconductor Corporation, *Hybrid Product Databook*
4. Linsley Hood, John. *Preamps and inputs (input switching)*, pp. 337-340, *Audio Electronics Reference Book* (edited by Ian R. Sinclair), BSP Professional Books, 1989
5. Horowitz and Hill. *Field Effect Transistors (fet switches)*, pp.140-151 *The Art of Electronics* (2nd edition), Cambridge University Press
6. "Don't trade off analogue switch specs – vmos – a solution to high speed high current low resistance analogue switching. Application Note 77-2, Siliconix Mospower Design Catalogue.
7. Salerno, Ahmed and Nadolshi. *The Use of Video Switches, Multiplexers, Crosspoints and Buffer Amplifiers*. Part 1. Pp. 35-44, *Electronic Engineering*, September 1987. Morgan Grampian.
8. Duncan, Ben. How clean is your audio op-amp? pp. 42-46, *Electronics and Wireless World*, January 1993.

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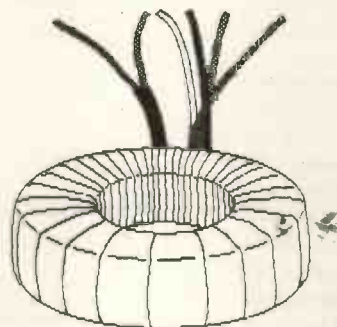
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# CLOSING THE LOOP

**T**wo features form the basis for PLL modulators and demodulators: voltage at the output of a PLL phase detector is proportional to the PLL signal input frequency; and the PLL only processes signal-frequency changes within its bandwidth.

A demodulator PLL tracks input signal frequency changes at the phase detector (PD) input. Change of signal amplitude at the output of the loop filter is the demodulated output.

In a frequency modulator, the modulating signal goes to the voltage-controlled oscillator (VCO) and the PLL is designed so that the input signal band may be beyond the range of the loop bandwidth; the PLL stabilises the carrier frequency. The modulating (baseband) signal, in contrast to that in the frequency demodulator, should not be tracked. Figures 1 and 2 show how the PLL is used as a frequency demodulator and modulator and illustrate the main differences in PLL arrangement. In fact there is little in common between a frequency modulator and demodulator: the frequency demodulator operates at the input signal frequency, whereas the modulator operates at a frequency many times lower than the VCO.

PLL frequency modulator circuitry looks very much like that of a frequency synthesiser, but the frequency demodulator circuitry uses slightly different design ideas. The main difference lies in the PD: in the demodulator it

## *3: phase and frequency modulators and demodulators*

*In his discussion of phase-locked loop theory and application, Dmitry Malinovsky concludes with a description of modulators and demodulators for frequency and phase, and includes some practical circuits.*

operates at high frequency – 10.7MHz IF in an FM broadcast receiver. In a demodulator, the frequency-phase detector (FPD) which eases the design of synthesisers, cannot be used. An FPD consists largely of logic circuitry, which is sensitive to the noise inevitably present in the input signal of frequency demodulators. Here, the signal-to-noise ratio is never as high as in the input signal of an FPD in frequency synthesis. In the absence of the FPD, it is necessary to calculate carefully all the PLL elements to achieve the required capture and lock ranges.

But there is one parameter which has similar requirements in both modulators and demodulators: linearity of the VCO transfer characteristic. With a nonlinear curve, modulation and demodulation are accompanied by non-linearity distortion. Figure 3 shows the char-

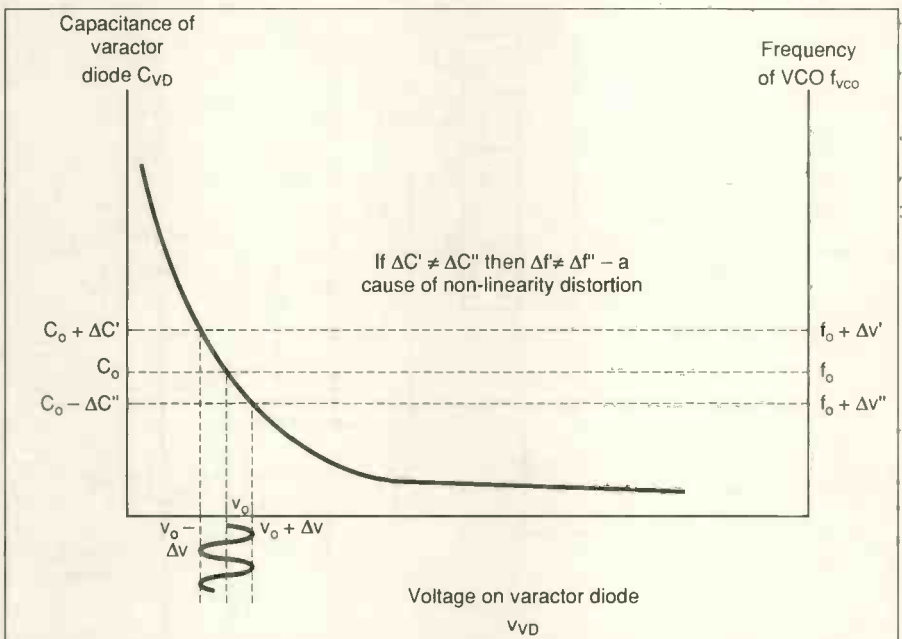
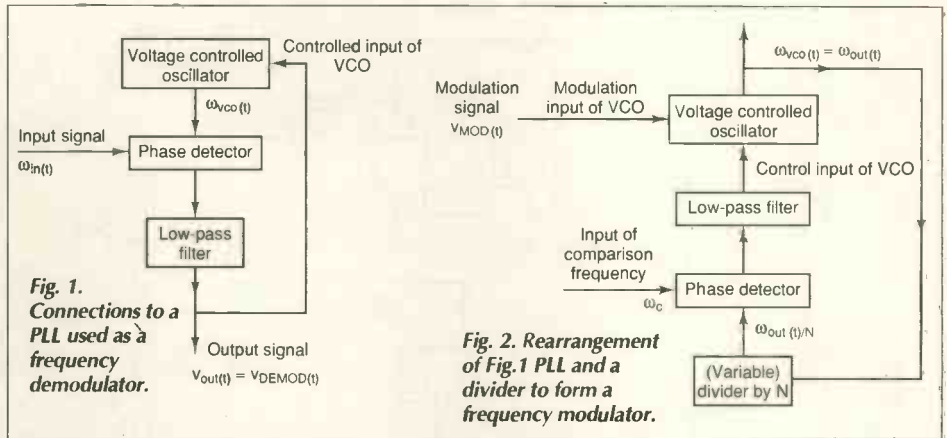
acteristic curve of a varactor diode, in which the bias voltage  $V_o$  determines the working point  $C_o$ . Modulating voltage  $V_{mod}$  changes about the bias voltage, changing varactor diode capacitance and causing frequency modulation of the VCO output; in a frequency demodulator,  $V_{mod}$  is an input frequency function and the process is reversed. When the modulating voltage on the varactor diode is reduced, nonlinearity distortion decreases, as does the frequency deviation. In a VCO,  $V_o$  is selected for least distortion; for large frequency deviation, such as the  $\pm 13\text{MHz}$  in an FM transmitter, carrier frequencies of 300-600MHz are used in the modulator. To give the wide deviation, varactor capacitance is changed by 10-15% when using varactor diodes such as the BB405, resulting in a total video signal distortion between 0.1 and 0.2%.

**IC demodulators**

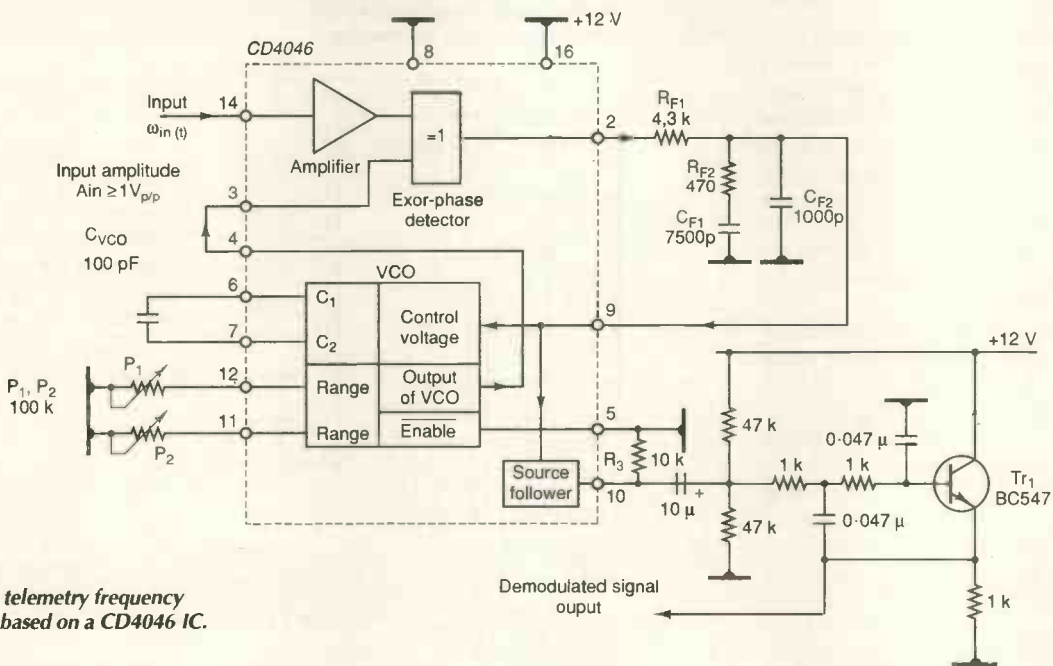
It is sometimes desirable to use digital ICs in demodulators.

Figure 4 is the circuit diagram of frequency demodulator for a 50kHz carrier modulated by speech signal in the range 300Hz-3kHz, which is used in a communication channel combined with the telemetry channel in one of the fire signalling systems of a big plant. Frequency deviation reaches  $\pm 5\text{kHz}$ ; a CD4046 is used as the demodulator, including a VCO, PD, input amplifier and source follower. Only one of the two available PDs is used – an Xor type, which offers high immunity to noise. The control signal comes from the output of the lag-lead loop filter (LF) on the PD output and goes to the VCO input and to the source follower with resistor  $R_3$  as a load. Demodulated signal passes to the low-pass filter in the  $Tr_1$  circuit, where the remaining 50kHz is filtered out.

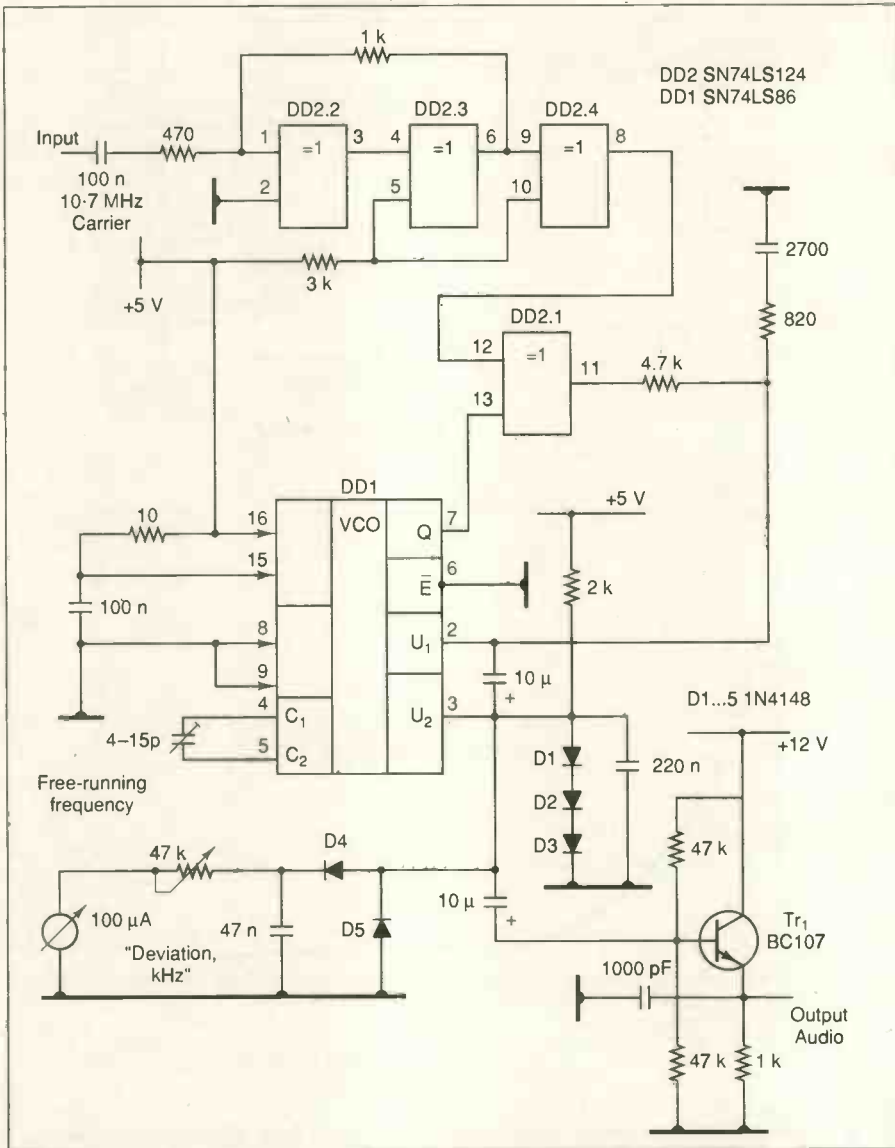
Capacitor  $C_{vco}$  determines the free-running frequency of the PLL and variable resistors  $P_1$



**Fig. 3. Voltage/capacitance transfer characteristic of a varactor diode, showing cause of non-linearity distortion.**



**Fig. 4. 50kHz telemetry frequency demodulator based on a CD4046 IC.**



and  $P_2$  set the maximum and minimum output frequency of the VCO.

Figure 5 shows such a demodulator for a VHF FM broadcasting receiver with a 10.7MHz IF and using LSI TTL ICs. I have used this circuit as a test demodulator and FM-index meter. The distortion factor of the demodulator for a  $\pm 150$ kHz deviation was less than 0.1% (the measurement accuracy was determined by the measuring equipment). The limiter amplifier using the four Xor gates in a 74LS86 determines the demodulator sensitivity of about 300mV pk-pk.

There are specialist PLL frequency demodulator ICs for satellite TV receivers, for example the Plessey SL1451 and Philips TDA8730, which include on one chip a VCO (one LC-element type), PD, DC amplifier and limiter amplifier. A satellite receiver frequency demodulator using an SL1451 is shown in Fig. 6, in which the input signal is the frequency-modulated IF at 610MHz with a  $\pm 13$ MHz frequency deviation. This is taken to the limiter amplifier on pin 11 and then to the PD, from one of whose outputs (pins 12 and 15) the control signal goes through the loop filter to the VCO varactor diode. In this IC the PD is a

Fig. 5. TTL ICs used in a 10.7MHz IF FM receiver - a similar circuit arrangement to that in Fig.4. This has been used in a test receiver.

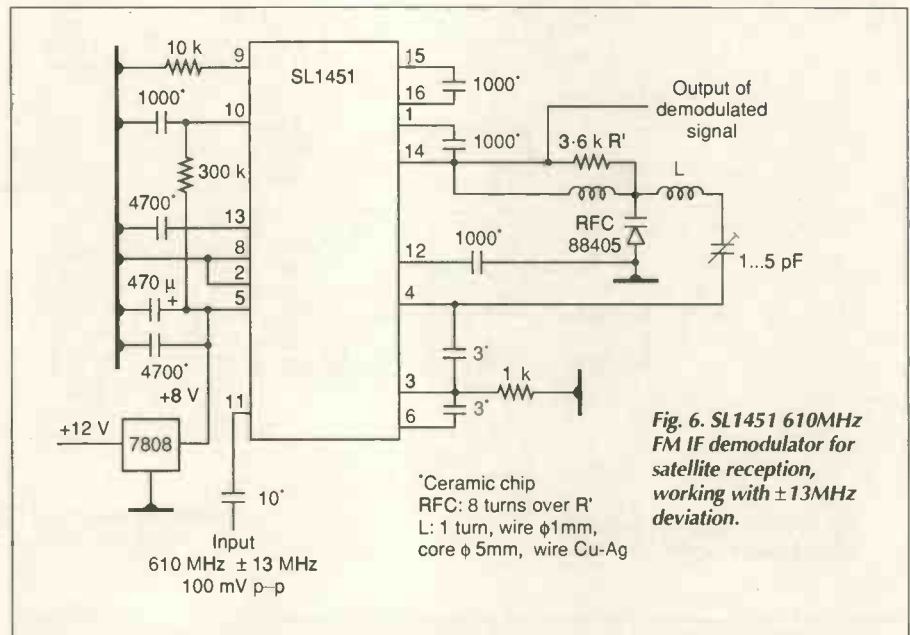


Fig. 6. SL1451 610MHz FM IF demodulator for satellite reception, working with  $\pm 13$ MHz deviation.

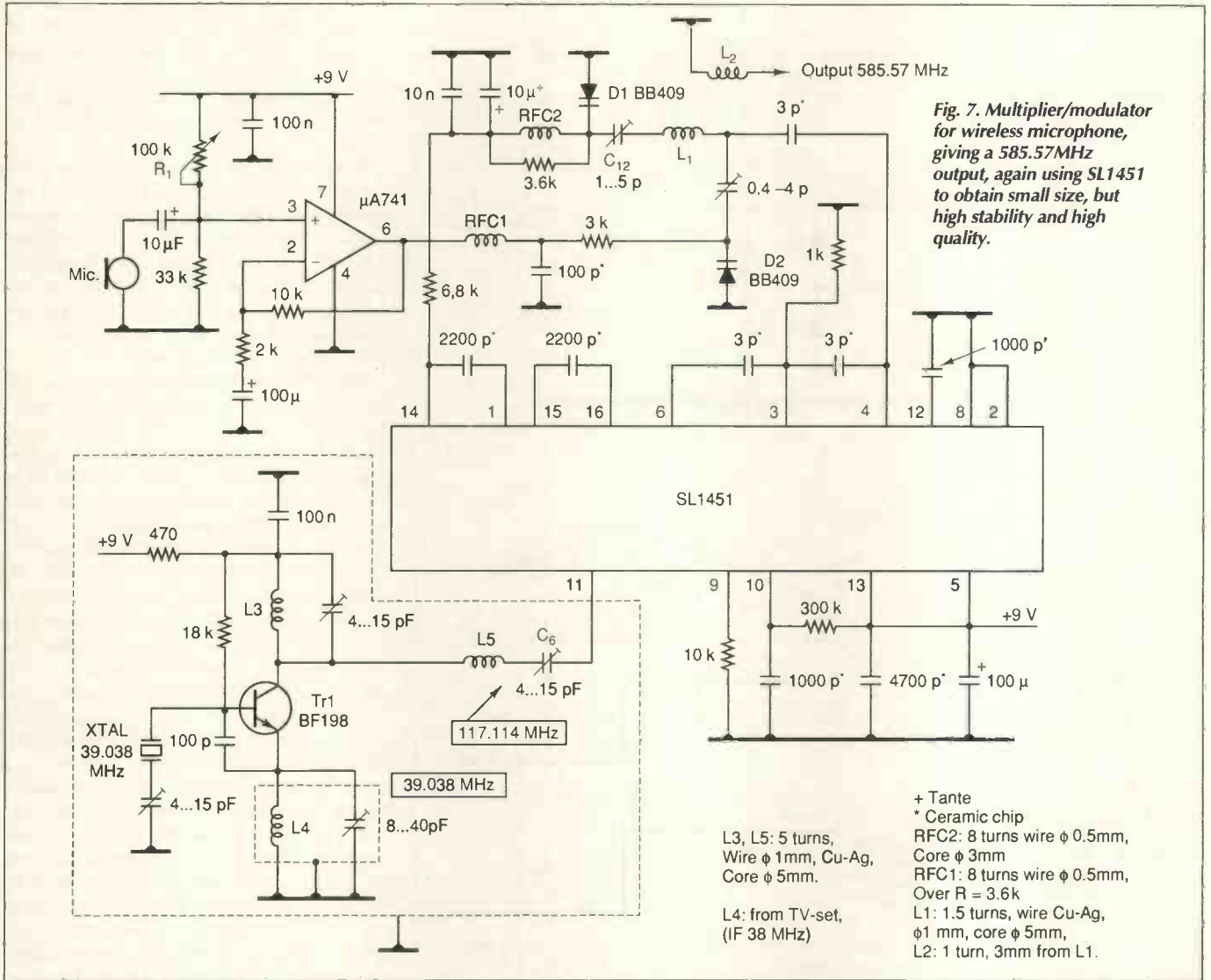
double-balanced mixer, providing excellent demodulation linearity. The demodulated signal from pin 14 is video, together with the FM sound subcarrier.

**SL1451 FM modulators and multipliers**  
ICs of the SL1451 type can be successfully used in frequency modulators and frequency multipliers. Figure 7 shows a 585.57MHz wireless microphone in which both functions are carried out by the SL1451. Clearly, these devices must be small and light and yet provide good frequency stability and high quality for concert work - to some extent mutually exclusive properties.

The SL1451 in Fig. 7 operates as a PLL frequency multiplier, the output frequency of the multiplier being modulated by the low-frequency signal received from the microphone amplifier at the 741 op-amp input. A third-overtone crystal oscillator collector circuit is tuned to the third harmonic of the crystal at 117.114MHz, which is one-fifth of the required 585.57MHz. Tuned circuit  $L_5C_6$  resonates at 117MHz for more effective output filtering.

Limiting in the SL1451 is accompanied by harmonic generation and, if the input-signal waveform is symmetrical about zero, only odd harmonics of the input signal appear at the output of the limiter. A PLL using a double-balanced mixer as a phase detector will synchronise on harmonics. In this case, the VCO in the SL1451 operates at about 585MHz and the PLL synchronises the VCO frequency with the fifth harmonic of the input-signal frequency.

To ensure stability, the VCO frequency should change within a range of  $\pm 10\%$  from its free-running frequency, a limit to the tuning range of varactor diode  $D_1$  being set by the capacitance of  $C_{12}$ . Varactor diode  $D_1$  controls the PLL and  $D_2$  the frequency modulator;  $D_2$  working point is set by potentiometer  $R_1$  between 4V and 6V. Signal from  $L_2$  is passed to a single-transistor power amplifier. Power



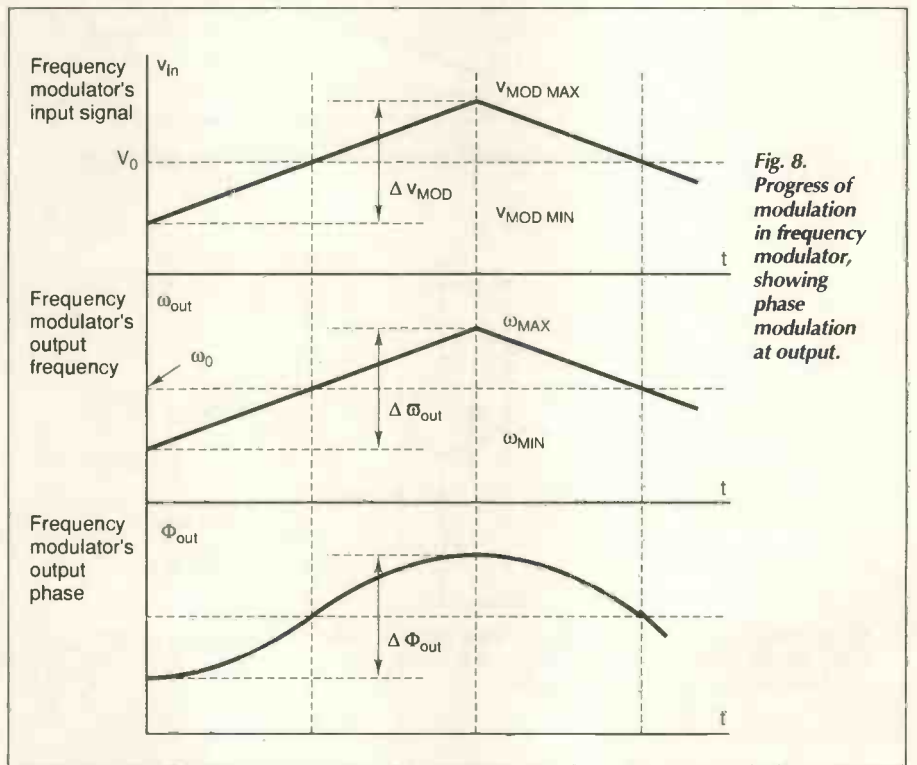
amplifier and antenna are not shown in Fig. 7.

