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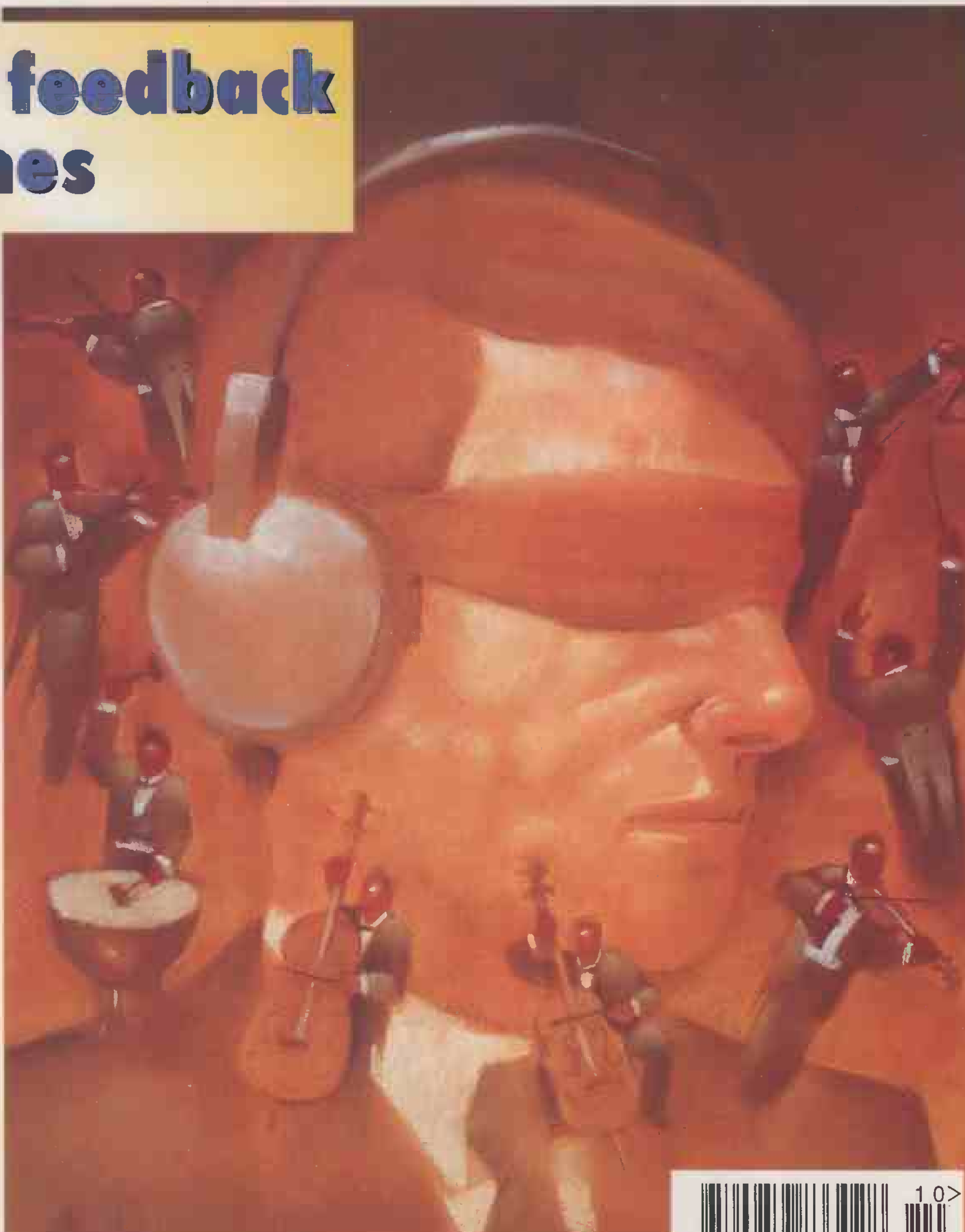
Motional feedback headphones



New voltage multiplier

Selling the radio spectrum

Analogue pc interface

Digits to speech chips

Low-loss rf coupler

Phono preamplifier

PCB CAD reviews – Ranger 2 and Workbench

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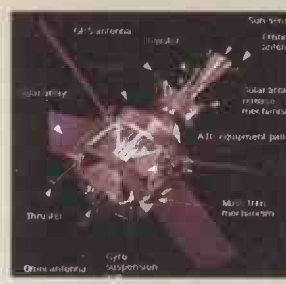
Contents

Cover – Jamel Akib

Regulars

This directional coupler works at gigahertz frequencies but is fabricated using standard fibre-glass pcb – page 763.



Gyroscopes aboard the Gravity probe B mission could answer a lot of questions posed by Einstein's theories on gravity as a field – page 728.

Measuring 21.5 by 8.5 by 7.6mm, the ENC-05E gyroscope handles up to 50 changes in direction a second and a maximum angular velocity of ±90°/s. EW readers can buy one for around £80 – see page 734.

NOVEMBER ISSUE ON SALE 10 OCTOBER

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Practical Wireless July 96

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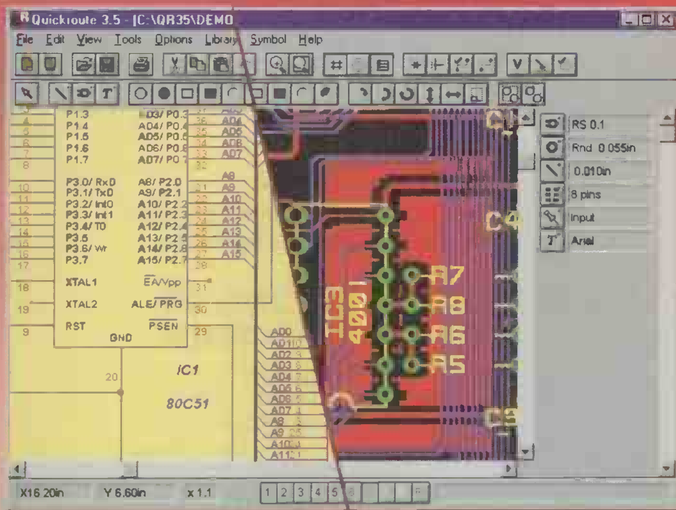

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Design Rule Checking		★	★	★
Connectivity Checking		1	1	2
RouteASSIST (assisted routing)		★	★	★
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Export