A circuit analogous to that in Fig. 6 but with a 200MHz IF is used as a demodulator in the receiver. The local oscillator is also part of the SL1451, working as a frequency multiplier for 585.57 - 200 = 385.57MHz, the crystal frequency being 42.841MHz (42.841 x 3 = 128.523MHz, 128.523 x 3 = 385.57MHz). A transistor crystal oscillator and the frequency multiplier/modulator based on the SL1451 makes for stability of the UHF signal frequency and also for compact design, which were the requirements. When designing the radio-microphone the author was inspired by the description of such a frequency multiplier by Westerwelle (see further reading list).

It should be mentioned that the SL1451 has several drawbacks, the most important one being large current consumption (up to 40mA), which limits the field of its application.

**Phase modulation**

Frequency modulation is not the only method of angle modulation; phase-modulated systems are widespread and require modulators and demodulators. When a carrier is modu-



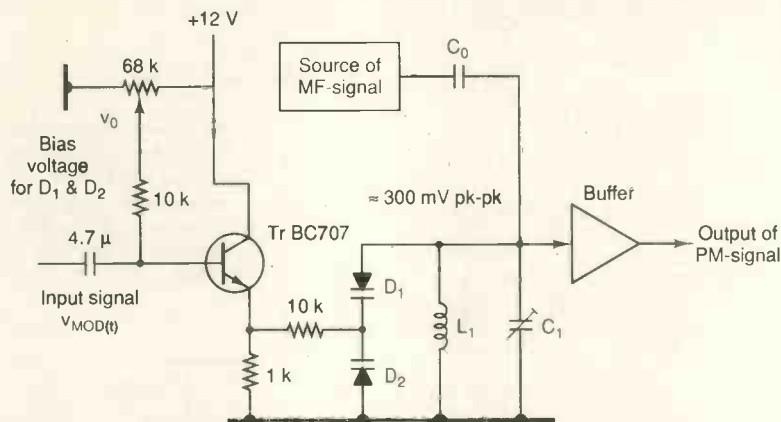


Fig. 9. Linear circuit for phase modulation, providing high frequency stability.

lated by a single tone with no amplitude change, it is impossible to distinguish an FM spectrum from that of PM. From the definition of frequency – the first differential of phase with respect to time – one cannot get pure FM or PM, since an FM signal has PM and vice versa.

Figure 8 indicates how the modulating signal influences frequency and phase in the frequency modulator; the triangular wave represents the modulating signal. A frequency modulator can be converted into a phase modulator by differentiating the frequency modulator input. Analogously, one can turn a phase modulator into frequency modulator by integrating the modulating signal.

Figure 9 shows direct phase modulation, the modulating signal being applied to the varactor diode across the  $F_o$  tuned circuit. Theoretically, a linear circuit cannot change the input signal frequency and can only change its phase. If the varactor circuit is linear for small signals and the input frequency is constant, the modulating signal at the varactor diode gives rise to PM; it will, however, be accompanied by considerable nonlinearity distortion if the modulation index is more than 0.5-0.7rad and this fact almost precludes such methods of obtaining PM in communication. The method of differentiating the input of a frequency modulator is used in all broadcast FM transmitters, where it is called the pre-emphasis RC chain, having a 50µs or 75µs time constant, depending on the standard. A second-order low-pass filter in the receiver, with the same time constant, reverses the process. Pre-emphasis and de-emphasis increase the level of high frequencies in the modulating signal spectrum, frequency deviation for these spectrum components increases and signal-to-noise ratio in the demodulated and de-emphasised signal is increased. Figure 10 is the block diagram of a phase demodulator using an FM demodulator and integrator, with signals at the relevant points at (b), while Fig. 11 shows pre-emphasis and de-emphasis circuits with 50µs time constants used in FM-broadcasting. The integrator and differentiator shown in Fig. 12 are very simple but accurate working circuits, with the operating band limited to 0.3-3.5kHz, which is quite enough for professional communication systems with PM.

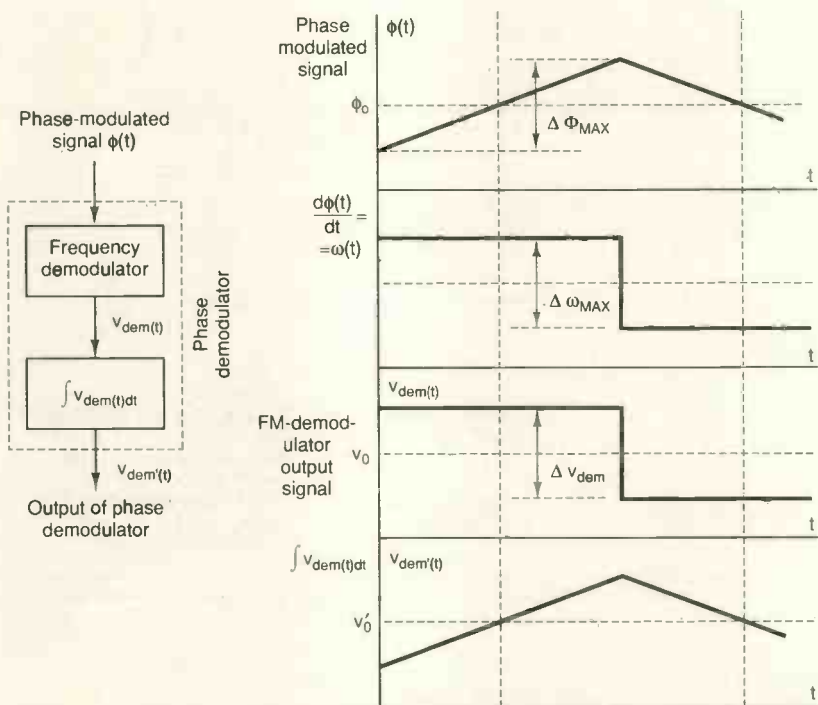


Fig. 10. Frequency demodulator, its output integrated, provides phase demodulation, as shown in diagrams at (b).

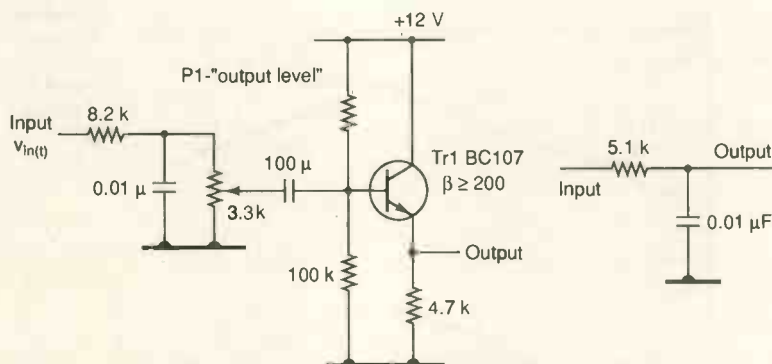


Fig. 11. Pre-emphasis and de-emphasis circuits with 50µs time constants to improve FM broadcast signal-to-noise ratio. In 30Hz-15kHz range, departure from IEC recommendation not more than ±0.6dB.

**Acknowledgments**

I wish to express my gratitude to my wife Olga for her patience in translating these articles and to Mr V Zhukov for his assistance in their preparation.

**Further reading**

- V Manassevitch. *Frequency Synthesizers: Theory and Design*. John Wiley & Sons, New York, 3rd edition. Excellent handbook on the theory and practice of frequency synthesiser design. Many practical examples.
- U L Rohde. *Digital PLL frequency synthesizers: Theory and Design*. Englewood Cliffs, New York, Prentice-Hall Corp., 1983. All aspects of design are examined.
- A J Viterbi. *Principles of Coherent*



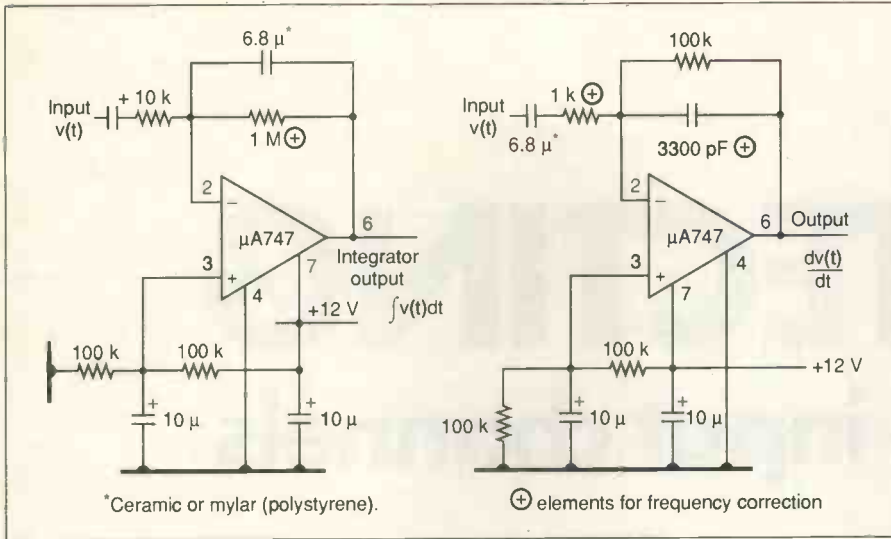


Fig. 12. Integrator and differentiator circuits for speech baseband, giving 1% accuracy.

Communication. McGraw-Hill Book Company, New York, 1966. A good theoretical book for those who want to extend their knowledge of PLL theory. Many worked examples with proofs.  
F M Gardner. *Phaselock Techniques*. John

Wiley & Sons, New York, 2nd Edition. Very accurate analysis of PLL systems.  
M Bomford. "Selection of Frequency Dividers for Microwave PLL Applications", *Microwave Journal*, November 1990, pp.159-160, 162, 164, 166-167. Survey of technical and

economic aspects of different frequency dividers to about 15GHz. A very practical article.  
K Johnson. Measure PLL Open-Loop Response with the Loop Closed, *Electronic Design*, November 1990, pp.79-86. Witty and easily understood description of method of taking Bode diagram of a PLL, irrespective of operating frequency.  
R Oxley. "Digital Computer Modelling of Linear Systems", *Electronics and Wireless World*, January 1987, pp.107-111. Useful for those who need to simulate or analyse a projected or existing system on any home computer.  
T Brook. AM Synchronous Demodulator. *Electronics World and Wireless World*, September 1989, pp.858-860. Practical circuit in which PLL is used for synchronous demodulation of an AM signal.  
H Ammon, B.Schenkel. "1.3GHz PLL with HC-bus. IEEE" *Transactions on Consumer Electronics*, Vol CE-31, No 3, August 1985, pp.124-131. Minute description of the internal circuit of the single-chip frequency synthesiser.  
H Westerwelle. "Wetterfrosch fuer Funkamateure", *Funkschau* (Munich), 1988, No 1, pp.59-60,89-91, No 2, pp.61-62,91-92. Description of a 778.5MHz frequency multiplier using the SL1451.

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# PROTECTING analogue input channels

*A number of currently available microcomputers provide A to D converters permitting direct measurement of analogue signals by computer. Uses include processing, control, recording and display, etc. Few have protection against input overvoltage. Providing protection without upsetting circuit function and accuracy is by no means as straightforward as it seems. By William Barr.*

There are two basic forms of A-to-D converter, monopolar and bipolar. The first measures voltages of one polarity only, typically from zero volts up to +2.55V. The second measures voltages over a range which includes both positive and negative values. For instance, -2.56V up to +2.54V.

Some converters operate from a single supply voltage while others work off dual supplies. Generally speaking the rules governing safe input voltages may be summarised as values which include the range from  $V_{CC}$  down to 0.3V below the most negative supply rail.

For a single supply of 5V, safe input voltages of +5V down to a minimum -0.3V may be applied. A converter which operates off a dual supply of  $\pm 5V$  has safe input voltages over the range of +5V down to -5.3V.

Figure 1 illustrates the ideal characteristics of protection circuitry.  $V_b$ , and hence  $V_c$ , tracks  $V_{in}$  precisely over the analogue ranges, while good voltage clamping occurs just outside each end of these ranges. The design of protection circuitry has to take into account the type of voltage supplies used and the monopolar or bipolar nature of the A to D converter's hardware.

Circuit protection added on to an analogue to digital converter should transmit voltage values faithfully over the whole analogue range yet should provide good voltage clamping, at safe values, for input voltage values outside the measurement limits.

Fig. 2 shows the usual method of arranging protection. An op-amp connected as a voltage follower is used to buffer the protection circuit from the A to D converter. Input signals

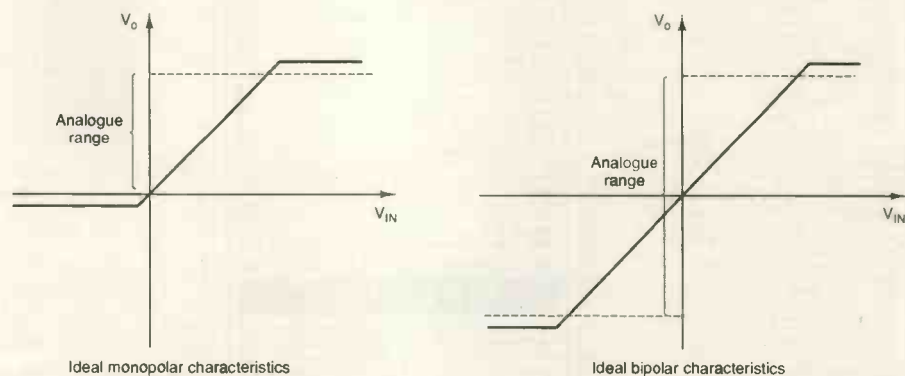


Fig. 1. Ideal characteristics of protection circuitry.  $V_b$ , and hence  $V_c$ , tracks  $V_{in}$  precisely over the analogue ranges, while good voltage clamping occurs just outside each end of these ranges.

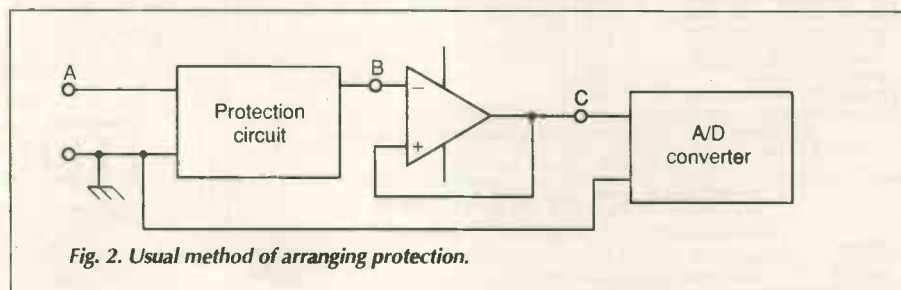


Fig. 2. Usual method of arranging protection.

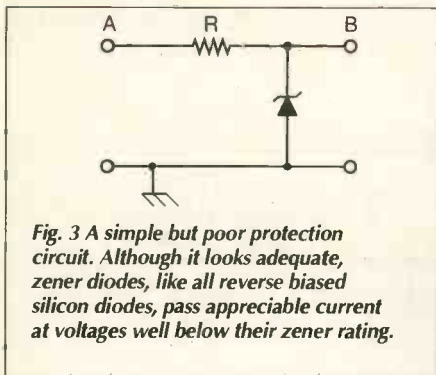


Fig. 3 A simple but poor protection circuit. Although it looks adequate, zener diodes, like all reverse biased silicon diodes, pass appreciable current at voltages well below their zener rating.

applied at A pass through to the analogue input at C. To ensure adequate protection is given by the voltage follower used to buffer the protection circuitry, it is useful to power it from the same supply as the A-to-D converter, single or dual as the case may be. Monopolar converters should use an op-amp which can include ground within its permissible range of input potentials.

Fig. 3 shows a simple but poor protection circuit. Although it looks adequate, zener diodes, like all reverse biased silicon diodes, pass appreciable current at voltages well below their zener rating. Such a circuit offers protection against excessive positive input voltages but is likely to result in measurement

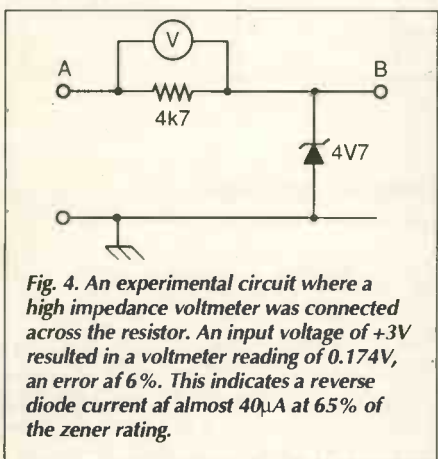


Fig. 4. An experimental circuit where a high impedance voltmeter was connected across the resistor. An input voltage of +3V resulted in a voltmeter reading of 0.174V, an error of 6%. This indicates a reverse diode current of almost 40µA at 65% of the zener rating.

inaccuracy. The resistor, R, drops voltage when  $V_{in}$  exceeds  $V_z$ . The difference voltage,  $V_i - V_z$ , appears across R. The maximum safe input voltage has the value

$$V_{in(max)} = V_z + \sqrt{PR}$$

where R is the resistance in ohms and P is its rating in watts.

For negative input voltages the zener begins to conduct at about -0.4V.

For large negative inputs, and larger zener currents, the diode begins to saturate clamping terminal B to around -0.7V. In theory this circuit seems suitable for dual supply converters but is clearly unsuitable for single supply converters. To illustrate this Fig. 4 shows an experimental circuit where a high impedance voltmeter was connected across the resistor. An input voltage of +3V resulted in a voltmeter reading of 0.174V, an error of 6%. This indicates a reverse diode current of almost 40µA at 65% of the zener rating.

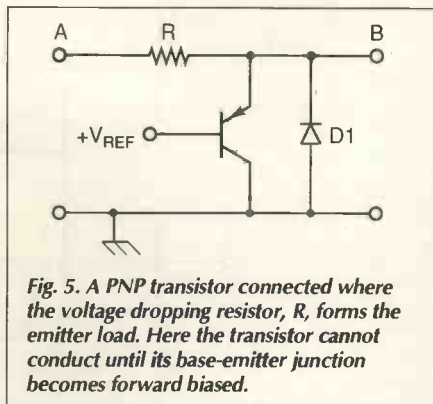


Fig. 5. A PNP transistor connected where the voltage dropping resistor, R, forms the emitter load. Here the transistor cannot conduct until its base-emitter junction becomes forward biased.

### Transistor voltage clamps

A much improved voltage clamp uses emitter follower action. Fig. 5 shows a PNP transistor connected in this way where the voltage dropping resistor, R, forms the emitter load. Here the transistor cannot conduct until its base-emitter junction becomes forward biased. The transistor will begin to conduct when the emitter potential exceeds  $V_{ref}$  by about 0.4V. For input voltages between zero and  $(V_{ref} + 0.4)$

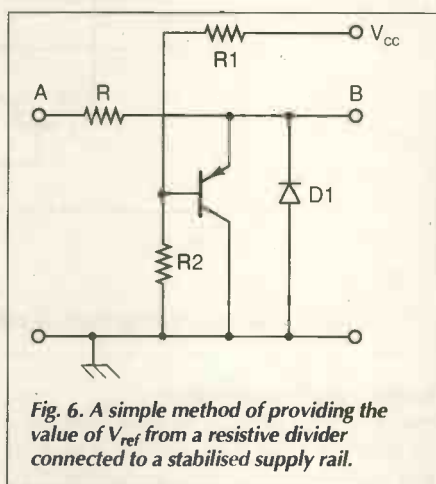


Fig. 6. A simple method of providing the value of  $V_{ref}$  from a resistive divider connected to a stabilised supply rail.

volts the potential of B follows that of A with good precision. Larger positive input voltages simply turn the transistor on more fully so that B becomes clamped at a value of  $V_{ref} + V_{be}$ . In practice  $V_{be}$  might rise to 0.7V depending on the emitter current flowing.

The silicon diode  $D_1$  must be included to provide protection against negative input voltages applied at A.  $D_1$  also protects the transistor by limiting its reverse collector-emitter voltage to one forward diode volt drop when large negative input voltages are applied.

Figure 6 shows a simple method of providing the value of  $V_{ref}$  from a resistive divider connected to a stabilised supply rail.

Where supply stability is inadequate, zener diode may be used for better control. This is shown in Fig. 7(a) but the addition of a potentiometer as in Fig. 7(b) permits  $V_{ref}$  to be set more accurately if desired.

### Safety limits

Silicon transistors exhibit base-emitter breakdown at relatively low voltages - typically 5 to 7V. For such transistors  $V_{ref}$  should be cho-

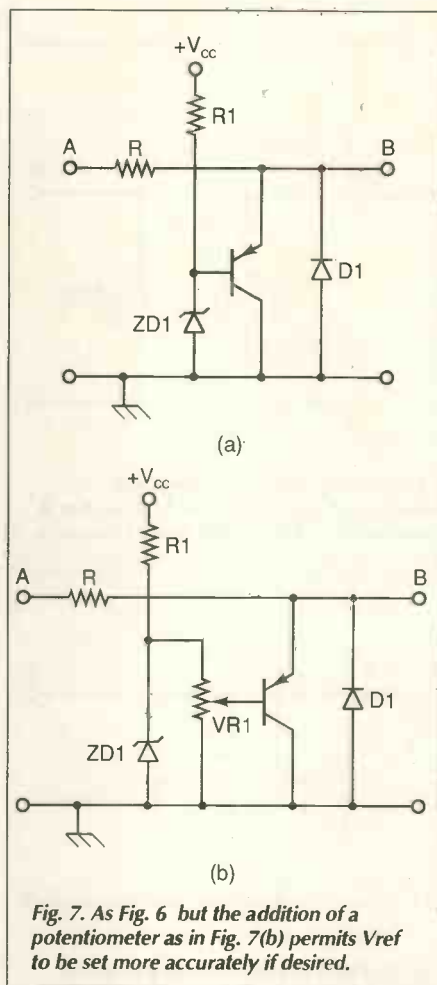


Fig. 7. As Fig. 6 but the addition of a potentiometer as in Fig. 7(b) permits  $V_{ref}$  to be set more accurately if desired.

sen to be less than this value by about one diode volt drop.

The analogue range for both circuits shown in Fig. 7 is therefore limited to about 4.5V or so. Fig. 8 illustrates a circuit which appears good in theory but has practical limitations. A zener diode is added in series with the emitter. Ideally this prevents the transistor conducting until  $V_{in}$  reaches a value given by  $V_{in} = V_{z1} + V_{z2} + V_{be}$ .

However  $ZD_2$  begins to conduct well below this value of  $V_{in}$  due to leakage and while hard voltage clamping takes place at about +10.4V with large positive voltages at A, the signal may begin to degrade around +7V. One solution is to replace  $ZD_2$  with a low leakage diode and for the new reference base potential

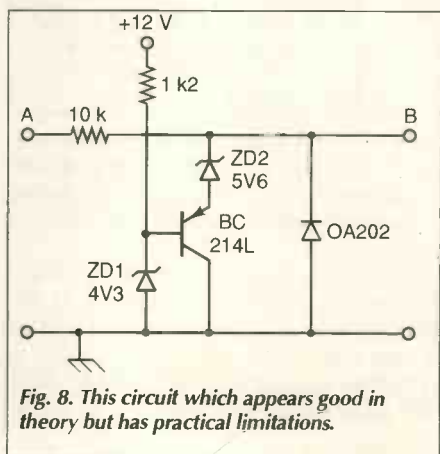


Fig. 8. This circuit which appears good in theory but has practical limitations.

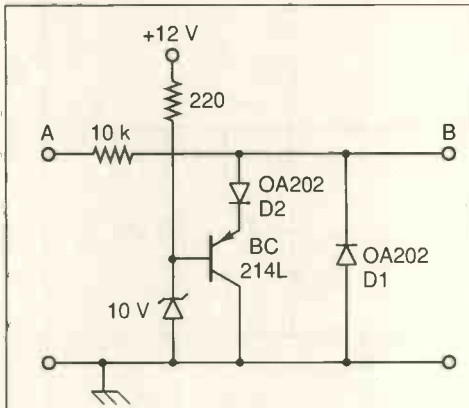


Fig. 9. Diode  $D_2$  prevents the transistor conducting although its base-emitter junction is reverse biased well beyond its breakdown value.

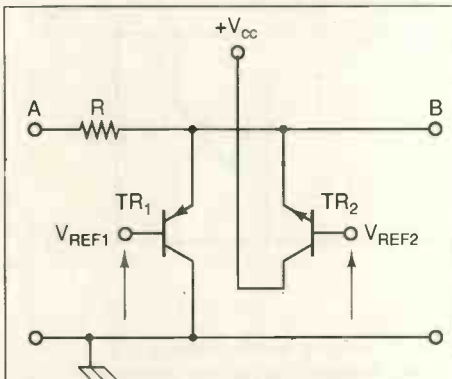


Fig. 10. Protecting input circuitry powered from a single supply is more difficult: both transistors share the common protection resistor  $R$ .

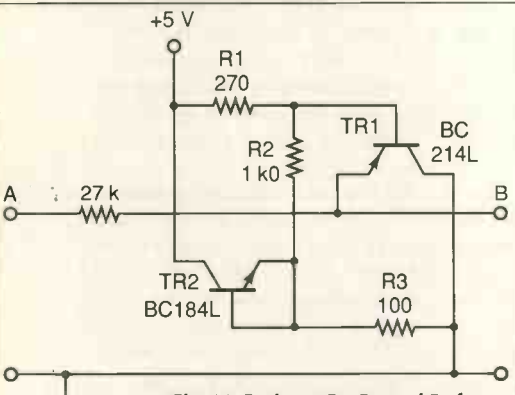


Fig. 11. Resistors  $R_1$ ,  $R_2$ , and  $R_3$  form a potential divider arrangement to generate the reference voltages for both transistors.

to the necessary higher value. This is shown in Fig. 9. This diode,  $D_2$ , prevents the transistor conducting although its base-emitter junction is reverse biased well beyond its breakdown value.

Conduction commences, providing protection, when  $V_{in}$  rises above about  $V_{ref} + 1.0V$ . This circuit gave no measurable degradation of input signal up to +10.9V yet clamped  $B$  at +11.3V for inputs of +18V up to +40V, and is very useful for protection over the range 0 to 10V.

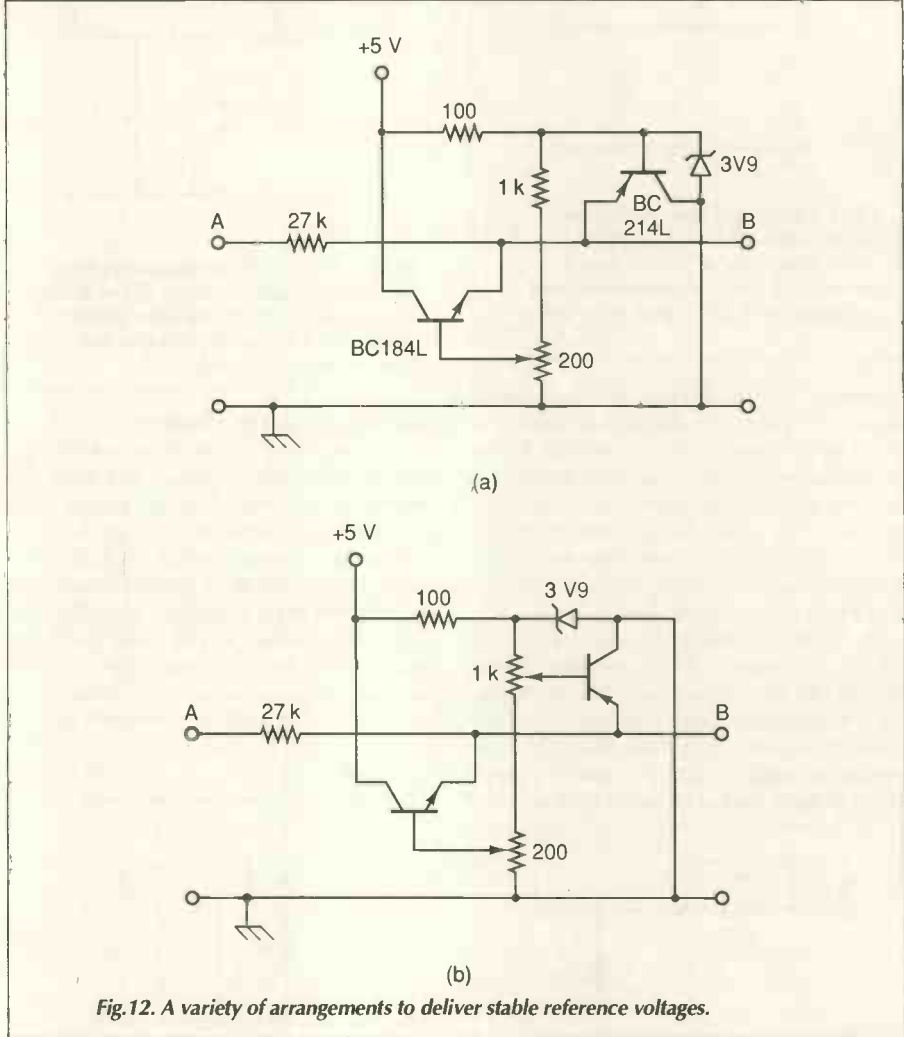


Fig. 12. A variety of arrangements to deliver stable reference voltages.

Single supply protection

Protecting input circuitry powered from a single supply is more difficult. This is because peak negative signals, appearing at terminal  $B$ , must not exceed  $-0.3V$ . One method of achieving this is to replace  $D_1$  by a second emitter-follower using an NPN transistor. This is shown in Fig. 10 where both transistors share the common protection resistor  $R$ . The peak negative potential appearing at  $B$  will have the value  $V_{b(min)} = V_{ref2} - V_{be2}$  where  $V_{ref2}$  is the base potential of the NPN transistor  $TR_2$ , and  $V_{be2}$  is the forward volt drop of its base-emitter junction. In practice the value of  $V_{ref2}$  is greatly restricted. If greater than about +0.4 volt,  $TR_2$  may begin to conduct with input signals just above zero volts thereby degrading low level signals. In addition a diode drop below  $V_{ref2}$  should not exceed 0.3V. A good value to choose is  $V_{ref2} = 0.35V$ . The circuit of Fig. 11 uses resistors  $R_1$ ,  $R_2$ , and  $R_3$  in a potential divider arrangement to generate the reference voltages for both transistors. It is worth choosing metal film resistors for this application. They have 1% tolerance, possess excellent temperature stability and are very low noise devices. In the circuit of Fig. 11 the values of  $V_{ref1}$  and  $V_{ref2}$  are

$$V_{ref1} = \frac{1100}{1370} \times 5 = 4.01 \text{ volts}$$

$$V_{ref2} = \frac{100}{1370} \times 5 = 0.36 \text{ volts}$$

This circuit passed input voltages very faithfully over the range zero to +4.45V. An input voltage of +40V clamped  $B$  at +4.75V, while a  $-40V$  input clamped  $B$  at  $-0.24V$ . The circuits of Fig. 12 show a variety of arrangements to deliver stable reference voltages. Also the 200 $\Omega$  potentiometer permits an optimum setting of  $V_{ref2}$  for the chosen NPN transistor. The circuit in Fig. 12(b) also allows adjustment of  $V_{ref1}$ .

The circuits of Fig. 11 and Fig. 12 are also suitable for monopolar ranges whose circuitry operates off dual supplies. The reduced leakage in  $TR_2$ , compared with  $D_1$ , is one important advantage.

To protect single supply circuitry over larger analogue ranges, say zero to +10V, the same trick as before may be used. This is shown in Fig. 13 where the diode  $D_2$  is added in series with the emitter of the NPN transistor. Each emitter diode protects the corresponding transistor when base reference potentials are larger than the base-emitter breakdown voltage. An additional diode volt drop is required across  $D_2$  before  $TR_2$  begins to conduct with negative input voltages. Consequently  $V_{ref2}$  must be set somewhere

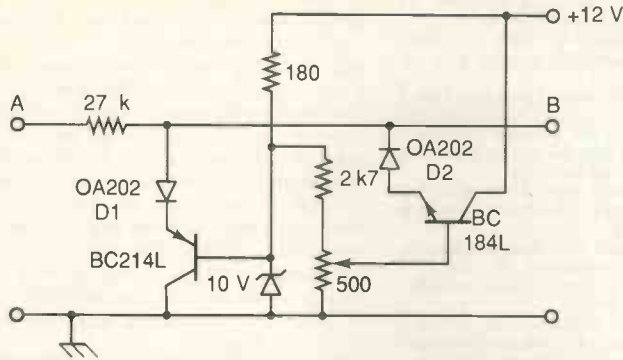


Fig. 13. Diode  $D_2$  is added in series with the emitter of the NPN transistor. Each emitter diode protects the corresponding transistor when base reference potentials are larger than the base-emitter breakdown voltage.

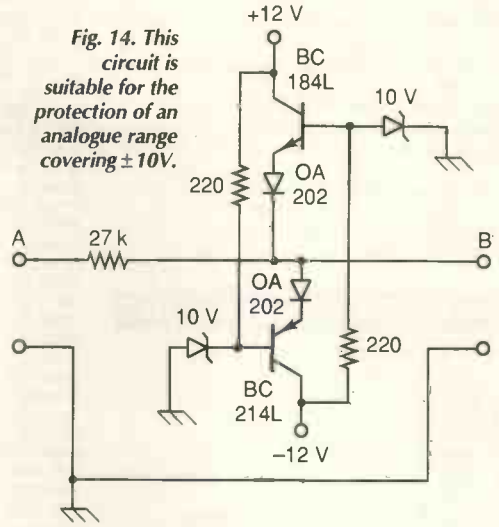


Fig. 14. This circuit is suitable for the protection of an analogue range covering  $\pm 10V$ .

between 1.0V and 1.2V. Under test large positive input voltages (+40V) were clamped at 11.3V while large negative voltages (-40V) were clamped at -0.22V.

**Protecting bipolar ranges**

Using the same principles discussed so far, it is an easy matter to protect voltage ranges that may or may not be centred about zero.

In this case the base of  $T_{12}$  requires a suitable negative reference potential. The circuit of Fig. 14 is suitable for the protection of an analogue range covering  $\pm 10V$ . Faithful signal transmission takes place over the range of  $\pm 10.9 V$  while good clamping restricts the potential of  $B$  to  $\pm 11.3V$ .

It is quite straight forward to extend protection to several input channels without unnecessary circuitry duplication. Fig. 15 shows a scheme designed to give protection to four channels employing monopolar ranges operating off a single (or dual) supply. For each additional channel three additional components only are required: the voltage dropper,  $R$ , one PNP and one NPN transistor. The base of each PNP device shares the common potential,  $V_{ref1}$ , while the base of each NPN transistor shares the common potential,  $V_{ref2}$ . The collector of each PNP transistor is connected to its individual analogue ground terminal, while the NPN collectors are each commoned to  $V_{cc}$ . This permits multichannel protection to be achieved with few additional components.

All the protection circuits discussed use a series connected voltage dropping resistor. Large excursions outside the normal voltage range will cause significant power dissipation in this component. Its power rating should take this into account.

While high values will reduce dissipation for a given overvoltage, the value chosen should not be so high that it induces error due to converter input capacitance or resistance. Also, excessively high values may also introduce a noise penalty with high resolution ADCs. ■

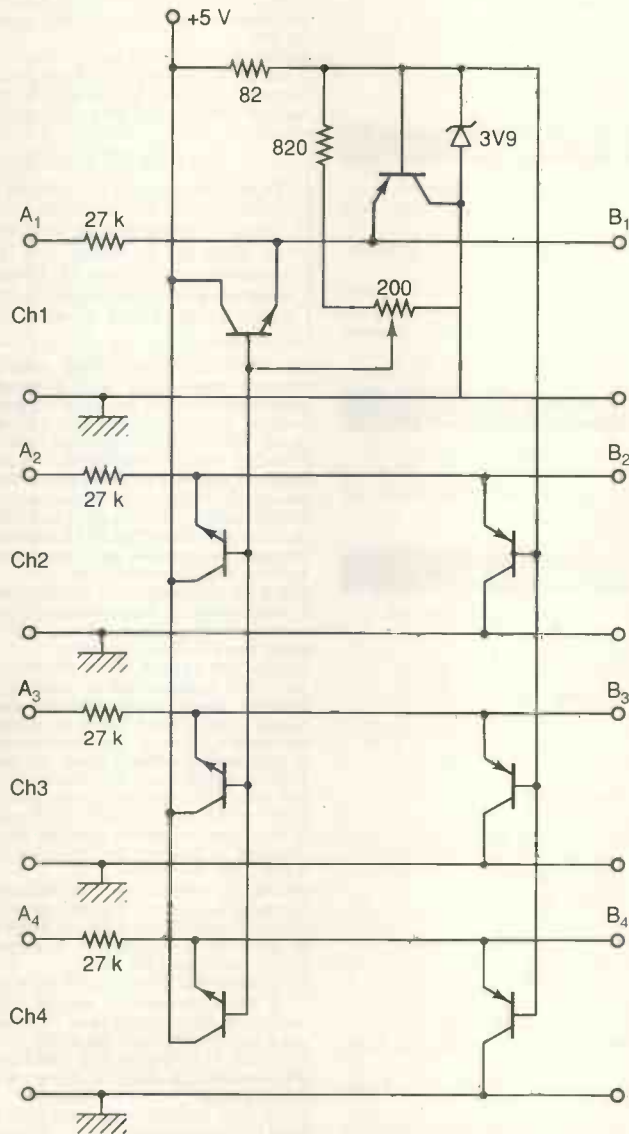


Fig. 15. A scheme designed to give protection to four channels employing monopolar ranges operating off a single (or dual) supply.

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There are many digital signal processors on the market which operate in the sub-MHz range but many applications for DSP involve video frequencies which are in the MHz band range – digital television being only one example. To perform DSP operations within this frequency range requires special VLSI designs and Harris have recently released their HSP43481 digital filter which can operate with a maximum sample rate of 30MHz. Designed specifically to perform vector operations which are common in finite impulse response (FIR) digital filtering, the HSP43481 contains four filter cells which are cascaded internally. Each cell has its own 8 x 8 multiplier, a set of decimation registers and a 26-bit accumulator which is sufficient to prevent

overflow. By cascading devices it is possible to construct very high order filter structures, possibly up to a 1032 taps.

Figure 1 shows a block diagram of the device. Vector operations require at least two data paths and these are shown as DINO-7 (for the 8-bit sampled input data) and CINO-7 (for the coefficients). The output data from each cell can be added to form a resultant 26-bit sum in the output stage buffer. When implementing a fir filter, the filter's coefficients are passed to the HSP43481 via the CINO-7 bus into the C register as seen in the cell block diagram (Fig. 2). The coefficient follows two paths, the first for decimation purposes. If decimation is required, the contents of the C register is passed to D registers otherwise

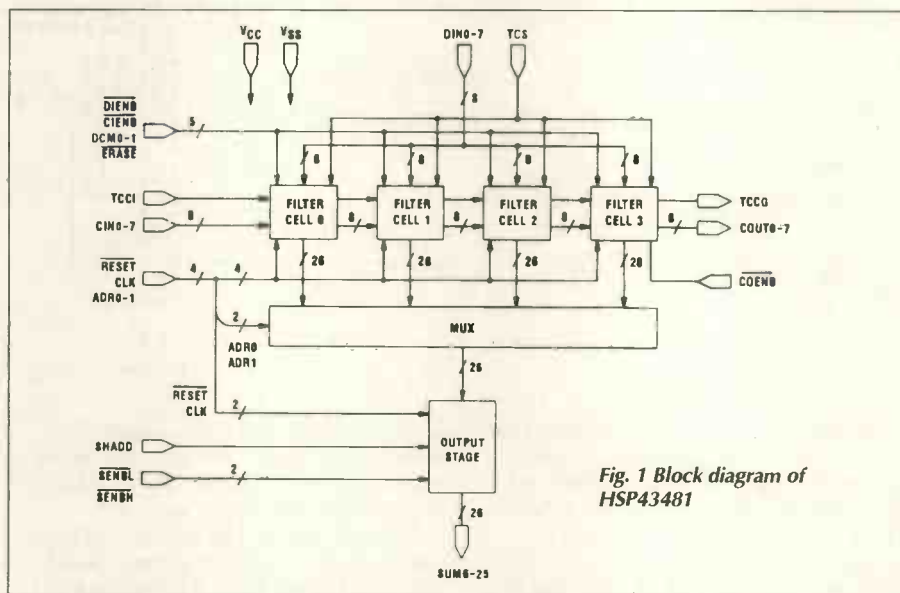


Fig. 1 Block diagram of HSP43481

Table 1 Sequence of calculations for performing the 4-tap FIR filter

Clk and Sample	Cell 0	Cell 1	Cell 2	Cell 3	Output
0	x(0)	c3 x(0)	-	-	-
1	x(1)	+ c2 x(1)	c3 x(1)	-	-
2	x(2)	+ c1 x(2)	+ c2 x(2)	c3 x(2)	-
3	x(3)	+ c0 x(3)	+ c1 x(3)	+ c2 x(3)	c3 x(3)
4	x(4)	c3 x(4)	+ c0 x(4)	+ c1 x(4)	+ c2 x(4)
5	x(5)	+ c2 x(5)	c3 x(5)	+ c0 x(5)	+ c1 x(5)
6	x(6)	+ c1 x(6)	+ c2 x(6)	c3 x(6)	+ c0 x(6)
7	x(7)	+ c0 x(7)	+ c1 x(7)	+ c2 x(7)	c3 x(7)
8	x(8)	c3 x(8)	+ c0 x(8)	+ c1 x(8)	+ c2 x(8)

the coefficient is passed to the COUT0-7 bus to be cascaded to other cells. The decimation option is selected by appropriately asserting the DCM pins. The second path is to the multiplier, the other input (the data sample) to the multiplier comes from the X register which is loaded via the DINO-7 bus. The multiplier is actually pipelined and has two pipeline registers MREG0 and MREG1.

The sign extended output from the multiplier is passed into the adder which enables the sum of the multiplier result and

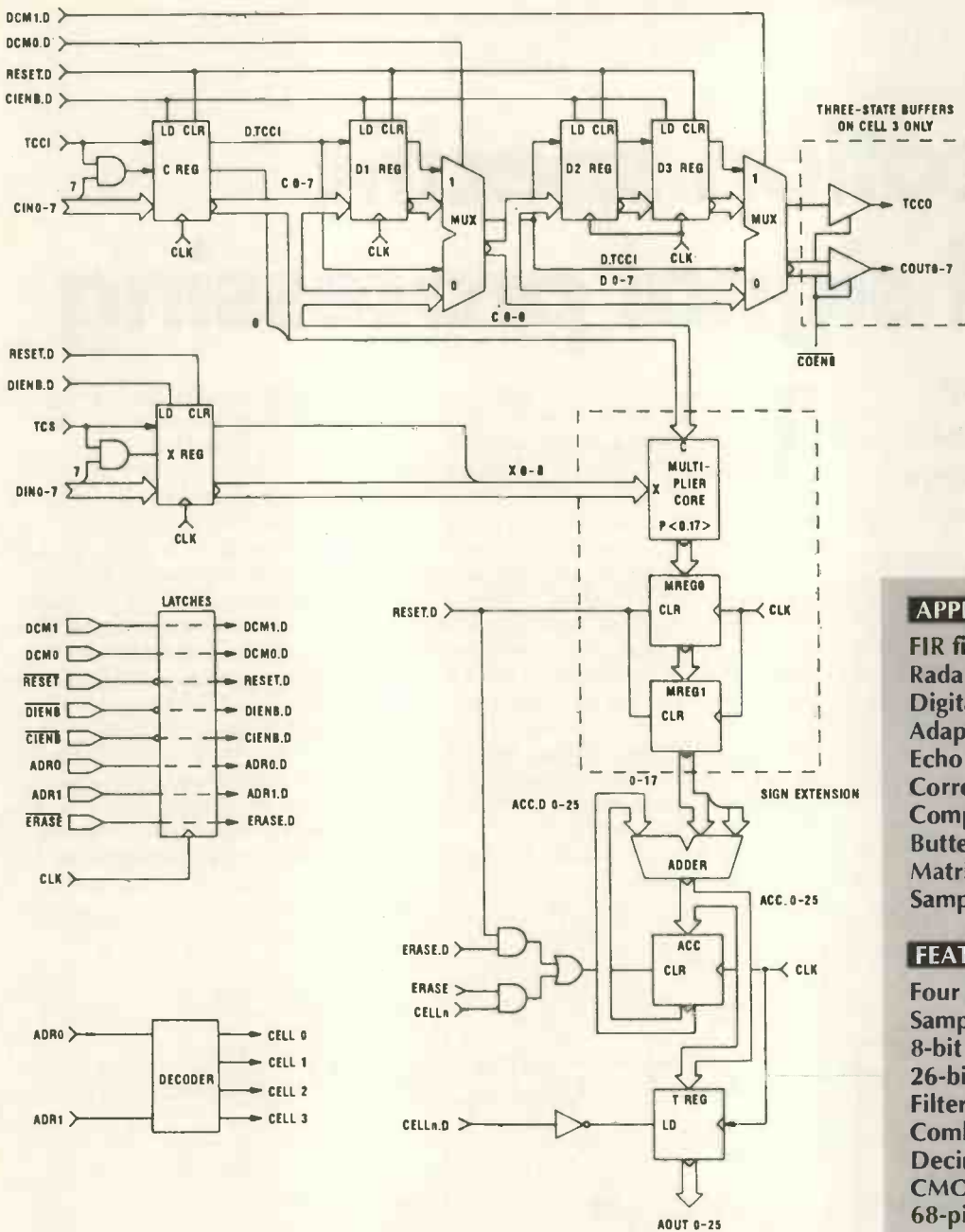


Fig. 2 Block diagram of cell unit

**APPLICATIONS**

- FIR filters
- Radar/sonar
- Digital video and audio
- Adaptive filters
- Echo cancellation
- Correlation/convolution
- Complex multiply/add
- Butterfly operation
- Matrix maths
- Sample rate converters

**FEATURES**

- Four filter cells
- Sample rate DC to 30MHz
- 8-bit data and coefficients
- 26-bit accumulator/stage
- Filter lengths up to 1032 tap
- Combinatorial output stage
- Decimation
- CMOS power dissipation
- 68-pin PLCC package

accumulator contents to be calculated. The net result (the sum-of-products) is then loaded back into the cell accumulator and the T-register. The accumulator is in fact loaded every clock unless otherwise controlled by the ERASE and RESET lines. Control is exercised over the use of the T-register by asserting the CELLn signal which is derived from the ADR0-1 signals which selects the cell. The T-register is loaded whenever the output of the cell is not selected which means that in practice the T-register is loaded every clock except the clock following the cell selection. The purpose of this scheme is to permit the T-register to hold the result of the calculation while the accumulator is cleared for the next sum-of-product calculation.

The output stage of the HSP43481 is shown in Fig. 3. It has a 26-bit adder, a 26-

bit register and a 26-bit zero register feedback multiplexer (0-mux) between the adder and the register. This allows the adder to perform the addition of any cell accumulator output with the eighteen most significant bits of the output buffer which takes place in one clock. The feedback 0-mux has an input control line SHADD which either allows the eighteen data bits from the output buffer to pass through to the adder or to set the eighteen data bits to zero and pass them to the adder. The effect of only passing eighteen bits is to right-shift the original 26-bit data by eight binary places which means that it becomes 18-bit data having lost the least significant 8-bits. Although this leads to reduced precision it does minimise the likelihood of overflow. The output from the 26-bit buffer is fed into the three state output buffer. Alternatively when the SHADD

control line is set to 1, the output from the selected cell passes directly to the three state buffer onto the SUM0-25 bus.

**Designing with the HSP43481**

Having considered the operation of the HSP43481 the question that remains is how to use it. Unlike a digital signal processor where almost everything is performed through software control the HSP43481 has no control registers. All control is exercised through the timing and the polarity on the control pins. A simple example of a 4-tap filter is shown in Fig. 4. The calculation to be performed is,

$$y(n) = c_3 x(n) + c_2 x(n-1) + c_1 x(n-2) + c_0 x(n-3)$$

Since  $x(n < 0) = 0$ , the input data will be



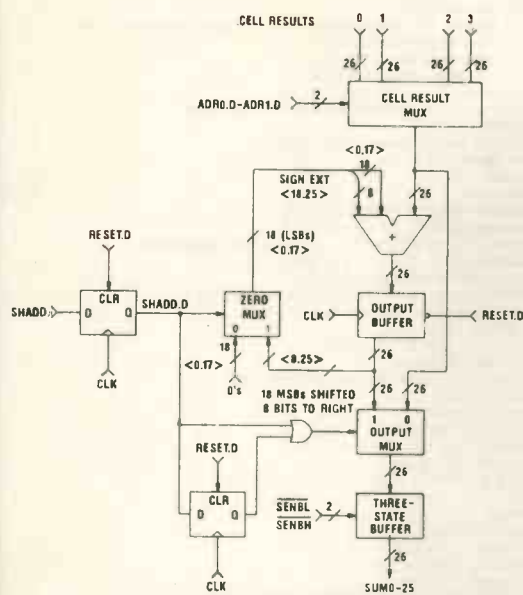


Fig. 3 Block diagram of the output stage of HSP43481

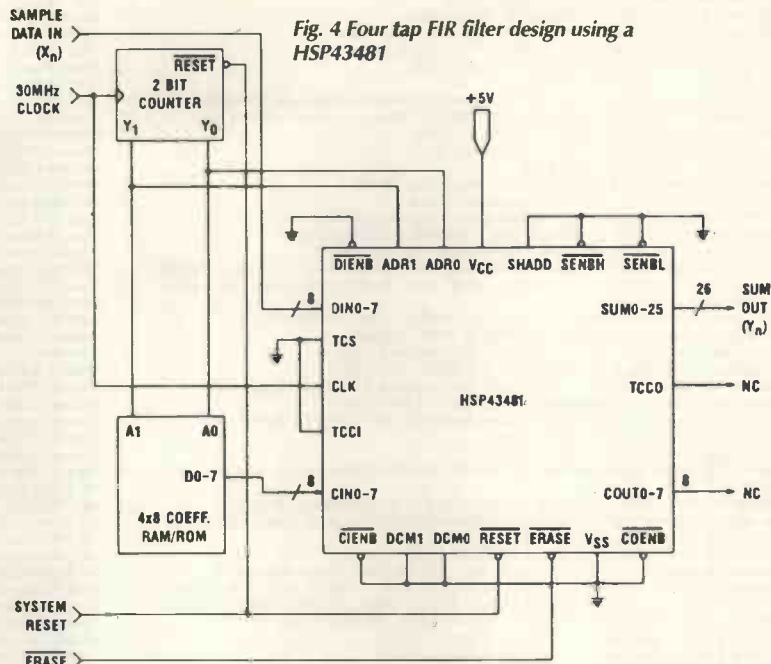


Fig. 4 Four tap FIR filter design using a HSP43481

{ x(0), x(1), x(2), x(3), x(4), ... }.

This task is distributed among the four filter cells. The coefficients are stored in the 4 x 8 rom or ram and a 2-bit counter is used to generate the addresses. The coefficients are passed to the HSP43481 from the ram/rom in the sequence

c3, c2, c1 and c0 via the CIN0-7 bus and after four clocks the sequence is repeated. After each clock, the coefficients are rippled

through the cells. The sequence of calculations is shown in Table 1. For more involved designs then a sequential controller will be required. High speed pals are quite capable of performing this task and it should not be too taxing to design the dedicated logic. There are several commercially available software design tools to assist in this task.

**Applications**

The HSP43481 is likely to be used in high speed image and signal processing. Real-

time image processing and digital video for television requires fast computational engines where the normal word size is 8-bits or less. The device can comfortably perform image smoothing, equalisation and feature enhancing (which requires high-pass 2-D filtering). The main problem which faces the design engineer is the need to reduce the DSP algorithms to actual sequential control events. Although not as convenient to use as a digital signal processor it is nevertheless a very impressive device.

**GLOSSARY**

**Decimation** – in a digital system (such as a digital filter) the output rate of data may be lower than the input rate. For example for every ten samples that pass into the system only one data output sample is produced. This is known as decimation and the ratio of the input to the output sample rates is called the decimation ratio. In the case of the HSP43481, it has decimation ratios of 4, 3, 2 or 1 (no decimation) which is enabled through the use of its decimation registers. Digital filters which operate in this manner are referred to as multirate filters.

**Finite Impulse Response filters** – commonly used digital filters where the output is only dependent upon the current input and previous inputs. It is unconditionally stable because none of the output samples are fed back. It is also called a non-recursive filter or an all zero filter.

**Overflow** – when performing fixed point additions it is quite possible for the size of the result to exceed the word width of the registers used to hold them. When this happens the condition known as overflow occurs. To avoid this it is necessary to perform frequent scaling of the numbers. The cost of the scaling operations is a reduction in the processor's bandwidth since time must be spent performing the scaling calculations. Motorola addressed the scaling issue when designing their DSP56000 processor by providing it with 56-bit accumulators which reduces the frequency of scaling

operations.

**Taps** – a digital filter can be constructed from an array of multipliers, adders and shift registers. For example, the filter,

$$y(n) = c_0 x(n) + c_1 x(n-1) + c_2 x(n-2)$$

may be represented with the shift registers, the multipliers and the adder. The term tap derives from the data taped off from each shift register in the filter.

**Vector Operations** – many signal processing operations do not deal with single numbers (scalars) but with arrays of numbers and calculations which involve numerical arrays are referred to as vector operations. Digital filtering is in fact a vector operation. A FIR filter can be represented as

$$y(n) = \sum_{m=0}^{m=M-1} c(m)x(n-m)$$

By using matrix and vector notation this expression may be rewritten as

$$Y = CX^T$$

There is a new version of C called Numerical C which has been specifically designed to manipulate matrices and vectors directly without having to address each individual element.

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# LETTERS

## Unkind cut

When I read the letter "Cable con trick cut by Occam's razor" (*EW + WW*, May), I wondered if part of our profession goes perpetually around in circles.

In essence these correspondents are saying "We can hear no difference between two audio components and the theoretical difference is, to our minds, insignificant; therefore there is no difference".

If there exists one mortal being who can hear the difference repeatedly under controlled conditions then it matters not what the rest of us believe. However, I cannot let the writers get away with the outrageous statement: "the figure (3dB) generally accepted as the smallest change detectable by the human ear".

Perhaps we do not inhabit the same planet but I don't listen to music consisting of single continuous pure tones. In my world it is accepted that broadband

differences of 0.5dB or even less are audible. After all a 1dB difference in level over 2 to 10kHz can, with a music signal, represent a significant difference in the overall energy in the room.

Many of those working in the audio industry develop quite acute sensitivity to differences but surely this is not surprising for the hunter develops great sensitivity of hearing and smell; just as a blender of tea develops very sensitive taste buds.

Unfortunately such constant practice often makes possible "party tricks" which can really annoy others. One of mine is to recognise two different loudspeakers from only the first note of a piece of music. Indeed I demonstrated this recently when fine-tuning a new loudspeaker design where two samples differed in the size of a resistor in series with the tweeter. This led to a difference of 1dB or so above about 3kHz with a consequent change to the harmonic structure and hence timbre of an instrument. Hearing the difference on the first

note is really no big deal and, given a little practice the other engineer on the project could identify the two loudspeakers accurately time after time.

**Stan Curtis**  
*St Ives Cambridgeshire*

## Speakers' corner

I am writing with reference to "Cable con trick cut by Occam's razor" (*EW + WW*, May).

Hi-fi equipment is used for the reproduction of music. The quality of reproduction is a subjective quantity which varies from one listener to the next. If speaker cables make the music sound better and if the difference justifies the cost, then they are a good buy. It doesn't matter whether the difference exists in objective terms or not, or if the good doctors can hear or measure it.

Some years ago, I replaced the internal wiring in a pair of speakers, and reinforced the crossover PCB

tracks by laying solid-core wire along them and soldering it on. I did one speaker first, then used a mono signal source for comparison. The difference was clear, although nothing else was changed. On a later occasion I changed my speaker leads from multi-strand to solid-core (both with cheap but reasonable quality plain copper conductors). Again, the difference was clear to me and well worth the cost.

As an electronics engineer and a hi-fi enthusiast, I am often frustrated by my inability to explain some of the things I hear. This does not mean that my perceptions are incorrect. They are, of course, subjective, and perhaps this explains some of the things I hear (or others don't hear). The remainder illustrates the imperfection of scientific theory.

Because of the subjective nature of hi-fi, the only reliable tools we can use are our ears, and common sense. If your correspondents can hear no improvement when using better cables, then they shouldn't buy them. I have had no experience with expensive super-cables, but I have heard clear and consistent differences between loudspeaker cables that should sound the same according to the theories of Doctors Blake-Coleman and Yorke.

**Stephen J Merrick**  
*Stockport*

## Saving batteries

With reference to Steve Winder's "Preset on time for battery equipment" (*EW + WW*, Circuit Ideas, April), if one assumes that the resistor, 10R is ten times the value of R, the circuit as shown will not work because the inverter will never discharge state.

In order to work, the resistor 10R must be much smaller than R so that C charges rapidly to the battery voltage. To set the inverter, the voltage on C must be greater than the upper trigger threshold of the inverter for the battery voltage. And 10R could be a low value of resistance to limit inrush current to the capacitor, such as 1kΩ. The unit will cut off when the voltage on C discharges to the lower transition limit for the inverter.

With this change it should save a lot of batteries in our battery operated test boxes.  
**Gaines M Crook**  
*Chatsworth California*

## CD...

How can the reversal of the mains live and neutral wires to an amplifier or CD player possibly affect sound quality – even though comments in two magazines suggested that this could make a worthwhile difference?

Surely there can be no rational justification for this claim especially bearing in mind that double-wound mains isolation transformers are almost invariably used. Such a claim is even more puzzling as it does not appear that any commercial profit could be made from it.

My second point concerns all those claims that various fancy gadgets, which range from damping rings to green pens, can improve the quality of the output from a CD player; I used the term quality rather than a more meaningful term as it is this word which almost invariably appears in misinformed articles.

I recorded the digital output from the head amplifier of a CD player (that is before error

correction) and after processing was able to determine that the residual error rate after error correction was insignificant. I then repeated the tests with the player on a vibration table driven with a swept frequency and at various amplitudes; finally a loudspeaker was placed close to the player.

It was not until the disturbance to the player significantly exceeded that which could possibly be experienced in practice that the residual uncorrectable error rate took an upturn. Several runs were compared and, predictably, there was a very small variation in the bit pattern as read from a given section of the disc.

But this variation was minute and well within the error correction capability of the system. Most importantly, there was no detectable change when damping rings, green pens and so on were tried.

Finally, I borrowed the cheapest and nastiest CD player that I could find; the results were the same.

**Roger Castle-Smith**  
*Hanslope Milton Keynes*

## ...Or not CD

Ronald Young in his letter "CD or NBG?" (*EW+WW*, May) has missed the point of the compact disc completely. The human ear responds best to mid-frequency, so to cut a very long and involved story short we boost the LF and the HF in the pre-amp so to the ear it sounds level (a true level response sounds terrible).

If you emphasise a cassette recording to hear the

HF you run into noise; with a capital N. What I tend to do when forced for convenience away from my Ferrograph is to use emphasis on the recording. As yet I am not an owner of a CD player but have played with my sister's and all I can say to Mr Young is that the system sounds brilliant, long live digitisation.

**Peter Chadwick Gregory**  
*Ashton-Under-Lyne*

## E wakes up

With reference to John Ball's letter "E=Zzzzzz<sup>2</sup>" (*EW + WW*, June), it is not so much whether photons exist as waves, but how many cycles of waveform would be representative and whether or not the waveform may be modulated!

**J Glazer**  
Rochester  
Kent

## Tailoring op amp noise

In the article "Operational amplifiers, the supreme activators" (*EW + WW*, April), Robert Pease gave some good advice concerning troubleshooting in operational amplifier circuits. One of his suggestions, however, seems to be a trouble enhancer, and I wonder if one could think of any situation where his idea could be considered a good idea.

The suggestion in question is to insert a resistor between the op amp input terminals in a standard inverting amplifier circuit. The purpose of this circuit modification is claimed to be tailoring the noise gain, and, as correctly stated in the article, the noise gain can be raised in this way, namely because the attenuation in the feedback path is increased.

But this purpose is a highly dubious one to pursue. The noise gain is a factor assigned to each noise source in a circuit for the estimation of its contribution to the output noise. The problem is that the noise factor can only be raised by the suggested modification, not reduced.

If the op amp gain is sufficiently high the circuit gain will not be influenced by the resistor inserted, but the performance of the amplifier will be deteriorated as follows: noise contribution from the op amp is increased; the resistor inserted adds extra noise to the circuit; the loop gain of the amplifier circuit is reduced which means that the bandwidth is reduced; and the feedback reduction of nonlinearity, output impedance will be decreased as well.

In the article the inverting amplifier was given as an example, but the same deteriorations will take

place in any circuit where the operational amplifier is used with feedback as in integrator circuits, filters, and so on. In conclusion, inserting a resistor between the op amp input terminals should not be recommended.

**Ole Trier Andersen**  
Electronics Institute  
Technical University of Denmark

## Walking the Planck

Immo Bock is right in his letter "Variable Planck" (*EW + WW*, May) that in my article "Gravity and electric force link up in black hole?" (*EW + WW*, February) I used a Planck's time which differs from the currently known value by exactly  $\pi/2$ . The number we find in the books, however, does not represent an experimental result but is merely a mathematical value.

The same we may say for Planck's mass and length and, to quote R Cohen, "the physical significance of these quantities is not clear". The real Planck's time might even be  $\pi+2$  times larger.

On the other hand I could have simply stated that  $F_g/F_e \pi+2$  is 0.2% different from the currently known Planck's time; the result is the same.

As regards Bock's equation on the electron potential, it might be interesting to see how he gets the ratio  $F_g/F_e$ . With the scarce data supplied I did not go very far and I would be happy to exchange information.

In any case it is an absolute must that all calculations are carried out with the highest precision and the most accurate values used for the constants. I once ran a 14 digit calculation program but the poor resolution would give misleading results. The 20 digit precision I use at present seems to be adequate.

Bock might try the accurate value for the constant  $G$  using the equation below (the one in the original article had a printing error):

$$G = c^5 a^2 (2 - a)^2 (e/4\pi^2)^4 / \pi h$$

Another equation he might find useful is the one giving the fine structure of the constant  $\alpha$ :

$$\alpha = (2\pi^2/c)(\pi/c)^{0.5}(2G/h)^{0.25}(c/\pi h G)^{0.0625}$$

This is 0.02% different from the real value due to approximations in the description of the black hole electron.

**D Di Mario**  
Milan  
Italy

## Firm belief in EM healing

I couldn't get into all the jargon in "The healing face of electromagnetic fields" (*EW + WW*, April) but whenever this subject is occasionally raised it separates the scientists from the engineers.

Scientists generally retreat to their text books which cannot explain adequately the effect of these fields on the body. Just as the bumble bee is not supposed to be able to fly, electromagnetic fields (weak ones rather than strong ones) are not supposed to have any detrimental effect on the body.

Enter the engineers. They carry out experiments to find the truth. Build a piece of equipment and then get the engineers, scientists and doctors together. I know of some success stories but in my opinion there are not enough of them.

Our bodies work electrically, magnetically, and electromagnetically. For example, millivolt pulses flash along neurons to send messages to our brains. Magnetic fields of 3000 gauss can anaesthetise a salamander, so what can it do to us?

In the 1970s, pulsed electromagnetic fields were used to speed up bone fractures by placing coils sheathed in plastic pads around the limb while sleeping. Low and high DC and pulsed EMFs all have similar benefits in treating fractures. But why is this cheap treatment not available on the NHS to make more beds free for other patients? What happened, for example, to equipment such as Lakhovsky's HF EM field generator which cured the Pope of cancer in the 1930s?

I have read of such treatments considerably improving various conditions from rheumatoid arthritis, migraine, depression, alcohol craving, and blood cholesterol to cancer. We can buy pills over the counter to do all sorts of things to us, so why cannot we find any electrical or electronic equipment?

Gone are the days when fancy electrical gizmos claimed cures for just about everything.

Some questions that need answering are:

1. Some people are allergic to EM fields. My wife is one of them, she gets a headache near overhead lines. But do they affect the rest of us in a subconscious way too?

2. My wife and I get repeatedly lost in the town of Cumbran. My EM field meter shows that there are concentrations of EM fields in the town far higher than for overhead lines. Is this the cause and could it have more widespread implications?

3. Why are there more psychiatric admissions just after magnetic disturbances to the Earth's geometric field?

4. Is it a coincidence that the last six peaks of the 11 year sunspot cycle have coincided with major flu epidemics?

5. Does travelling on electric trains, including the underground, have any effect on us?

All matter is ultimately an EM phenomenon. The world consists of atomic structures held together by EM forces. The human body is a conglomerate of such structures. Once upon a time, the only radiation affecting us was from the Earth, Sun, and planets.

Now, the density of radio waves around us is about 100 million times the natural level. Who can say what we are turning into? I say come on engineers (and you analogue electronic experts) devise equipment to measure these effects, help our health, and raise our status to that of doctors and scientists. Let us put electronic medicine on the map.

**John Carver**  
Nantyglo  
Gwent

## Catt out of the bag

Ivor Catt is unlikely to receive any response to his challenge to classical electromagnetic theory (*EW + WW*, May) because the anomaly to which he referred in 1987 is explicable in terms of phase quadrature at the level of quanta. It is already axiomatic that only the phase of the magnetic field vector is reversed when an electromagnetic signal is subjected to 180° reflection onto itself. The electric field vector is then, by definition, the geometrical

location of potential energy which remains unaltered at the instant of reflection.

The phase reversal of the magnetic field vector, however, necessarily entails a shift in space of the reflected signal by a distance equivalent to half a wavelength at the frequency of oscillation, bringing a 180° reflected signal into parallel antiphase with its incident signal, as required by quantum theory (linear phase conjugacy).

The summation of successive nodes and antinodes then needs to be taken into account in relation to the quantised directional components of rotation (circular polarisation) of the incident and reflected signal quanta. These act as alternating reference and differential phases, yielding a condition of quantised diphasic 270° quadrature. The axioms of differential computation in phase conjugate quadrature, a new machine mathematic, are being developed on the basis of these considerations as an expression of electronic holography.

**Brian Clement**  
Powys

## Red reconciliation

I was pleased to see from the letters in the April issue that at least two readers appreciate my difficulty in reconciling an invariant speed of light with the Doppler effect, the cause of the red shift.

I cannot go so far as Arenon Goldberg does in concluding that Darwin was wrong and that the universe is only a few thousand years old - he has an uphill task before him to convince readers of this and of a geocentric universe.

John Ferguson, however, combines mathematics with plain English (a refreshing change!) to cast doubt on the constancy of the speed of light, although he does so in the case of radiation transverse to the direction of motion of the source.

My concern is with the simpler case of radiation between source and observer where the source is travelling directly away from the observer and no transverse motion is involved. It seems to me that, in such a case, if a Doppler shift is in fact observed then the observer must perceive the speed of light from the source as  $c - V$ , which is incompatible with the constancy of the speed of light.

What is more interesting than the correspondence received is the absence of any response from those who believe in the constancy of the speed of light. Surely it must be a

simple matter for those who support the conventional viewpoint to demonstrate the errors of my thinking?

I look forward to hearing more on this subject.  
**Martin W Berner**  
Trinidad

## Relatively mixed standards

I find it hard to understand all this song-and-dance about special theory and the speed of light. Agreed that Einstein's second postulate is a general one and as such has admitted shortcomings, but special theory is by no means general - the first postulate sees to that. The shortcomings of the second can only be relevant to the theory if they persist within the strict limitations of the first. Which they don't.

The first limits the theory to "all frames of reference for which the equations of mechanics hold good", in other words to the same basic reference system which underlies all classical Newtonian mechanics, the Galilean inertial reference system (GIRS). This has to be so since it is only within this system that Newton's principle of relativity is completely valid.

The GIRS requires all frames to be in Galilean inertial motion, without rotation and in flat Euclidean space. Galilean inertial motion is inertial motion in the complete absence of gravitation. Since the majority of the objections to the second postulate are based on the alteration of the speed of light due to gravity, or on rotation (for example, the Sagnac effect), it is clear that they do not occur within the GIRS, so are irrelevant to the argument.

When Newton overlaid the GIRS with his gravitational theory, he did so under the impression that there would be no secondary effect which would invalidate the idea. Equally in 1905 Einstein did not suspect trouble, but by 1911 he had learnt better. His own theory had alerted him. He had played the same trick as Newton, and for the first time the result showed up that light must be effected by gravity.

Worse still, he realised that gravity destroyed the Euclidean flatness of space, making the concept of "straight lines" meaningless. In his book "Relativity", which first came out in 1916 (the original German language version), Einstein pointed out that his theory "cannot claim an unlimited domain of validity; its results hold only so long as we are

able to disregard the influences of gravitational fields on the phenomena (eg of light)".

Einstein did not go on to point out, as he might have done, that precisely the same must be said of Newtonian theory, as gravity and the GIRS are mutually exclusive. Since we are only too prone to ignore this for Newton, we really ought to turn the same blind eye towards Einstein, or else publicly admit to possessing double standards. Wherever Newtonian theory works, special theory does too. And in some cases it works where Newtonian theory fails, as most high-speed particle physicists will tell us.

**Alan Watson**  
Mallorca  
Spain

## Have the twins gone with the wind?

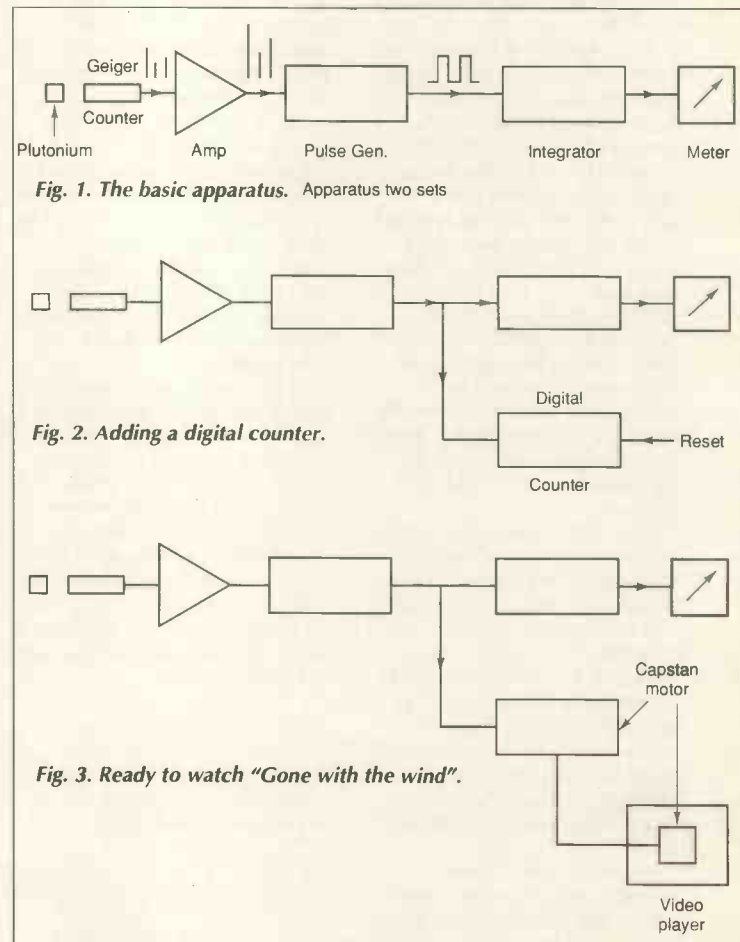
Of all the bizarre ideas that the theories of relativity and quantum wave mechanics present for our consideration, one is preeminent. It concerns two twins, let us call them Jack and Jill. Jill undertakes a journey at close to light speed. It is

concluded that Jill will not have aged as much as Jack.

The capricious idea that they could undergo any process in which one of them grows older slower than the other is, in normal circumstance, unacceptable. However, when the circumstances include the acceptance of the idea by virtually all the scientific experts, common sense conclusions may have to be abandoned. They will definitely have to be abandoned if one wishes to survive in the profession of a theoretical physicist.

However, all the arguments I have encountered for the so-called twins paradox have one thing in common. They all attempt to resolve the problem, that is essentially one associated with time and its passing, by using arguments that include the word time. Attempting to define the nature of time using the word time is an illogical step and is certain to lead to confusion and failure.

My argument takes the form of a thought experiment. Start by dividing into two equal parts a small piece of radioactive substance with a half life longer than about a year, say plutonium. The rate at which it radiates particles will not vary in a detectable way during our experiments.



Next construct in your mind two identical sets of apparatus (Fig. 1). A geiger counter is placed to respond to the radiation and gives out an electrical signal whenever an ionised particle issuing from the plutonium passes through it.

After amplification, the resultant signal triggers a fixed period pulse generator (monostable). The output pulses of the generator are then smoothed out by an integrator circuit, the integrator's output being displayed on a moving coil meter.

The amount of plutonium and other adjustable parameters are selected to give a full scale reading. As the two sets of apparatus are identical, they give the same reading.

Jack and Jill take one set each and monitor them constantly (Jack at home and Jill on the journey). Jill travels at a constant speed of 0.866 times the speed of light. Let us assume that acceleration has no detectable effect, a condition that can always be met if the trip is long enough.

Jill's reading of her meter would

be the same as it would if she were stationary. When she returns both sets of apparatus are modified by the addition of a digital counter connected to the pulse generator's output (Fig. 2).

Again Jill goes on the same trip, but just before she leaves the counters are reset to zero. Since the meters will again always read the same both counters must also display the same number. Reunited again Jack and Jill find both their counters have the same reading. During their next separation they decide to watch a video. As far as Jack is concerned the trips take about 3.5h so he selects "Gone with the wind". An output is connected from the counters to control the stepping motor that drives the capstan of their respective video players (Fig. 3). Both start the video just as Jill leaves.

Jack has seen Rab Butler leave when Jill returns, but does Jill know if Rab cares a damn or not?

If we were to accept the interpretation of devotees of the special theory of relativity, then Jill

would still be watching the burning of Atlanta – that is time would have passed at only half the rate for Jill compared with Jack. But as simple souls who have a considerable experience with electronics, we know better.

Jill and Jack have had the same amount of experience, that is each watched all of the same video and did nothing else. It follows that having had the same amount of experience they will also have grown older by the same amount. This analysis will remain true no matter how long a distance a trip Jill takes.

If they had started identical clocks as they began to watch their videos would they have had different readings at the end? I think not.

Notice that the word time has not entered into my argument. It has been used directly or indirectly but only in stating the views of the realtivists and the conditions they specify. It has not been used in the argument that proves them wrong regarding the differential time issue.

I am not suggesting that all the

ideas in theory of relativity are wrong. The twins problem was never advanced by Einstein and has been shown not a paradox at all but the result of the use of an undefined word.

Some people will insist that real experiments have shown that time passes slower for things that travel at extremely high speeds. The experiments are fine but the interpretation is flawed. Take for example the one in which a very accurate caesium clock is flown round the world and found to give a smaller elapsed time reading than another caesium clock that has remained stationary. The man who invented this type of clock has said they are not accurate enough for a definite conclusion to be formed.

Now the really sad ending. However many times Jack and Jill recount their experiences, diehard establishment scientists are unlikely to be moved to reconsider their views.

*David A Chalmers*  
Finchley  
London

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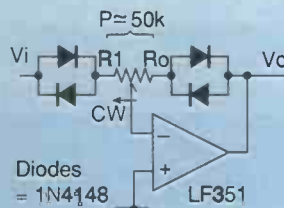


Fig. 1. Simple log. amplifier with adjustment from exponential, through linear, to logarithmic characteristics.

be varied by the addition of further resistance in series or parallel with the diodes.

C J D Catto  
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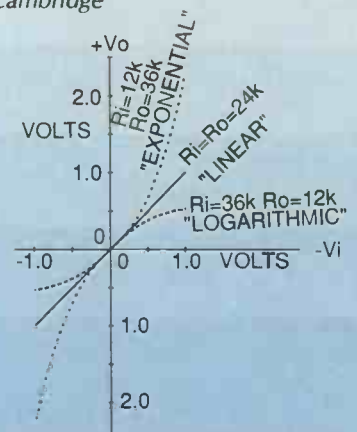


Fig. 2. Transfer characteristics of the Fig. 1 circuit with various pot. settings. Curves can be modified by resistance in series with or across diodes.

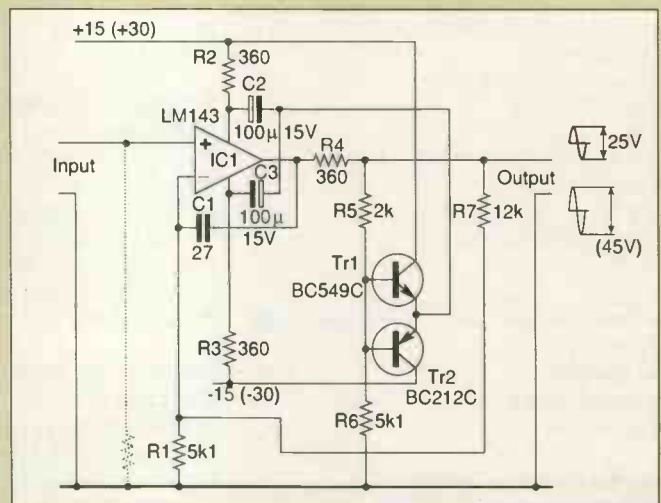
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*Emitter follower provides floating power supply to increase op-amp output swing by a minimum of 1.8 times, improving slew rate and leaving THD unaffected.*



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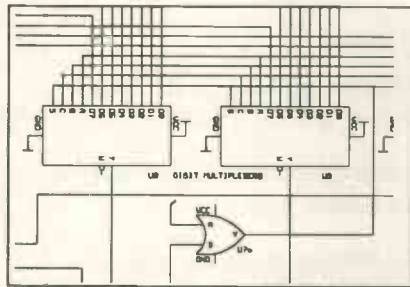
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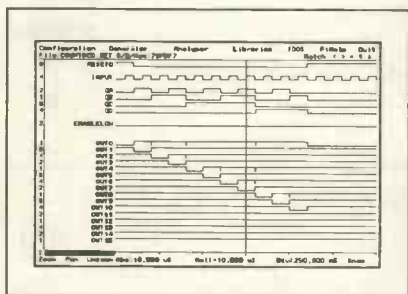
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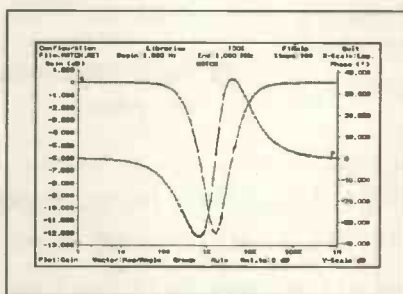
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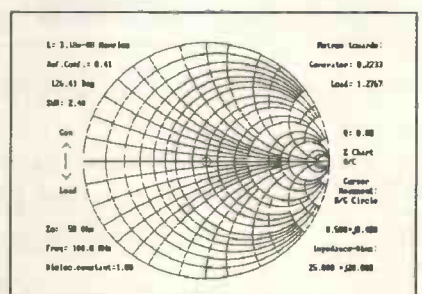
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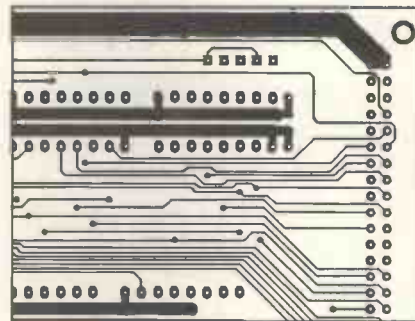


Z-MATCH II

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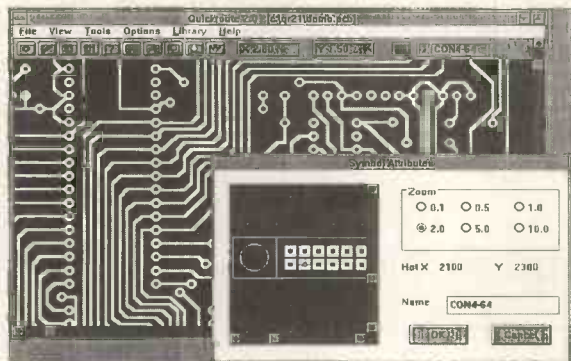
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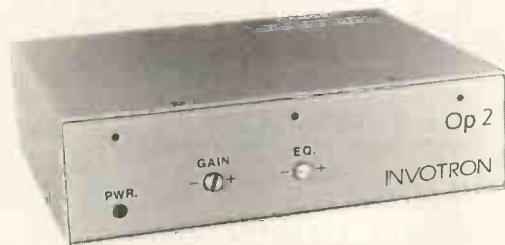
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# NEW PRODUCTS CLASSIFIED

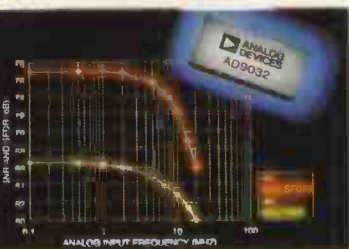
## ACTIVE

### Discrete active devices

**3.3V delay line.** Lerox's *98800* series 5 5-tap digital delay line uses 3.3V logic and drives 75Ω loads. Total delays are up to 600ns, the taps being upwards of 10ns. Packages are either 8-pin dip or surface-mounting types. Active Electronic Labs Ltd, 0926 484050.

### Linear integrated circuits

**Video op-amp.** Analog's *ADEL2020* is a second-sourced Elantec *EL2020* with 80% greater bandwidth, 30% less power consumption and improved output drive. Analog's device has a -3dB bandwidth of 90MHz, with 25MHz 0.1dB gain flatness, differential gain error 0.02%, diff. phase error 0.04% and voltage noise 2.9nV/√Hz Analog Devices Ltd, 0932 232222.



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

**25.6Msample/s ADC.** Claimed to be the fastest 12-bit analogue-to-digital converter with its own track/hold amplifier, Analog's *AD9032* offers guaranteed sampling rates from DC to 25.6Msample/s. It is ECL-compatible and needs no external circuitry. Signal-to-noise ratio is 64dB, with a dynamic range to 74dB without spurious response for bandwidths to 12MHz. An evaluation board is available. Analog Devices Ltd, 0932 232222.

### Single-supply dual op-amp. OP-213

is a dual op-amp by Analog offering 5nV/√Hz voltage noise, 100μV voltage offset and typically 0.2μV/deg. C voltage drift. It is therefore suited to applications in which initial offset and gain can be coped with, but in which drift is a problem. Gain-bandwidth is 3.4MHz and slew rate 1.2V/μs. Analog Devices Ltd, 0932 232222.

**Vari-gain amplifiers.** Higher performance and lower cost than in earlier versions are claimed for H-P's *IVA-14228* and *IVA-14208* MMIC silicon bipolar variable-gain amplifiers. Operating bandwidth is 2.5GHz or 3.4Gb/s on data; gain 24dB; control range 34dB; control response less than 10ns. Both input and output can be single-ended or differential. Hewlett-Packard Ltd, 0344 362277.

**3V linear devices.** TI has a family of op-amps, comparators and voltage regulators characterised for 3.3V working and packaged in the thin shrink small outline package (TSSOP). There is the regulator and a single op-amp, the rest being dual and quad packages, all of which operate down to 2V single-ended. Texas Instruments, 0234 223252.

### Logic building blocks

**Taxi chip.** AMD announces volume production of a 275MHz taxi (transparent asynchronous transmitter/receiver interface), a serial interface to cope with ESCON, ATM and fibre channel standards for data at 275Mbaud. Once the data has been transmitted, the receiver translates the data back to parallel form to eliminate data bottlenecks. Advanced Micro Devices UK Ltd, 0483 740440.

**Digital synthesiser.** Waveform synthesis, modulation and demodulation are the functions of the *TMC2340* by Raytheon, which offers frequency resolution of 0.006Hz at the maximum 12.5MHz output frequency. By selecting 15-bit amplitude and 32-bit phase increment values, quadrature matched pairs of 16-bit sine and cosine waves are produced in DAC-compatible 16-bit offset binary form. Outputs can be frequency, phase or amplitude modulated. Ambar Components Ltd, 0844 261144.

**Fastest cmos DDS.** Claimed to be the industry's fastest cmos direct digital synthesis IC, Analog's *AD9955* runs at up to 100MHz. It combines a 32-bit phase accumulator and a 15-bit



phase-to-12bit sine amplitude converter in an 80-pin PQFP. A clock and a D-to-A converter complete a two-chip DDS. With 32bit frequency resolution, 12bit sinewave resolution and a dynamic range of more than 90dB without spurious outputs, the chip dissipates 600mW with a 50MHz clock. Analog Devices Ltd, 0932 232222.

**5.5GHz prescalers.** Silicon bipolar MMIC divide-by-4 frequency dividers by H-P, *IFD-53110/53010*, work up to 3.5GHz and 5.5GHz respectively. Sensitivity is typically better than -15dBm, power output -5dBm, 1kHz offset phase noise -143dBc/Hz at 3GHz and 50mA operation. Hewlett-Packard Ltd, 0344 362277.

**Fast, low-noise cmos.** A new logic family, the VHC cmos range, is claimed by National to offer the industry's lowest noise performance, low power, 3V and 5V working and a fine-pitch surface-mount package; it is meant to supersede HCMOS devices in equipment needing high speed and these attributes. Propagation delay is 8.5ns and output drive from high to low is 8mA, with a power consumption of 0.01μW. National Semiconductor, 0793 614141

### Memory chips

**4Mbit sram.** The *SYS8512FK* 4Mbit static ram by Syntaq emulates the JEDEC type, but has a much lower price. It is a 512K by 8 device, consisting of four 128K by 8 sops, incorporating on-board decoding and decoupling. Access times of 55ns and 70ns are available, but standard times

**Pin diodes.** In SOT23 packages, Zetex's *FMMP3000* single and dual pin diodes have capacitances from 300fF to 1pF, are rated at between 50V and 200V and a series resistance at 1mA or 10mA, depending on type, between 0.5Ω and 100Ω. As voltage-controlled attenuators, their useful range is 50MHz-3GHz. Zetex plc, 061 627 4963.

are 85-150ns. Power consumption is 80mW (0.4mW on standby) and there is a low-power type with a standby power of 40μW. Syntaq Ltd, 0670 731866.

### Microprocessors and controllers

**Low-power microcontroller.** Although an 9-bit device, Hitachi's *H8/300L* family of microcontrollers require only the power of 4-bit designs. These units are based on the established *H8/300* series and offer clock rates to 5MHz to obtain a cycle time of 200ns. Development tools include a C compiler and the options of Hitachi's real-time operating system (HIOS) or fuzzy logic. In "sub-active" mode, current consumption is 10μA. Hitachi Europe Ltd, 0628 585000.

### Mixed-signal ICs.

**Reed Solomon error correction.** LSI's *L64712/13/14* family are Reed Solomon error correction devices for low-cost application to data communications such as cable



television, HDTV, DBS and others, also finding application in digital VCRs, digital video laser discs and other mass storage devices. Encoding is provided by the L64711. LSI Logic GmbH, 010 49 89 99 313 0.

**DTMF transceiver.** Mitel's MT8880C integrated DTMF transceiver is a CMOS device with low power dissipation and high reliability. D-to-A conversion is by a switched-capacitor technique for accuracy and low distortion and internal counters provide a burst mode to allow tone bursts with precise timing. A call-progress filter is selectable. Mitel Semiconductor, 0291 430000.

**DTMF receiver.** Mitel's MT8870D is a fourth-generation DTMF receiver which contains both band-split filter and digital decoding. It also has a differential input amplifier, clock oscillator and latched, three-state bus interface. The device is compatible with the earlier MT8870C. Mitel Semiconductor, 0291 430000.

**V.32bis chipset.** Samples of Rockwell's new RC96ACi and RC144ACi devices, forming a low-cost V.32bis modem chipset, are now being dispatched. They are intended for the PC market and reduce costs by avoiding the need for external memory, glue logic and the optional 16550 UART for use in the Windows environment. Rockwell Digital Communication 010 33 93 00 3301.

**Audio codecs.** Crystal Semiconductor's CS4248 and CS4231 are stereo, 16-bit, multimedia audio codecs for computer systems, pin compatible with Analog's AD 1848 but with enhancements such as 4:1 ADPCM compression/decompression. Software, including Windows drivers, is to be available. The aim of the system is to make available CD quality sound from PCs. Sequoia Technology Ltd, 0734 311822.

**Power semiconductors**

**Motor driver IC.** Driving both windings of a bipolar stepper motor or

**EMI test receiver.** ESM1 by R&S combines the facilities of a test receiver and a spectrum analyser. It makes EMC measurements in the 20Hz-26.5GHz range to conformance with standards including CISPR, VDE, FCC, EN, VCCI, MIL, VG, DEF-STAN, BS, DO 160 and GAM EG 13. It has a number of detectors for maximum, minimum, average, RMS and quasi-peak readings and built-in sine and pulse calibration sources. Rohde & Schwarz UK Ltd, 0252 811377.

bidirectionally controlling two DC motors, the SLA2918 from Allegro is a dual, full-bridge motor driver IC in which both bridges sustain 45V and include PWM output current control to 1.5A. Ground clamp and flyback diodes are incorporated and there are dead times to prevent crossover currents. Allegro Microsystems, 0932 253355.

**Schottky barrier rectifiers.** In both leaded and surface-mounting form, ITT's 1N5817/8/9 are 1A devices with a p-n junction guard ring for protection and handling peak inverse voltages of 20/30/40V, Surge forward current is 25A at half cycle and forward voltage drops are 0.45/0.55/0.6V at 1A, reverse current being 0.1mA at 20/30/40V. ITT Semiconductors, 0932 336116.

**Step-up converters.** With an efficiency of 85% and quiescent current of 95µA, the MAX756/7 converters give a 5V output from 3V input. The pulse frequency modulation control used combines the power and efficiency of pulse width modulation with the low current of the pulse-skipping type of PFM. Inputs can be down to 1.8V or 0.9V at reduced current output, which is normally 200mA or 300mA, depending on output voltage. Maxim Integrated Products Ltd, 0734 845255.

**4A switching regulator.** Switching at 100kHz, the Linear Technology LT1269 can be used as a boost converter, a PC power supply with multiple outputs, as a battery up-converter and as a negative-to-positive converter. The 4A switch, oscillator, control and protection circuitry are all on one chip. Supply voltage is between 3.5V and 30V and current drawn is 7mA. Micro Call Ltd, 0844 261939.

**Power fet.** Less than 10mΩ on resistance is claimed for Motorola's MTB75N05HD high cell-density power fet, which has a maximum constant current of 75A at up to 175deg. C while dissipating 150W. Motorola Ltd, 0908 614614.

**Multiple power chip.** Eight low-side drivers in the Texas TPIC2802 Octal power IC offer enhanced reliability. Each is a darlington stage and needs only 50mA drive current and dissipating 20mW in standby mode. Outputs sink 1A each simultaneously, with 45V transient clamping and 20mj rating. An 8-bit shift register feeds an 8-bit parallel latch for independent output control; data is entered serially via the serial input. Texas Instruments, 0234 223252.



**Passive components**

**Chip trimmer capacitor.** AVX claims its CTZ2 series of trimmer chips to be the smallest available, measuring 3 by 2.5 by 1.3mm maximum. They are the washable type with an open trimmer and a maximum value of 20pF. Solder reflow up to 240°C is possible, with or without a wash condition, depending on the version. AVX Ltd, 0252 336868.

**Small HF electrolytics.** "Marathon caps", miniature aluminium electrolytics by Waycom, are designed for applications in which low impedance and ESR are needed at high frequencies and at temperatures from -55°C to 105°C. Values are between 0.47µF and 15,000µF at ratings from 6.3V to 100V. Acal Electronics Ltd, 0344 727272.

**Surge suppressors.** Transient voltage suppressors from Harris for automotive use can withstand a 24.5V jump start for five minutes and up to 24J of transient energy, yet take up less than half the board space of a Zener. They are intended to protect against spikes from car systems including wiper motors and other

inductive devices, the most severe being spikes caused by alternator load dumps when a battery becomes disconnected. Device types are V18AUMLA1210 (3J), V18AUMLA1812 (10J) and V18AUMLA2220 (25J). Harris Semiconductor (UK), 0276 686886.

**Small coils.** William Hughes has new coil-winding machinery capable of manufacturing air-cored coils around 2mm diameter in wire down to 0.2mm diameter. Ferrite cores can be fitted and leads formed to suit individual applications, tinned if necessary. William Hughes Ltd, 0747 52235.

**Connectors and cabling**

**Audio connectors.** Deltron 7000 audio connectors use push-in colour buttons and rings for speed in connecting large patch panels. A squeeze clip allows rapid, single-handed un-mating and assembly requires no tooling or loose screws. These connectors are compatible with XLR types and are available with 3, 4 or 5 contacts in ratings from 7.5A to 16A. Verospeed, 0703 644555.

**Displays**

**Flat-panel displays.** Planar's multi-colour flat displays meet the full VGA standard of 640 by 350 pixels, combining red, yellow, green and intermediate colours to provide an eight-colour palette. The panels measure 226 by 153 by 16.5mm to give a viewing area of 179 by 122mm and weigh 380g, using 16W. Viewing angle is 140°. Planar International Ltd, 0344 762261.

**Filters**

**EMI suppression.** At 3.2 by 1.25 by 0.7mm, the NFM40R noise suppression filters are claimed by Murata to be the world's smallest. They are based on the three-terminal capacitor principle and operate up to 1GHz, being available in capacitance values from 22pF to 22nF. They are non-polarised. Murata Electronics UK Ltd, 0252 811666.

**Instrumentation**

**Three DSOs.** Digital storage oscilloscopes from Amplicon, the 20MHz OX7520-2 and the 30MHz OX7525 and OX7530, are dual-channel types with 2 by 8K (7520) and 4 by 8K memories, all having RS232/HPGL output with autoplots. The 7520 and 7525 have 2kV accelerating voltages, while the 7530 has a higher resolution 10kV PDA. Sample rate is 2 by 20Msamples/s and there are dual 8-bit converters with 2Kword memory; roll refresh and single displays; and 50% pre-trigger. Amplicon Liveline Ltd, (Free)0800 525 335.

**RF test.** A basic set of RF and microwave test gear by Atlantic is meant to give easy-to-use measurement facilities where simple, repetitive testing must be done. Signal sources from 5MHz to 110GHz with various options, amplifiers in broad-band or narrow-band form from 5MHz to 45GHz, switching and white noise sources are all included. Atlantic Microwave Ltd, 0376 550220.

**Garrulous DVM.** When one is too busy holding the probes to read the meter, Maplin's talking digital multimeter could be the answer. It makes an announcement when a probe button is pressed or when either the reading changes or the range or function is changed. A memory switch records measurements or recalls the last memory entry. Maplin Electronics, 0702 554161.

**Hand-held DSO/meter.** Series 90 Scopemeter by Philips is a combination digital storage oscilloscope and digital multimeter, which is now enhanced by a software upgrade to version 4 to give increased measurement resolution and other facilities. Voltage, frequency and duty cycle readings are continuously displayed in Meter mode. Top model in the family, the PM97, includes a signal generator for square, sine and ramp waveforms and an optically isolated RS-232 interface. Philips Test and Measurement, 0923 240511

**RF signal generators.** Two Lodestar signal generators, SG-4160B and SG-4162AD, cover the 100kHz-150MHz range on fundamental and up to 450MHz on third harmonic, generating 100V RMS via a switched attenuator and continuously variable level control. 30% AM modulation at 1kHz is internal and a socket allows external drive. The 4160 has an analogue dial, while the 4162 indicates frequency digitally. Saje Electronics, 0223 425440.

**Colour DSOs.** Tek's new TDS 544A and TDS 644A digital storage oscilloscopes offer a colour display by means of a liquid-crystal colour shutter in front of a monochrome CRT for enhanced colour purity and better convergence. The unit includes a floppy disk drive to provide a PC with PCX, BMP, EPS or TIFF files, video triggering from any broadcast format up to HDTV1 125/60, FFT averaging and expanded template testing to include maths waveforms. Real-time bandwidth is 500MHz in four channels and sampling rate is up to 1Gsamples. Tektronix UK Ltd, 0628 486000.

**Television measuring Rx.** ITT's VX600 is a receiver meant for measurements during installation and test of television aerials, cable

systems and satellite dishes and is available in PAL-BG, Secam-L and Secam-DK versions, all having D2MAC and digital sound as options. The instruments comprise field-strength measurement at VHF and UHF, satellite and FM frequencies, a monitor for video testing and a spectrum analyser. Thurlby Thandar Instruments, 0480 412451.

**Hand-held DSO.** Leader's model 300 is a hand-held instrument comprising a digital storage oscilloscope, an auto-ranging multimeter and an eight-channel logic probe. The 'scope is a two-channel type sampling at 30Msamples, displaying on a super-twist nematic LC screen. Up to ten traces per channel can be saved, a memory card adding up to 40; memory length is 180 words or 1800 words. Auto setup optimises the display. Data-logging is provided. Thurlby Thandar Instruments, 0480 412451.

**Noise figure meter.** Maury Microwave's MT2075B gives simultaneous gain and  $\pm 0.05$ dB noise figure of linear circuits, corrected for system noise, cold reference temperature, noise generator output variation with temperature and frequency-dependent insertion loss, in the 10MHz-1850MHz range. No external mixers, local oscillators or preamplifiers are needed. Tony Chapman Electronics Ltd, 0378 78231/2/3/4.

**60MHz oscilloscope.** The 9016 60MHz dual-timebase instrument from Wavetek (formerly part of Beckman) offers multiple triggering and other features commonly found in more expensive equipment. It has a delay line for leading-edge viewing, a 5ns/division horizontal resolution and 12kV acceleration voltage. Various sweep modes are available and there is a component tester built in. Wavetek Ltd, 0384 442393.

### Interfaces

**Re-mappable keypad.** Icon Board by IGT is a universal re-mappable keypad for use when the application interface needs frequent reconfiguration. It is made in 256-key A3 and 256-key or 64-key A5 versions, the layout being definable by software to 128 and 32 keys. It generates standard ASCII output or user-definable codes, all keys being software-definable. Intercept and setup software is provided and the units interface directly with PCs, Macs, BBC micros, Commodore and others. Industrial Graphic Technology, 0703 701881.

### Literature

**RS-232 chips.** An application note from Analog, AD2XX Family for RS-232 Communications, details a range



of ICs designed for the purpose, all meeting or exceeding the relevant standards, including EIA-232D. Analog Devices Ltd, 0932 232222.

**Transformers.** Control circuit and isolation transformers by Douglas cover the range 25VA to 10kVA, with specials up to 100kVA, as detailed in the a new brochure. Douglas Electronic Industries, 0507 604008.

**Farnell catalogue.** 2500 new items in Farnell's electronic component catalogue takes the range up to 30,000 in total, all of which are available from stock. A notable addition is a range of pneumatic equipment, including filters, regulators, air cleaning equipment and miniature cylinders for linear movement from compact packages. Farnell Electronics plc, 0937 587241.

**RF transistors.** A book entitled "Radio Frequency Transistors — Principles and Practical Applications" by two Motorola engineers contains a summary of wide-band matching techniques, RF power fets, design and construction techniques and small-signal circuit design using s-parameters. It has 288 pages and costs \$39.95. Motorola Inc., (USA) (800)441-2447.

### Power supplies

**750mW DC-to-DC converter.** In single or dual in-line packages, Acal's UMS/UMD 750mW converters are PCB-mounted types with input/output isolation to 500V DC. Inputs are 5V, 12V and 24V DC to give single or dual outputs of 5V, 12V, 15V or  $\pm 12$ V and  $\pm 15$ V at up to 80% efficiency. No output capacitor is needed. Acal Electronics Ltd, 0344 727272.

**Battery scanner.** Intended for scanning the voltage of large numbers of cells for standby power, BCH's 921 scanner is permanently connected to the cells, data being collected by a Psion and later downloaded to a PC for analysis. Safety features include audible and visible alarms for overvoltage and reverse voltage. BCH Communications Ltd, 0827 717558.

**Twin pulse generator.** Two independent pulse generators in Levell's 233 50MHz instrument provide up to 10V positive or negative output into 50 $\Omega$ . A and/or B pulse width, square setting, external width and DC level are adjustable, all outputs being invertible and combinable with no amplitude loss or reflection. An oscilloscope trigger output is adjustable for level and slope. ITM Ltd, 0202 872771.

**Universal PSU.** Davtrend power supplies used by Feedback in swipe-card devices have been rationalised to make one type fit most of the terminals, with a view to saving in stockholding costs. Two outputs are provided: 5V at 1.5A and 13.8V at 300mA, automatic mains-failure cut-in and battery control being incorporated. Davtrend Ltd, 0705 372004.

### Radio communications products

**US cellphone chipset.** IS-54 is the US equivalent to the European GSM cellular telephone standard and AT&T says it has the first pair of chips to make a transceiver to the standard. Working at 900MHz, the W2005 receiver and W2010 transmitter detect and transmit analogue and digital modulation. Phase imbalance in the transmitter is less than 0.95°, and amplitude imbalance less than 0.15°. AT&T Microelectronics, 0344 865927.

**Microwave oscillator.** The KDI/Triangle KDO series microwave dielectric oscillators are available from Anglia. They are intended for use in RF circuits that need a frequency stability of  $\pm 0.1\%$  and the facility of either manual or digital control; mechanical tuning gives  $\pm 25$ MHz variation in the 8-18GHz range. Power output is +12dB minimum at a stability of  $\pm 1.5$ dB, phase noise is 70dBc/Hz at 10kHz and load VSWR is 2:1. Anglia Microwaves Ltd, 0277 630000.

Please quote "Electronics World + Wireless World" when seeking further information

**Microwave education.** A microwave educational kit by Siviers contains everything needed to carry out waveguide and antenna experiments. The PM7006X is modular and comes with a manual which gives a theoretical introduction to microwaves and experimental procedure. Anglia Microwaves Ltd, 0277 630000.

**Radio modems.** Two new radio modems from RDT are the *RDM-1200* desktop model and the *RMUX-1200* multiplexer, both using the *RM-1200* radio modem board, which is a UHF FM synthesised transceiver and a 1200b/s FFSK baseband modem with an RS-232/485 interface and buffer. The *RM-1200* is updated to carry binary protocols such as Modbus RTU. *RMUX-1200* connects to the printer port of a PC and enables communication with 256 outstations. Radio Data Technology Ltd, 0376 501255.

**IS-54 baseband chip.** *RCC54M* from Rockwell is an IS-54-compatible dual-mode cellphone baseband system, the first in a range to handle both baseband and RF functions. It communicates with a host controller to form a processor covering all baseband functions, C code development software being provided. The chip is a modem/framer/vocoder module and includes RF, oscillator and power supply interfaces. Rockwell Digital Communication 010 33 93 00 3301.

**Voltage-controlled oscillators.** A range of VCOs working in the 100MHz-26GHz spread of frequencies made by Eurwave combine good linearity, low phase noise and low microphony in leaded and SM packages — a recent introduction is in a MMIC package. Frequency excursion under 1GHz is 10% and 2% above that frequency. Wavelength Electronics Ltd, 0843 602869.

**Telemetry transceiver.** Wood and Douglas's *TSV450* transceiver has synthesised tuning, so that it is ettable to one of 250 channels with no crystal change. Transmit modulator frequency response is low for DC coupling, with no settling time compromise. Frequency stability is  $\pm 3\text{ppm}$  and receiver sensitivity  $0.3\mu\text{V}$ , with image and spuri rejection of better than 70dB. The transmitter develops up to 500mW of RF in any 3MHz band between 400MHz and 470MHz. Wood and Douglas, 0734 811444.

**Switches and relays**

**Miniature relays.** Genlcom type 3SCC relays are 2-pole, double-throw, 2A, 170mW sealed units which, with pin spacing of 0.15in and a height off board of 0.32in, are claimed to be the smallest available. Offering a 100 million cycle life, contact ratings are 2A at 28V DC resistive, 0.5A at 28V DC inductive and low-level 50 $\mu\text{A}$  at 50mV peak AC or DC. Operating and release times are 4ms and bounce 1.5ms. Gothic

Crellon Ltd, 0734 788878.

**Modular relays.** Wieland's new 24V relay, which has one normally-open contact, is intended for interfacing between controllers and field circuits. Wiring time is reduced by the inclusion of a supply link, which also allows for isolation. The relays include a led for fault finding and a bridge rectifier at the input so that either AC or DC may be used, with no problem with polarity. Wieland Electric Ltd, 0483 31213.

**Transducers and sensors**

**Shaft encoder.** Model *E2* from Control Transducers is a 25mm diameter modular encoder providing from 100 to 1024 pulses per revolution. It has an integral signal-processing chip and can cope with up to  $\pm 0.25\text{mm}$  of axial shaft play without damage. Options include shaft diameters from 3mm to 8mm, dual channels with or without index pulse and differential line-driver output. Control Transducers, 0234 217704.



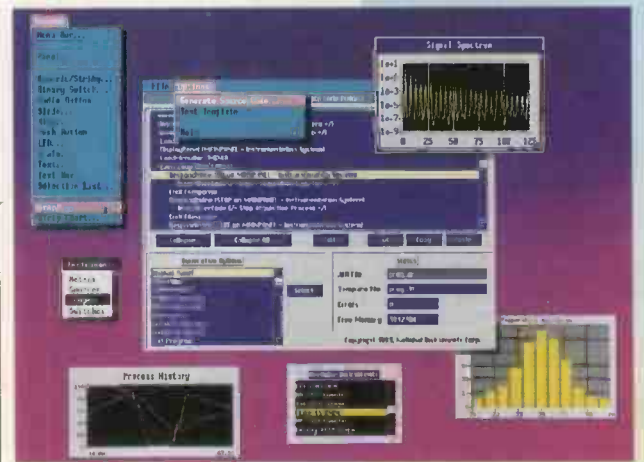
**Computer board level products**

**8051 modules.** Phytec *8051* microcomputer modules are complete control-oriented microcontroller units for low to medium volume use, in which they form a complete microcomputer. Each board contains the *8051* and peripheral hardware, hosting either a Basic interpreter or a C/assembler monitor with 128Kbyte of memory. Modules are credit-card-sized and offer both RS232 and RS485 communications. Hitex (UK) Ltd, 0203 692066.

**PC and VME boards.** LSI's *C40* range now includes PC and VME boards for I/O-intensive application. DBV42 (VME-based) and DPC/C40B mother boards take one or two standard C40 modules to give a processing power of 100Mflops. Both boards provide external access to the 20Mbyte/sec C40 comms ports and have peripheral expansion interfaces. Loughborough Sound Images Ltd, 0509 231843.

**Computer systems**

**Tough workstation.** Intecolor's *WS-14* workstation is an industrial panel-mounted type with a display up to Super VGA standard, sealed drive door, keyboard port and an optional comms port, the whole thing being proof against water, dust, vibration, shock and high temperature. The computer module slides in from the rear and the equipment is provided with an 80Mb hard disk drive and a



3.5in floppy drive. Lighthouse Electronics Ltd, 0825 768849.

**Data communications products**

**Credit-card fax/modem.** *Rapido DF96* PCMCIA measures 85 by 54 by 5mm and provides full 9600b/s fax send and receive, and V.22bis, V.22, V.23, V.21 data modes with V.42b/s and MNP-5 data compression, V.42 and MNP-4 error correction. Line interface is within the modem and its power comes from the host PC. Telecom Design Communications, 0256 332800.

**Development and evaluation**

**Microcontroller development.** Microchip's *PIC* family of 8-bit risc controllers now has *PICSTART-16A*, a low-cost evaluation and development tool. It supports the entire low-end *PIC16C5X* range and includes the *PICALC* assembler, *PICSIM* simulator software, a programmer board and PIC samples. The package includes a 500-page applications handbook. Arizona Microchip Technology, 0628 850303.

**Fuzzy logic development.** Fuzzy logic may be used with embedded microprocessors using *Byte Craft's Fuzz-C*, a C pre-processor which allows fuzzy logic to be mixed with C statements in the application source code. It converts fuzzy logic functions to ANSI C source code, which is then compilable by most embedded C compilers. Pentica Systems Ltd, 0734 792101.

**Inmos T9000 real-time kernel.** *Cexecutive* is a real-time, multi-tasking, rom-able kernel running on a variety of risc and risc processors and is soon to be available for the Inmos *T9000* — it is already available for existing transputers in the Inmos ANSI C compiler. RTS, 0624 623841.

**Software**

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**GUIs with LabWindows.**

Version 2.3 of National's *LabWindows* automatic code-generating software for dos instrumentation includes the *CodeBuilder* interface, an interactive prototyping and programming utility to ease the writing of programs with graphical user interfaces. National Instruments UK, 0635 523545.

update now provides an application interface for RS232 to allow the creation of custom software for serial comms. A Script Program facility has a command language which allows the setting of baud rate, view mode and display format. One can now export *COM-Watch* files to other programs and with *Activity* view, one can look at data in a time-based view from 1ms to 12h/division. Amplicon Liveline Ltd, (Free)0800 525 335.

**Labview update.** National has announced version 2.5.2 of *LabVIEW* for Windows, which includes new virtual instruments, new DSP development capability and a new DSP Custom Function VI for accessing existing DSP board functions. New VIs include signal generation, frequency-domain operations, windowing, array manipulation, filtering and memory management. There are also new C development tools for DSP development. National Instruments UK, 0635 523545.

**DESQview updates.** Version 1.1 of *DESQview/X* Network Manager offers support for Sun's *PC-NFS*, H-P's lan manager, Microsoft's lan manager, Beame & Whiteside networking software and Wollongong Pathway for DOS. *DESQview/X* version 1.1 supports *NetBIOS* networks and offers cross-concentrator support for Novell Netware *IPX* networks, allowing a user to run remote dos and Windows programs over gatewayed Novell networks. Quarterdeck Office Systems, 0245 496699.

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# Imaginary numbers for a real world

*Imaginary numbers have many practical applications in electronics from describing alternating currents and voltages to calculating the frequency response of filters. In this extract from his book Understand Electrical and Electronics Maths, Owen Bishop explains what these numbers are and how to work with them.*

When any real number is squared, the square is positive. There is no way in which the square of a real number can be negative. But though all real numbers have positive squares, it is interesting to imagine a number which has a negative square, and to deduce what the properties of such a number might be. As the basic imaginary number we select the number which, when squared, equals  $-1$ . Since it has no value that is expressible in real numbers, we represent it by a symbol. Mathematicians use the symbol  $i$ , because  $i$  and  $1$  look alike. The difficulty with this is that, in electronics and electric circuits, we commonly use  $i$  for representing current. So electronic and electrical engineers use  $j$  instead of  $i$ . We define  $j$  by the equation:  $j = \sqrt{-1}$  or  $j^2 + 1 = 0$ .

As we shall see later,  $j$  is rather more than just an imaginary number. It is an operator which performs real actions. For the moment, we will treat it as if  $j$  were just a number.

## Working with $j$

It is not difficult to decide how  $j$  behaves when it is subjected to some of the simpler arithmetical operations:

**Addition:** Clearly  $\sqrt{-1} + \sqrt{-1} = 2\sqrt{-1}$ . In terms of  $j$ :  $j + j = j2$ . Note that we use the form  $j2$ , not  $2j$ . This is because  $j$  is not just a quantity. As explained later, it is an operator and therefore is written before the number on which it operates. Similarly  $j2 + j = j3$ , or, in general  $ja + jb = j(a + b)$ . So, when two imaginary numbers are added together, the sum is also imaginary.

**Multiplication by a real number:** Multiplication follows the rules of algebra so that, for example,  $j2 \times 3 = j6$ . When an imaginary number is multiplied by a real number, the product is imaginary.

**Multiplication by another imaginary number:** This gives results that are unlike those obtained with real numbers. By definition:  $j \times j = \sqrt{-1} \times \sqrt{-1} = -1$ . For larger imaginary numbers, we collect together the imaginary numbers and the real numbers:  $j2 \times j3 = (j \times j)(2 \times 3) = -1 \times 6 = -6$ . In general:  $ja \times jb = -ab$ . When two imaginary numbers are multiplied together, the product is real.

**Powers of  $j$ :** It follows from the previous paragraph, as well as from the definition of  $j$ , that  $j^2 = j \times j = -1$ . By extension of this equation  $j^3 = j \times j^2 = j \times -1 = -j$ , and  $j^4 = j \times j^3 = j \times -j = -(-1) = 1$ . After this, with increasing powers of  $j$ , the sequence repeats, so that  $j^5 = j$ ,  $j^6 = -1$ ,  $j^7 = -j$ , and so on. The rule for finding the value of a power of  $j$  is to divide the power by 4, and note the remainder. If the remainder is 0, the result is 1. If the remainder is 1, the result is  $j$ . If it is 2, the result is  $-1$ . And if it is 3, the result is  $-j$ .

It seems that, though it is imaginary,  $j$  has properties that are easily understood and easy to work with. Also, although it often follows the rules of ordinary algebra, it has some distinctive behaviour of its own.

## The imaginary number line

Imaginary numbers can be positive or negative and have a range of values. They can be represented by an imaginary number line (Figs. 1 and 2).

For each number on the real number line, there is a corresponding number on the imaginary number line. For example, the real numbers 3,  $-5$ , 0,  $4.27$ ,  $\pi$ ,  $3/4$ , and  $\sqrt{7}$  all have their counterpart on the imaginary number line  $j3$ ,  $-j5$ ,  $j0 (= 0)$ ,  $j4.27$ ,  $j\pi$ ,  $j3/4$ , and  $j\sqrt{7}$ .

The imaginary number line is just like the real number line, except that every number on it is a real number operated on by  $j$ . The real number line is continuous from  $-\infty$  to  $+\infty$  while the imaginary number line is continuous from  $-j\infty$  to  $+j\infty$ .

The number zero is found on both lines, for  $j0 = 0$ . If we draw both lines on one diagram, and let them cross at zero, we have a way of representing both real and imaginary numbers on the same diagram (Fig. 3). The most interesting thing about this diagram is the area around the lines. Any point in this area can be represented by a pair of values that indicate its position; the difference is that one coordinate is a real number and the other is imaginary. So point A in Fig. 3 has the coordinates 2 and  $j3$ . These coordinates combined ( $2 + j3$ ) give the location of A. The other points in Fig. 3 are B =  $-3 + j2$ ; C =  $-1 - j4$ ; and D =  $4 - j3$ .

Hence, point A is defined by two values, one real, the other imaginary. We say that the point A represents a complex number. The complex number consists of a real part (2) and an imaginary part ( $j3$ ). Note that  $j$  does not appear in the imaginary part; it is simply an indicator that the value which follows the  $j$  is to be taken in the  $j$  direction. This is the way in which  $j$  is an operator. We sometimes use the symbols Re and Im to represent the real and imaginary

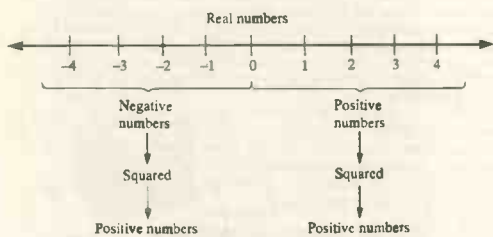


Fig. 1. Real number line.

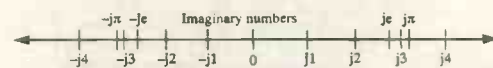


Fig. 2. Imaginary number line.

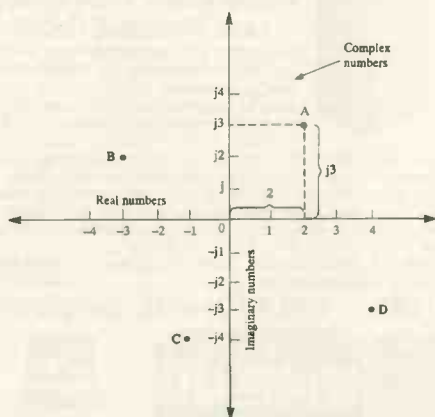


Fig. 3. Representation of real and imaginary numbers on the same diagram.

parts of a number. Referring to point B,  $\text{Re}B = -3$  and  $\text{Im}B = 2$ . Every point in Fig. 3 represents a complex number and the area of the diagram is the complex number plane. The real number line is the real axis and the imaginary number line the imaginary axis. Specifying a complex number by its real and imaginary parts is equivalent to locating a point on a graph by giving its rectangular coordinates. For this reason, a complex number expressed like this is said to be rectangular form, sometimes referred to as standard form.

**Another approach**

One way of getting from zero to the point A (Fig. 3) is to travel two units along the real axis, then turn  $90^\circ$  to the left and travel three units up in the  $j$  direction (parallel to the imaginary axis). In the equation  $A = 2 + j3$ , the numbers 2 and 3 indicate the distances to be travelled and the  $j$  represents a  $90^\circ$  turn (anticlockwise) between the two stages of the journey.

Consider the diagram as a map of a field. A person is standing at zero facing along the real axis in the positive direction, we can issue that person with instructions on how to get to point A. Assuming the numbers are distances expressed in paces, the instruction  $2 + 3j$  represents: "Move 2 paces forward; turn  $90^\circ$  left; move 3 paces forward" (Fig. 4).

Similarly, for point B, the value  $-3 + j2$  means: "Move 3 paces backward; turn  $90^\circ$  left; move 2 paces forward." If  $j$  is negative, it means turn  $90^\circ$  right, so for point D  $4 - j3$  means: "Move 4 paces forward; turn  $90^\circ$  right; move 3 paces forward." An alternative interpretation takes  $-j3$  to be  $j(-3)$  and the corresponding instruction is: "Move 4 paces forward; turn  $90^\circ$  left; move 3 paces backward." This also brings the person to D.

If  $j$  means turn  $90^\circ$  left, then  $j^2$  means turn  $90^\circ$  left and turn  $90^\circ$  left again. In other words turn  $180^\circ$  left (Fig. 5). The person is then facing in the opposite direction, in the negative direction along the real axis. Any forward step from zero takes the person to a negative real number. This is consistent with the fact that  $j^2 = -1$ . In the same way  $j^3$  means turning  $3 \times 90^\circ$ , or  $270^\circ$  to the left. The person is now facing in the negative direction of the imaginary axis. This corresponds to the identity  $j^3 = -j$ . Note that  $-j$  means turn  $90^\circ$  right which also brings the person facing in the negative  $j$  direction. Finally,  $j^4$  is equivalent to a complete turn, facing in the original direction, since  $j^4 = 1$ .

The idea of  $j$  meaning a  $90^\circ$  turn explains why the real and imaginary axes are drawn at right angles in Fig. 3. Swinging the real axis about zero for a quarter of a turn anticlockwise turns all the real numbers on it to imaginary ones. This is the sense in which  $j$  is an operator.

The essential point to remember when adding or subtracting complex numbers is that the real part of the numbers and the imaginary parts must be dealt with separately. This is because they represent coordinates in perpendicular directions; an increase or decrease in one coordinate must have no effect on the other. For example, add  $(4 + j7)$  to  $(3 + j2)$ . Collect the real parts together and the imaginary parts together:

$$\Rightarrow (4 + 3) + (j7 + j2) = 7 + j(7 + 2) = 7 + j9$$

This is indicated in Fig. 6. After a little practice, additions like this can be done mentally. So:

$$(3 + j5) + (2 - j3) = 5 + j2 \quad \text{and} \quad (2 - j6) + (4 - j) = 6 - j7$$

The calculations follow the usual rules. Just as in algebra, terms with  $j$  in them must be kept separate. The same applies to multiplication; we follow the usual algebraic routines. For another example, multiply  $(4 + j5)$  by  $(3 + j2)$ . Set this one out as a multiplication:

$$\begin{array}{r} 4 + j5 \\ \times \quad 3 + j2 \\ \hline 12 + j15 \\ \quad j8 + j^2 10 \\ \hline = \quad 12 + j23 - 10 \end{array}$$

Add the imaginary parts. The term which comes from  $j5 \times j2$  is now real, with a change of sign, because  $j^2 = -1$ . Collecting the real numbers together, the product is  $2 + j23$ . Equally:  $(3 + j4) \times (2 + j6) = -18 + j26$  and  $(2 + j5) \times (4 - j2) = 18 + j16$ .

**Conjugate complex numbers**

Conjugate numbers differ only in the sign of the imaginary part. In Fig. 7 the numbers are  $A = 4 + j3$  and  $A' = 4 - j3$ . Calculating the product of these two numbers:  $(4 + j3) \times (4 - j3) = 16 + 0j - j^2 9$ . The product is a real number.

In general:  $(a + jb) \times (a - jb) = a^2 + b^2$ .

**Division of complex numbers:** This appears at first sight to be difficult. For example: divide  $(5 + j2)$  by  $(3 + j4)$ . Setting this out as a fraction, with numerator and denominator:

$$\frac{(5 + j2)}{(3 + j4)}$$

The problem is how to divide by a complex number. The solution is to convert it into a real

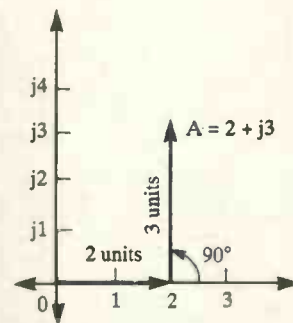


Fig. 4. Representation of  $2 + 3j$ .

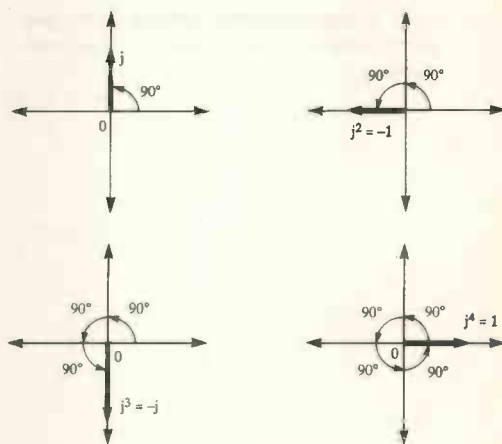


Fig. 5. Angles turned by powers of  $j$ .

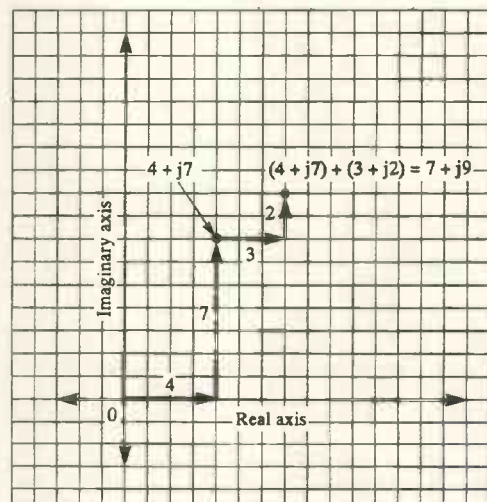


Fig. 6. Adding complex numbers.

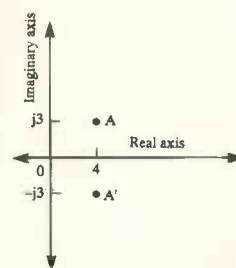


Fig. 7. Conjugate complex numbers shown schematically.

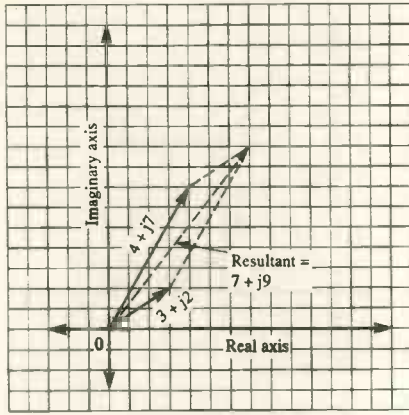


Fig. 8. Complex number addition drawn as a vector addition. This is known as an Argand diagram.

number. This is done by using the result obtained above when a complex number is multiplied by its conjugate. The value of the fraction is unaltered if we multiply both numerator and denominator by the conjugate of the denominator. The conjugate of the denominator is  $(3 - j4)$ , so the fraction becomes:

$$\frac{(5 + j2) \times (3 - j4)}{(3 + j4) \times (3 - j4)}$$

Multiplying out the numerator gives:  $23 - j14$ . Multiplying out the denominator gives:  $3^2 + 4^2 = 25$ . The value of the fraction is:

$$\frac{23 - j14}{25} = \frac{23}{25} - \frac{j14}{25} = 0.92 + j0.56$$

Another example:

$$\frac{(5 + j3)}{(2 + j)} = \frac{(5 + j3) \times (2 - j)}{(2 + j) \times (2 - j)} = \frac{13 + j}{5} = 2.6 + j0.2$$

**Complex numbers and quadratic equations:** We now have a way of finding the solution of a quadratic equation when the discriminant is less than zero. Take, for example,  $3x^2 - 18x + 39 = 0$ . The coefficients are:  $a = 3$ ,  $b = -18$ , and  $c = 39$ . The discriminant is:

$$\sqrt{b^2 - 4ac} = \sqrt{324 - 468} = \sqrt{-144} = 12\sqrt{-1} = j12$$

The discriminant is an imaginary number so the equation has complex roots. When inserted in the quadratic formula, we have:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{18 \pm j12}{6} = 3 \pm j2$$

Solutions to this are  $x = 3 + j2$  or  $x = 3 - j2$ . Other quadratic equations with negative discriminants are solved in the same way.

**Complex numbers and vectors:** Figure 6 shows the addition of vectors. In Fig. 8 the same addition is drawn as a vector addition. A diagram like this, which shows vectors drawn in the complex number plane, is called an Argand diagram. One particular kind of vector, used in describing alternating currents and voltages in circuits, is the phasor. The mathematics of imaginary and complex numbers is a useful tool for dealing with these phasors.

Phasors are usually given by length and phase angle, for we often know the amplitude and the phase angle of the sine wave they represent. So it is more convenient if the complex numbers that represent the phasors are in polar form, as a magnitude and an angle.

**Polar form**

Figure 9 shows a complex number at point  $z$  in the complex number plane. The real part of  $z$  is  $a$ , and the imaginary part of  $z$  is  $b$ . Thus:

$$z = a + jb$$

This is the way of expressing a complex number in rectangular form. The figure also shows a vector (or phasor) drawn from the origin to point  $z$ . The length of the vector is  $r$  and its phase angle is  $\theta$ . From the definition of the trig ratios:

$$a = r \cos \theta \quad \text{and} \quad b = r \sin \theta$$

Substituting these values for  $a$  and  $b$  in  $z = a + jb$ :  $z = r(\cos \theta + j \sin \theta)$ . This is the polar form of the complex number.

Given  $a$  and  $b$ , the real and imaginary parts of  $z$ , the conversion from rectangular to polar form is exactly the same as normal. The fact that  $b$  is the imaginary part of  $z$  (though not an imaginary number itself) makes no difference to the geometry. For example, convert the complex number  $z = 3 + j4$  into polar form (Fig. 10a):

$$r = \sqrt{3^2 + 4^2} = \sqrt{9 + 16} = \sqrt{25} = 5$$

$$\theta = \tan^{-1} \frac{4}{3} \approx 53.13^\circ$$

The polar form is  $z = 5(\cos 53.13^\circ + j \sin 53.13^\circ)$ . Convert  $z = -2 + j6$  to polar form (Fig. 10b):

$$r = \sqrt{2^2 + 6^2} = \sqrt{4 + 36} = \sqrt{40} \approx 6.32$$

$$\theta = \tan^{-1} \frac{6}{-2} \approx -71.57^\circ$$

The approximations have been done by calculator to two decimal places, which does not necessarily show the correct result. We might take  $-71.57^\circ$  to mean that the point is in the

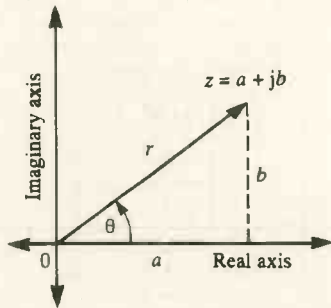


Fig. 9. Complex number in the complex number plane.



fourth quadrant. But Fig. 10b shows the number is in the second quadrant. Both angles have a tangent of 3. The calculator does not tell us which angle we require. This is why it is important to draw a sketch (not necessarily to scale) when converting to polar form. In this example, the sketch shows that the required value of  $\theta$  is  $180^\circ - 71.57^\circ = 108.43^\circ$ . This is the angle measured from the positive direction of the real number line. Using the appropriate angle:  $z = 6.32(\cos 108.43^\circ + j\sin 108.43^\circ)$ .

Convert  $z = 3 - j5$  into polar form (Fig. 10c):

$$r = \sqrt{3^2 + 5^2} = \sqrt{9 + 25} = \sqrt{34} \approx 5.83$$

$$\theta = \tan^{-1} \frac{-5}{3} \approx -59.04^\circ$$

This time the sketch shows that the point is in the fourth quadrant. The value of  $\theta$  should be  $360^\circ - 59.04^\circ = 300.96^\circ$ . In polar form  $z = 5.83(\cos 300.96^\circ + j\sin 300.96^\circ)$ .

All complex numbers expressed in polar form have the same format:  $z = r(\cos\theta + j\sin\theta)$ . It is only the  $r$  and  $\theta$  which vary, so there is no need to repeat the  $\cos$  and  $\sin$  every time we write out a number. The usual convention is to express the number as  $5.83(\cos 300.96^\circ + j\sin 300.96^\circ)$  as  $5.83/300.96^\circ$ .

**Converting from polar to rectangular form:** For example: Convert  $z = 5.39/21.80^\circ$  to rectangular form:  $a = r\cos\theta = 5.39 \times 0.928 = 5$  and  $b = r\sin\theta = 5.39 \times 0.371 = 2$ . The answers are 5 and 2 to two decimal places, so we can take them to be integers within the range of accuracy of the calculation. The rectangular form is  $z = 5 + j2$ . Another example is to convert  $z = 7.62/336.80^\circ$  to rectangular form:  $a = 7.62 \times 0.92 = 7$  and  $b = 7.62 \times -0.39 = -3$ . In rectangular form  $z = 7 - j3$ .

### Negative angles

When a complex number is in the third or fourth quadrant it is often more convenient to measure the angle in the clockwise (negative) direction. Fig. 11 shows the number  $z = 6 - j5$ . In polar form this is  $7.8/-39.8^\circ$ . Written out in full:

$$z = 7.8(\cos -39.8^\circ + j\sin -39.8^\circ) \quad (\text{equation 4})$$

But  $\cos -\theta = \cos\theta$  and  $\sin -\theta = -\sin\theta$ . Substituting these in equation 4:  $z = 7.8(\cos 39.8^\circ - j\sin 39.8^\circ)$ . This is the same as the usual rectangular form, except that the plus sign is replaced by a minus sign. Therefore, whenever there is a minus sign in the rectangular form, it means that the angle is in the third or fourth quadrant. For example:  $z = -3 - j2 = 3.61/213.69^\circ$ . Written out in full:  $z = 3.61(\cos 213.69^\circ + j\sin 213.69^\circ)$ . But  $213.69^\circ$  is the same as  $-146.31^\circ$  (Fig. 12), so we can write:  $z = 3.61(\cos 146.31^\circ - j\sin 146.31^\circ)$ . Both forms define the same point on the number plane. For negative angles we can use the alternative short form for writing polar coordinates:

$$3.61/213.69^\circ \equiv 3.61/-146.31^\circ = 3.61/146.31^\circ$$

**Adding complex numbers in polar form:** We are sometimes given two vectors in polar form, and asked to find their sum or resultant vector. The way to do this is to convert them to rectangular form, sum them, and convert the sum back to polar form. For example: Sum the vectors  $z_1 = 8.06/60.26^\circ$  and  $z_2 = 3.61/33.69^\circ$ . Converting  $z_1$  to rectangular form:  $z_1 = 4 + j7$ . Converting  $z_2$  to rectangular form:  $z_2 = 3 + j2$ . Summing these:  $z_1 + z_2 = 7 + j9$ . Converting the sum to polar form:  $z_1 + z_2 = 11.40/52.13^\circ$ . This is the summation represented in Fig. 8.

**Multiplying in polar form:** Multiplying two complex numbers together is made easier if they are in polar form. It is very much easier than the explanation which follows. If you are mainly interested in the *how* rather than the *why*, skip to the result at the end.

Suppose that we have two complex numbers  $z_1$  and  $z_2$ . We want to find their product. In polar form the two numbers are:  $z_1 = r_1/\theta_1 = r_1(\cos\theta_1 + j\sin\theta_1)$  and  $z_2 = r_2/\theta_2 = r_2(\cos\theta_2 + j\sin\theta_2)$ . Their product is:

$$\begin{aligned} z_1 z_2 &= r_1 r_2 (\cos\theta_1 + j\sin\theta_1)(\cos\theta_2 + j\sin\theta_2) \\ &= r_1 r_2 (\cos\theta_1 \cos\theta_2 + j\sin\theta_1 \cos\theta_2 + j\cos\theta_1 \sin\theta_2 + j^2 \sin\theta_1 \sin\theta_2) \end{aligned}$$

Rearranging terms and substituting  $-1$  for  $j^2$ , we obtain:

$$z_1 z_2 = r_1 r_2 [(\cos\theta_1 \cos\theta_2 - \sin\theta_1 \sin\theta_2) + j(\sin\theta_1 \cos\theta_2 + \cos\theta_1 \sin\theta_2)]$$

This lengthy equation can be simplified using two basic trig identities:  $z_1 z_2 = r_1 r_2 [\cos(\theta_1 + \theta_2) + j\sin(\theta_1 + \theta_2)]$ . Or, putting both sides of the equation into short form:  $z_1 z_2 = r_1/\theta_1 \times r_2/\theta_2 = r_1 r_2/(\theta_1 + \theta_2)$ .

The result is expressed as an easy rule: To multiply two complex numbers in polar form, multiply the  $r$ s and add the  $\theta$ s. For example:  $2/50^\circ \times 7/30^\circ = 14/80^\circ$  and  $1.5/100^\circ \times 6/-35^\circ = 9/65^\circ$ . The rule is extended to multiplication of three or more numbers. Just multiply all the  $r$ s and add all the  $\theta$ s. For example:  $3/80^\circ \times 2/30^\circ \times 5/120^\circ = 30/230^\circ$ .

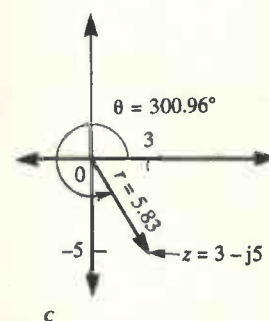
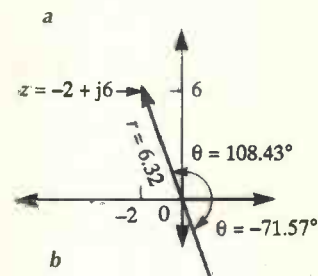
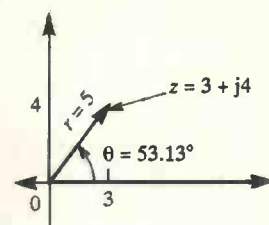


Fig. 10. Converting a complex number into polar form.

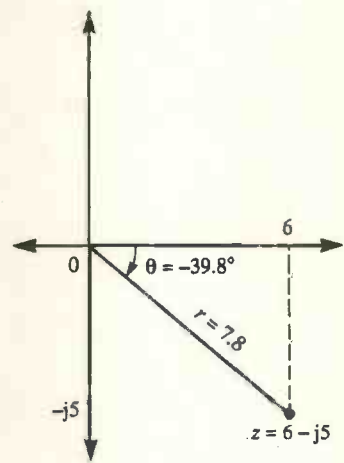


Fig. 11. Complex number  $z = 6 - j5$ .

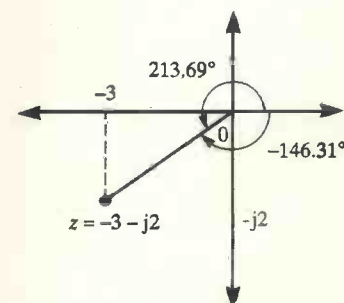


Fig. 12.  $z = -3 - j2$ .

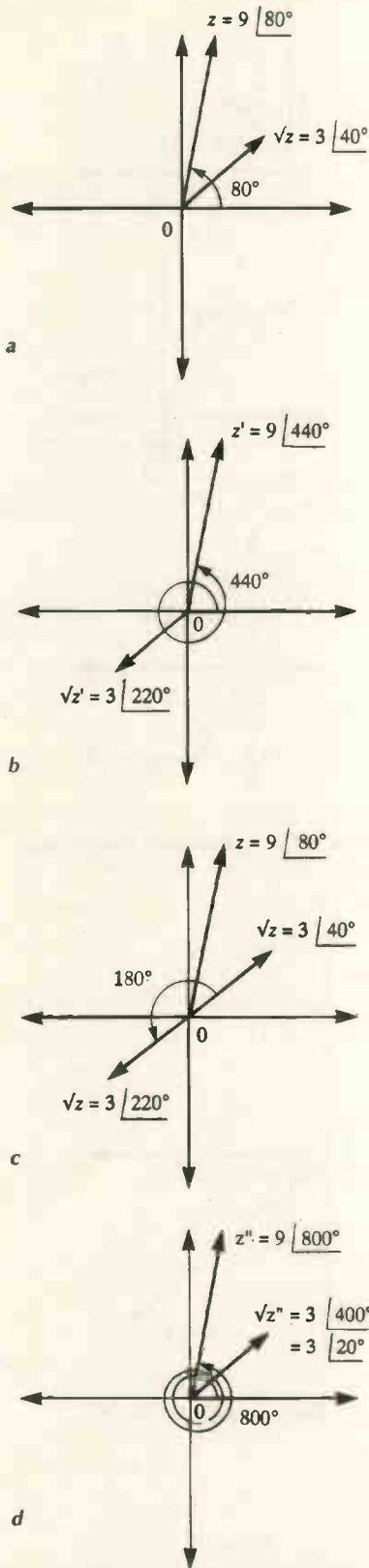


Fig. 13. Argand diagrams showing the roots of complex numbers.

**Dividing in polar form:** A similar argument to that given above leads to the rule for division: To divide two numbers in complex form, divide the *r*s and subtract the  $\theta$ s. For example:

$$\frac{6/75^\circ}{3/25^\circ} = 2/50^\circ \text{ and } \frac{2/30^\circ}{2/50^\circ} = 2.5/-20^\circ$$

**Powers of complex numbers:** It follows that to square a complex number we square the *r* and double the  $\theta$ :  $(r/\theta)^2 = r^2/2\theta$ . For example:  $(6/55^\circ)^2 = 36/110^\circ$ . Similarly for higher powers:  $(r/\theta)^3 = r^3/3\theta$  and  $(r/\theta)^4 = r^4/4\theta$ . And for the *n*th power:  $(r/\theta)^n = r^n/n\theta$ . This is known as De Moivre's theorem. The theorem also applies to fractional powers where *n* is between 0 and 1. For example, to find the square root of a complex number:  $(9/80^\circ)^{0.5} = 9^{0.5}/0.5 \times 80^\circ = 3/40^\circ$ . This apparently straightforward answer needs to be looked at more closely.

**Roots of complex numbers:** In the example above we found the square root of  $9/80^\circ$ . Figure 13a shows this number and its square root ( $3/40^\circ$ ) in an Argand diagram. The number is represented as a vector at an angle of  $80^\circ$ . If we let the vector swing round a whole revolution until it points in the same direction as before, the angle of the vector is  $80^\circ + 360^\circ = 440^\circ$  (Fig. 13b). The vector also represents the number  $9/440^\circ$ . The square root of this number is  $3/220^\circ$ , and this is shown in the diagram.

Now let the vector make another revolution, so that it represents the number  $9/800^\circ$  (Fig. 13c). The square root of this is  $3/400^\circ$ . The angle  $400^\circ$  of the square root gives it the same direction as the first square root,  $3/40^\circ$ . If we continue to add  $360^\circ$  to the number, we find that the square root increases by  $180^\circ$  each time. This is to be expected, since every increase in the angle of the number produces an increase of  $360^\circ/2$  in the angle of the square root.

Figure 13d illustrates the conclusions that the complex number has two square roots, situated  $180^\circ$  apart. This result applies to the square roots of all complex numbers.

Figure 14 shows the cube roots of a complex number,  $2/45^\circ$ . Using the rule, the cube root of 27 is 3 and one-third of  $45^\circ$  is  $15^\circ$ , so the cube root is  $3/15^\circ$ . We can continue to turn the vector  $360^\circ$ . Each  $360^\circ$  turn increases the cube root angle  $360^\circ/3$ , that is by  $120^\circ$ . So we get three cube roots  $120^\circ$  apart. Similarly a complex number has four fourth roots  $90^\circ$  apart, five fifth roots  $72^\circ$  apart, and so on. In general, a complex number has *n* *n*th roots  $360^\circ/n$  apart.

As well as the rectangular and polar forms, there is yet another form in which complex numbers are sometimes expressed. This is the exponential form. To understand this we need to know something about series. A series is the sum of a number of terms of a sequence of numbers (real or imaginary). The numbers of the sequence are calculated according to a set of rules, which may differ from one series to another.

For example, in the sequence 1, 2, 3, 4, 5, ... the numbers increase by 1 each time. Given the first few numbers, we can easily discover the rule and continue to write out the sequence indefinitely. The sum of the first five terms of the sequence is:  $S = 1 + 2 + 3 + 4 + 5 = 15$ .

As the number of terms increases, the series *S* increases more and more rapidly. With an infinite number of terms, *S* is infinitely large. We say the series is divergent.

In the sequence 1, 0.5, 0.25, 0.125, 0.0625..., the successive numbers are obtained by dividing the previous number by 2. The sum of the first five terms of this sequence is:  $S = 1 + 0.5 + 0.25 + 0.125 + 0.0625 = 1.9375$

As the number of terms increases, *S* increases less and less rapidly. It can be shown that the value of the series approaches a limit as the number of terms becomes infinite. The limit of *S* is 2. This series is said to be convergent. An interesting convergent series is this one:

$$S = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \frac{x^6}{6!} + \dots$$

The rule for generating the sequence is a little more complicated here. Begin with 1 and multiply by *x* to get from one term to the next. At the same time divide by a factorial number, increasing it by 1 each time. Although factorials do not appear in the first two terms in the equation above, these terms are divided by both 0! and 1!, respectively, but this is not shown because both 0! and 1! are equal to 1.

The value of the series depends on the value taken for *x*, which must be the same for every term. Suppose that  $x = 1$ . The value of the first seven terms works out to be:

$$S = 1 + 1 + \frac{1}{2} + \frac{1}{6} + \frac{1}{24} + \frac{1}{120} + \frac{1}{720} \approx 2.718$$

This is fairly close to the exponential constant *e*. Try the series with  $x = 2$ , summing the first nine terms, as this series converges rather slowly:

$$S = 1 + 2 + \frac{4}{2} + \frac{8}{6} + \frac{16}{24} + \frac{32}{120} + \frac{64}{720} + \frac{128}{5040} + \frac{256}{40320} \approx 7.387$$

Some research shows that this number is fairly close to  $e^2$ , which is about 7.389. As we increase the number of terms, this series converges exactly on the value of  $e^2$ . Further investigations or a formal proof show that, for any value of *x*, the value of the series equals  $e^x$ . We call it the exponential series. Here is a way of calculating  $e^x$  to any required degree of precision. There are two other important series of similar form but differing slightly in the way the terms are generated. These converge on trig functions:

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \frac{x^8}{8!} - \dots$$

This has the alternate terms of the exponential series, beginning with the first. The signs are alternately + and -.

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \frac{x^9}{9!} - \dots$$

This has the alternate terms of the exponential series, beginning with the second. The signs are alternately + and -. These series give the values for cosx and sinx, provided that the angles are expressed in radians. Above we substituted values 1 and 2 for x in the exponential series to obtain values for e and e<sup>2</sup>. See what happens if we substitute the imaginary number jθ to obtain a value for e<sup>jθ</sup>:

$$e^{j\theta} = 1 + j\theta + \frac{(j\theta)^2}{2!} + \frac{(j\theta)^3}{3!} + \frac{(j\theta)^4}{4!} + \frac{(j\theta)^5}{5!} \dots$$

$$= 1 + j\theta + \frac{j^2\theta^2}{2!} + \frac{j^3\theta^3}{3!} + \frac{j^4\theta^4}{4!} + \frac{j^5\theta^5}{5!} \dots$$

Simplifying the powers of j:

$$= 1 + j\theta - \frac{\theta^2}{2!} - \frac{j\theta^3}{3!} + \frac{\theta^4}{4!} + \frac{j\theta^5}{5!} \dots$$

Collecting even powers of θ and odd powers of θ, also taking out j as a factor from the odd-powered terms:

$$= \left( 1 - \frac{\theta^2}{2!} + \frac{\theta^4}{4!} - \dots \right) + j \left( \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \dots \right)$$

The expression in the first bracket is the series for cosθ, the expression in the second is for sinθ, so we get the result: e<sup>jθ</sup> = cosθ + jsinθ. The right side of the equation is the polar form of a complex number. Thus, a number in polar form is converted to exponential form: r(cosθ + jsinθ) = re<sup>jθ</sup>. For example: z = 4∠3rad = 4(cos3 + jsin3) = 4e<sup>j3</sup>. In exponential form the angle must be in radians. For example: z = 5∠125° = 5∠2.18rad = 5e<sup>j2.18</sup>. By reasoning similar to the above we get a result for negative angles. If: z = r(cosθ - jsinθ), then z = re<sup>-jθ</sup>.

Uses for the exponential form: The exponential can be used in a Laplace transform. Putting a number as a power of e makes it suitable for the transformation, since the transform of e<sup>at</sup> is:

$$\frac{1}{s-a}. \text{ A complex number } re^{j\theta t} \text{ is transformed to: } \frac{r}{s-j\theta}$$

Putting a complex number into exponential form also makes it possible to obtain the log of the number. Given that: z = r(cosθ + jsinθ) = re<sup>jθ</sup>. Taking natural logs: lnz = ln r + jθ. Similarly, for negative angles: z = re<sup>-jθ</sup> ⇒ lnz = ln r - jθ.

### Impedances in equations

The impedance of a circuit or part of a circuit is due to one or more of: resistance, R, inductive resistance, X<sub>L</sub>, and capacitive resistance, X<sub>C</sub>. All are expressed in ohms. The total impedance Z of a circuit is calculated by considering the various resistances and reactances to be in series or in parallel, according to the way they are connected. When an alternating voltage is applied to the circuit, the different kinds of circuit elements behave differently:

Element	Phase angle of voltage across element in series circuits	Phase angle of current through element in parallel circuits	Effect of frequency on impedance
Resistance	0°	0°	R is constant
Inductance	+90° (leads)	-90° (lags)	X <sub>L</sub> = ωL
Capacitance	-90° (lags)	+90° (leads)	X <sub>C</sub> = 1/ωC

Phase angles are relative to applied voltage. Fourth column values give the magnitude of the impedance, from which we can calculate the voltage across the element in a series circuit. But these do not take account of phase angle. So, we can calculate the length of the voltage phasor, but not the direction in which it points. The direction is given in the second column.

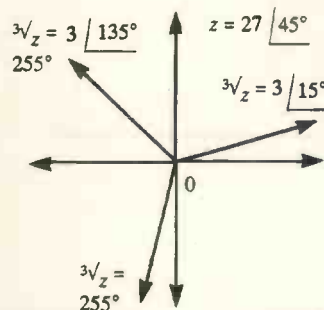


Fig. 14. Cube roots of a complex number.

### Factorial numbers

Factorial n consists of n multiplied by (n - 1), multiplied by (n - 2) and so on down to 1. A factorial number is indicated by an exclamation mark (!) following the number. Only positive integers can be made into factorials. For example:

$$3! = 3 \times 2 \times 1 = 6$$

$$7! = 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 = 5040$$

Factorials of quite small numbers are very large. For example 12! = 479001600. There are two special examples: 1! = 1, as might be expected, and 0! = 1, which is unexpected. This can be explained by working out a sequence of factorials in reverse. Starting with 5!, we obtain the next earlier term in the sequence by dividing it by 5:

$$\frac{5!}{5} = \frac{5 \times 4 \times 3 \times 2 \times 1}{5} = 4 \times 3 \times 2 \times 1 = 4!$$

Similarly:

$$\frac{4!}{4} = 3!, \quad \frac{3!}{3} = 2!, \quad \frac{2!}{2} = 1!, \quad \text{and} \quad \frac{1!}{1} = 0!$$

$$\text{But } 1! = 1, \text{ so } 0! = \frac{1}{1} = 1$$

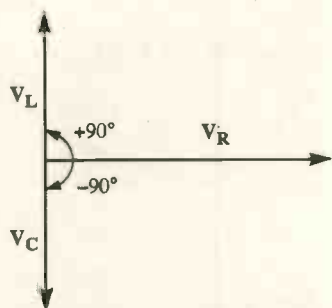


Fig. 15. Voltage phasors can be taken across three types of impedance and expressed as complex numbers in polar form.

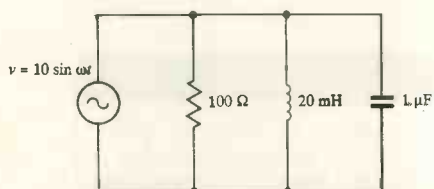


Fig. 16a. Conventional circuit diagram.

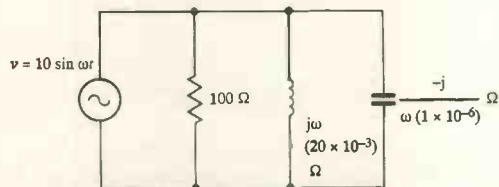


Fig. 16b. Components labelled with impedance vectors.

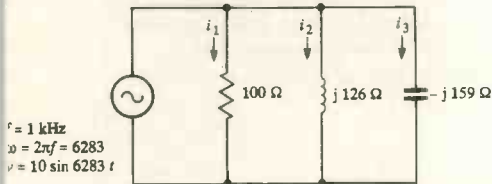


Fig. 16c. Incorporating the value of ω.

If we are interested in a parallel circuit, the direction is given in the third column. To handle phasors mathematically, as opposed to drawing a scale diagram and solving problems graphically, we need to be able to represent magnitude and direction in numeric form.

Since the *j* in a complex number represents a rotation of 90°, the complex number system is ideal for this purpose. Using the system we are able to take the voltage phasors across three types of impedance (Fig. 15) and express them as complex numbers in polar form:

Impedance due to	Voltage phasor in series circuit	Comment
Resistance	$V_R = I(R/0^\circ)$	In phase
Inductance	$V_L = I(\omega L/90^\circ)$	Reactance leads
Capacitance	$V_C = I\left(\frac{-1}{\omega C}/90^\circ\right)$	Reactance lags

The equations show the information of the third and fourth columns of the previous table. The expressions in brackets represent the impedance vectors  $Z_R$ ,  $Z_L$  and  $Z_C$ , respectively.

Figure 16a shows a conventional circuit diagram, and Fig. 16b shows the components labelled with impedance vectors. These come from the equations in the second column of the table above. If, as here, we know the frequency of the applied voltage, we can incorporate the value of  $\omega$  into the impedance vectors, as has been done in Fig. 16c. Using these values and applying the rules for adding, subtracting, multiplying, or dividing complex numbers, we can calculate the vectors for impedances, voltages, and currents in any part of the circuit.

For example, suppose the voltage applied to the circuit of Fig. 16 has a frequency of 1 kHz. The components have the impedances shown in Fig. 16c, calculated by substituting  $\omega = 2\pi \times 1000 = 6283$  in the values shown in Fig. 16b. The voltage phasor  $V$  equals  $10/0^\circ$ , indicating that its magnitude is 10V. The  $0^\circ$  shows that it is taken as the reference, to which the phase angles of other phasors refer. Now we calculate the current phasors:

$$I_1 = \frac{V}{100} = \frac{10/0^\circ}{100} = 0.1/0^\circ$$

$$I_2 = \frac{V}{j126} = \frac{10/0^\circ}{126/90^\circ} = 0.0794/-90^\circ$$

$$I_3 = \frac{V}{-j159} = \frac{10/0^\circ}{159/-90^\circ} = 0.0629/90^\circ$$

Summing these to get the supply current, after converting them to rectangular form:  $I = (0.1 + j0) + (0 - j0.0794) + (0 + j0.0629) = 0.1 - j0.0165$ . Converting to polar:  $I = 0.1/-9.37^\circ$ . Fig. 17 shows this as a phasor diagram.  $I$  is the resultant of  $I_1$  and  $(I_2 - I_3)$ . Figure 17 is drawn to scale to confirm that the calculations give a correct result. Although it often helps to draw a sketch, a scale diagram is not needed. Everything can be calculated using complex numbers.

### Solving real problems

**1. Alternating supply voltage:** *Problem:* Two sections of a circuit are connected in series and an alternating voltage is applied across them. The voltages across the two sectors are:  $v_1 = 40\sin\omega t$  V and  $v_2 = 25\sin(\omega t - 40^\circ)$  V. What is the rms value of the applied voltage? What is its phase angle with respect to  $v_1$ ?

*Solution:* The answer is to be an rms voltage, so we first calculate the rms voltages across the circuit section by dividing by  $\sqrt{2}$ .

$$v_{1\text{rms}} = \frac{40}{\sqrt{2}} \sin\omega t = 28.28 \sin\omega t$$

$$v_{2\text{rms}} = \frac{25}{\sqrt{2}} \sin\omega t = 17.68 \sin(\omega t - 40^\circ)$$

Expressing these as phasors in polar form (Fig. 18):  $V_1 = 28.28/0^\circ$  (the angle of this is the reference for the others) and  $V_2 = 17.68/-40^\circ$  (lags behind  $V_1$ ). Since we have to add these phasors, we must convert to rectangular form:  $V_1 = 28.28 + j0$  and  $V_2 = 13.54 - j11.36$ . Now we can add them:  $V = V_1 + V_2 = (28.28 + 13.54) + j(0 - 11.36) = 41.82 - j11.36$ . To find the rms voltage (the magnitude of the phasor) and phase angle we convert back to polar form:  $V = 43.34/-15.20^\circ$ . The applied rms voltage is 43.34V and its phase angle is  $-15.20^\circ$ .

Conversion from rectangular to polar form and the reverse are needed at several stages of this type of calculation. We use bold capital letters as symbols for vectors, including phasors.

Owen Bishop's book "Understand Electrical and Electronics Maths" is aimed at people who find maths difficult, making it hard to grasp electrical and electronics theory. This 256 page book is available by postal application to Lorraine Spindler, EW + WW, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Cost £15.95 including postage and packing. Cheques made payable to Reed Books Services. Credit card orders accepted by phone (081-652 3614). Published by Butterworth-Heinemann.

**2. Instantaneous voltage: Problem:** In the circuit of problem 1, given the frequency is 50Hz, calculate the instantaneous value  $v$  of the applied voltage 5ms after the start of the cycle  $v_1$ .

**Solution:** From the equation for the phasor  $V$ , we obtain an equation for  $v$ :

$$v = 43.34\sqrt{2}\sin(\omega t - 15.20^\circ)\text{V}$$

The  $\sqrt{2}$  converts the voltage from its rms value to instantaneous. We can work in degrees or radians, and choose degrees. If  $f = 50$ , then  $\omega = 360 \times 50 = 18000^\circ\text{s}^{-1}$ . Substituting for  $\omega$  and  $t$  in the equations:

$$v = 43.34\sqrt{2}\sin(18000 \times 0.005 - 15.20) = 61.29\sin 74.8 = 61.29 \times 0.965 = 59.15\text{V}$$

This problem does not directly involve complex numbers but it illustrates the fact that we may or may not need to know  $\omega$  or  $t$  to solve a given problem. When an alternating current or voltage is quoted in the form  $v = A\sin(\omega t + \phi)$ , as in problem 1, we can immediately write out the equation for the phasor without needing to know  $\omega$  or  $t$ :

$$V = \frac{A}{\sqrt{2}} \angle \phi$$

This is because angular velocity has no effect on the size of the phasor, and the time since the start of the cycle has no effect on the angles between the phasors. But, as in problem 2, the equation for the resultant phasor  $V$  of problem 1 can be turned back into an equation for instantaneous voltage. Then, given  $\omega$  and  $t$ , we are able to calculate  $v$  at any instant.

Make sure  $\omega$  and  $j$  are both in radian measure or both in degree measure before adding.

**3. Alternating supply current: Problem:** Two parts of a circuit are wired in parallel, and an alternating voltage is applied across them. Currents are  $i_1 = 40\sin(\omega t + 15^\circ)\text{A}$ ,  $i_2 = 15\sin(\omega t - 30^\circ)\text{A}$ , phase angles being with reference to supply voltage. What is supply current and phase angle?

**Solution:** Written in polar form, the current phasors are:  $I_1 = 40 \angle 15^\circ$  and  $I_2 = 15 \angle -30^\circ$ . Converting to rectangular form, so that they can be added:  $I_1 = 38.64 + j10.35$  and  $I_2 = 12.99 - j7.50$ . Adding the phasors:  $I = I_1 + I_2 = (38.64 + 12.99) - j(10.35 - 7.50) = 51.63 + j2.85$ . Converting to polar form:  $I = 51.71 \angle 3.16^\circ$ . The current is 51.71A with phase angle 3.16°.

**4. Resonance: Problem:** A circuit (Fig. 19) has two sections in parallel, with the impedances indicated. What value inductor is to be connected where shown to make the circuit resonate with the applied voltage?

**Solution:** First calculate the impedance  $Z_1$  of the two sections in parallel, using the same formula as for two resistors in parallel:

$$Z_1 = \frac{30/40^\circ \times 15/-30^\circ}{30/40^\circ + 15/-30^\circ}$$

Multiplying out the numerator gives: numerator =  $450 \angle 10^\circ$ . To add the terms in the denominator, convert to rectangular form and add: denominator =  $(22.981 + j19.284) + (12.990 - j7.500) = 35.971 + j11.784$ . Convert to polar form: denominator =  $37.85 \angle 18.14^\circ$ . Substituting these results:

$$Z_1 = \frac{450 \angle 10^\circ}{37.85 \angle 18.14^\circ} = 11.89 \angle -8.14^\circ = 11.77 - j1.68$$

Having the numbers in polar form makes the division easy, but we need the result in rectangular form for the next step. For the circuit to resonate, its total impedance must be in phase with the input. This means that the imaginary part of the impedance must be zero (that is no phase lead or lag). Therefore the reactance  $Z_2$  of the series inductor must be  $+j1.68$ , to cancel the  $-j1.68$  of the parallel sections. Now  $Z_2 = j1.68 = jX_L \Rightarrow X_L = 1.68$ . At 250Hz,  $X_L = 2\pi \times 250 \times L = 1571 L$ . But for resonance  $X_L$  must equal 1.68  $\Rightarrow 1571L = 1.68 \Rightarrow L = 1.68/1571 = 1.07\text{mH}$ . A 1.07mH inductor is required.

**5. Transmission lines: Problem:** The impedance of a pair of wires is measured for a signal of given frequency when the opposite ends of the wires are open circuited ( $Z_{OC}$ ) and again when they are short-circuited ( $Z_{SC}$ ) with the results:  $Z_{OC} = 45200 \angle -76^\circ$  and  $Z_{SC} = 0.63 \angle 66^\circ$ . Calculating the characteristic impedance,  $Z_0$  given that:

$$Z_0 = \sqrt{Z_{OC} \times Z_{SC}}$$

**Solution:** Multiplying the two terms:

$$Z_0 = \sqrt{45200 \angle -76^\circ \times 0.63 \angle 66^\circ} = \sqrt{28476 \angle -10^\circ}$$

Taking the square root:  $Z_0 = 169 \Omega \angle -5^\circ$ .

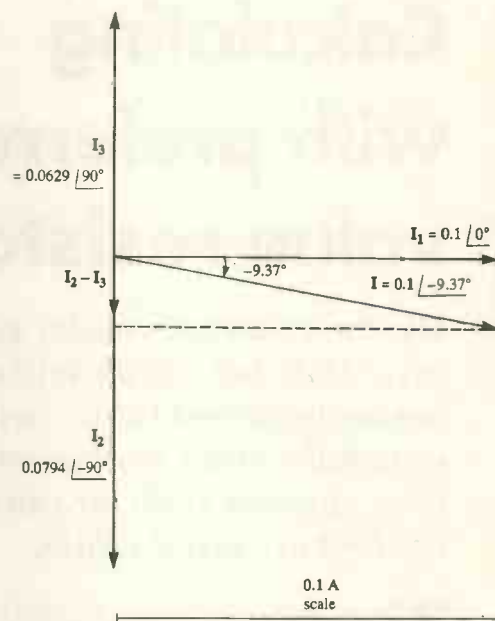


Fig. 17. Calculations for Fig. 16 shown as a phasor diagram.

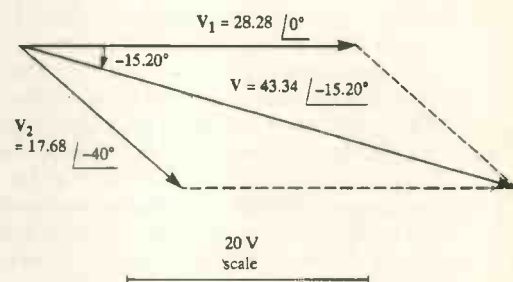


Fig. 18. Expression of phasors in polar form.

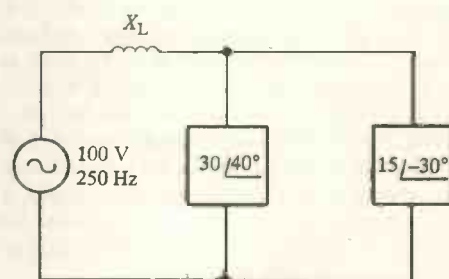


Fig. 19. Circuit with two sections in parallel.

# Calculating with preferred value resistors

*We can calculate resistor values accurately but usually end up buying preferred values because of supplier stock limitations. W Gray suggests code for calculating the best preferred values.*

These programs for calculating the best preferred values were originally written for a Casio pocket computer and then converted to *Basic A* for a PC. Users should have no trouble converting them to other languages. They are not optimised for speed but are certainly quick enough for laboratory use.

Data statements contain the E24 series values but can be rewritten to hold other preferred-value series if desired.

The first program (listing 1) calculates resistor ratios, mostly useful for setting the inverting gain of op amps. The desired ratio is stored in variable *D* and is approximated as *Ra/Rb*. The program makes adjustments to *Rb* or *Ra* depending on whether the ratio is above or below *D*. The best result is the one that gives the minimum error, *E*, calculated at line 50.

Variables *A* and *B* are not the resistances themselves, but are pointers into the array *R()* of preferred values.

A simple modification allows the calculation of potential dividers where the ratio is given by  $Ra/(Ra+Rb)$ . The non-inverting gain of an op amp is the reciprocal of this. Line 50 is edited to:

50  $E = C * R(A) / (R(B) + C * R(A)) - D$

where *C* is a power of 10 multiplier. Best values of *Ra* and *Rb* will be printed and the user can apply a multiplier (power of 10) to bring them up to practical values.

Listing 2 is a program to approximate a resistance value (stored in *F*) by two preferred values in series, *Ra+Rb*.

The principle of the calculation is similar to that of the previous program, but here each resistor has its own multiplier, so the result should not usually need rescaling by the user. The smallest component value allowed in the sum is 1 (unity) so the smallest sum that can be demanded is 2. Better resolution can be obtained by scaling-up the required sum by powers of 10. There does not seem to be much use for products of resistances. The most common product needed is usually an *RC* time constant. As these are generally not needed to be very accurate, it will be enough to use E12 series values. The series combination program (listing 2) can be altered by changing line 80;

80  $E = R(A) * C * R(B) * D - F$

Also, in line 100, *F/2* is replaced by *SQR(F)* as a terminating condition.

If products less than 1 are required, the desired value should be scaled up by powers of 10. Results can then be scaled down to practical values. The series combination program can be altered to calculate parallel combinations, and the revised program is shown in listing 3. Comparing it with listing 2 shows that the logic is upside-down because it is calculating sums of conductances.

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Please send your ideas to Frank Ogden, *EW + WW*, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS.

#### Listing 1. Ratios of resistors

```
10 N=23: DIM R(N): A=0: B=0: F=1.7E+38: G=-1
20 FOR E=0 TO N:READ R(E):NEXT E
30 INPUT "ratio is "; D
40 C=10^(INT(0.5+LOG(D)/LOG(10)))
50 E=C*R(A)/R(B)-D :REM error function
60 IF A=G THEN IF B=H THEN 120 :REM terminate
70 IF ABS(E)<F THEN F=ABS(E):G=A:H=B:I=C:PRINT "error=";E
80 IF E=0 THEN 120 :REM terminate
90 IF E>0 THEN B=B+1:IF B>N THEN B=0:C=C/10 :REM increment B
100 IF E<0 THEN A=A+1:IF A>N THEN A=0:C=C*10 :REM increment A
110 GOTO 50
120 PRINT "Ra=";I*R(G)
130 PRINT "Rb=";R(H)
140 DATA 1,1.1,1.2,1.3,1.5,1.6,1.8,2,2.2,2.4,2.7,3
150 DATA 3.3,3.6,3.9,4.3,4.7,5.1,5.6,6.2,6.8,7.5,8.2,9.1
```

A,B=Ra,Rb pointers  
C=multiplier for A  
D=desired value  
E=error  
F=best error  
G,H=best A,B  
I=best C  
R(N)=array of preferred values

#### Listing 2. Resistors in series

```
10 N=23: DIM R(N): A=0: B=0: C=1: G=1.7E+38
20 FOR E=0 TO N:READ R(E):NEXT E
30 INPUT "sum is ";F
40 D=10^(INT(LOG(F)/LOG(10))) :REM initialise B &
D
50 IF D*R(B)>F THEN 80
60 B=B+1:IF B>N THEN B=0:D=D*10
70 GOTO 50
80 E=C*R(A)+D*R(B) - F :REM error function
90 IF ABS(E)<G THEN G=ABS(E):H=A:I=B:J=C:K=D:PRINT "error=";E
100 IF D*R(B)<F/2 THEN 150 :REM terminate
110 IF E=0 THEN 150 :REM terminate
120 IF E>0 THEN B=B-1:IF B<0 THEN B=N:D=D/10 :REM decrement B
130 IF E<0 THEN A=A+1:IF A>N THEN A=0:C=C*10 :REM increment A
140 GOTO 80
150 PRINT "Ra=";J*R(H)
160 PRINT "Rb=";K*R(I)
170 DATA 1,1.1,1.2,1.3,1.5,1.6,1.8,2,2.2,2.4,2.7,3
180 DATA 3.3,3.6,3.9,4.3,4.7,5.1,5.6,6.2,6.8,7.5,8.2,9.1
```

A,B=Ra,Rb or R,C pointers  
C, D=multipliers for A, B  
E=error  
F=desired value  
G=best error  
H,I=best A,B  
J,K=best C,D  
R(N)=array of preferred values

#### Listing 3. Resistors in parallel

```
10 N=23: DIM R(23): A=N: B=0: C=1000000!: D=1: G=1.7E+38
20 FOR E=0 TO N:READ R(E):NEXT E
30 INPUT "parallel is ";F
40 E=1/C/R(A)+1/D/R(B)-1/F :REM error function
50 IF ABS(E)<G THEN G=ABS(E):H=A:I=B:J=C:K=D:PRINT "error=";E
60 IF C*R(A)<D*R(B) THEN 110 :REM terminate
70 IF E=0 THEN 110 :REM terminate
80 IF E>0 THEN B=B+1:IF B>N THEN B=0:D=D*10 :REM increment B
90 IF E<0 THEN A=A-1:IF A<0 THEN A=N:C=C/10 :REM decrement A
100 GOTO 40
110 PRINT "Ra=";J*R(H)
120 PRINT "Rb=";K*R(I)
130 DATA 1,1.1,1.2,1.3,1.5,1.6,1.8,2,2.2,2.4,2.7,3
140 DATA 3.3,3.6,3.9,4.3,4.7,5.1,5.6,6.2,6.8,7.5,8.2,9.1
```

(variables as for listing 2)

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The PC82 is the US version of the Sunshine Expro 60, and therefore can be offered at a very competitive price for a product of such high quality. The PC82 has undergone extensive testing and inspection by various major IC manufacturers and has won their professional approval and support. Many do in fact use the PC82 for their own use!

The PC82 can program E/EPROM, Serial PROM, BPROM, MPU, DSP, PLD, EPLD, PEEL, GAL, FPL, MACH, MAX, and many more. It comes with a 40 pin DIP socket capable of programming devices with 8 to 40 pins. Adding special adaptors, the PC82 can program devices up to 84 pins in DIP, PLCC, LCC, QFP, SOP and PGA packages.

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The PC82's hardware circuits are composed of 40 set pin-driver circuits each with TTL I/O control, D/A voltage output control, ground control, noise filter circuit control, and OSC crystal frequency control. The PC82 shares all the PC's resources such as CPU, memory, I/O hard disk, keyboard, display and power supply.

A dedicated plug in card with rugged connecting cable ensures fast transfer of data to the programmer without tying up a standard parallel or serial port. Will work in all PC compatibles from PC XT to 486.

The pull-down menus of the software makes the PC82 one of the easiest and most user-friendly programmers available. A full library of file conversion utilities is supplied as standard.

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Over 20 engineers are employed by Sunshine to develop new software and hardware for the PC82. Not many competitors can boast of similar support!

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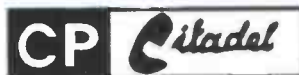
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If you've been waiting for S4 we have some good news. It's available now. S4 is the 1992 successor to Dataman's S3 programmer, which was launched in 1987. The range goes back through S2, in 1982, to the original Softy created in 1978. Like its predecessors, Softy4 is a practical and versatile tool with emulation and product development features. S4 is portable, powerful and self-contained. Design and manufacture are State of the Art. S4 holds a huge library of EPROMS, EEPROMS, FLASH and One Time Programmables. Software upgrades to the Library are free for the life of the product, and may be installed from a PROM by pressing a key. *S4 makes other programmers seem oversized, slow and outdated.* S4 is now the preferred tool for engineers working on microsystem development.

## Battery Powered

S4 has a rechargeable NICAD battery. On average, you can do a week's work without recharging. On a single charge, up to a thousand PROMS can be programmed – and charging is fast: it only takes an hour. Normal operation can continue during the charging process.

## Continuous Memory

Continuous Memory means never losing your Data, Configuration or Device Library. You can pick up S4 and carry on where you left off, even after a year on the shelf. If the NICAD battery loses all of its charge, RAM contents are preserved by the LITHIUM backup battery.

## Remote Control

S4 can be operated via its RS232 Serial Port. The standard D25 socket connects to your computer. Using batch files or a terminal program, all functions are available from your PC keyboard and screen.

## Free Terminal Program

You could use any communications software to talk to S4. But the Terminal Driver program, which we include free, is the best choice. It has Help Screens to explain S4's functions and it sends and receives at up to 115200 baud – that's twelve times as fast as 9600 baud. At this speed a 64 kilobyte file downloads in 9 seconds. There is a memory resident (TSR) option too, which uses only 6k of your precious memory, and lets you "hot key" a file to S4. Standard upload and



download formats include: ASCII, BINARY, INTELHEX, MOTOROLA and TEKHEX.

***S4 loads its Library of programmables from a PROM in its socket, like a computer loads data from disk. Software upgrades are available free. Download the latest Device Library from our Bulletin Board.***

## Microsystem Development

With S4 you can develop and debug microsystems using Memory Emulation. This is an extension of ROM emulation, used for prototype development, especially useful for single-chip "piggy back" micros. When you unpack your S4 you will find an Emulator Lead with a 24/28/32 pin DIL plug and a Write Lead with a microhook. Plug the EMULead in place of your ROM. Hook the Write-Lead to your microprocessor's write-line. Download your assembled code into S4. Press the EMULATE key and your prototype runs the program. S4 can look like ROM or RAM, up to 512K bytes, to your target system. Access-time depends on S4's RAM. We are currently shipping 85ns parts.

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Your microprocessor can write to S4 as well as read. If you put your variables and stack in S4's memory space, you can inspect and edit them. You can write a short monitor program to show your internal registers.

S4's memory emulation is an inexpensive alternative to a full MDS and it works with any microprocessor. Many engineers prefer it because their prototype runs the same code that their product will run in the real world.

## Dimensions & Options

S4 measures 18 x 11 x 4 cm and weighs 520 grams. 128k x 8 (1MB) of user memory is standard, but upgrading to 512k x 8 is as easy as plugging in a 4MB low-power static CMOS RAM.

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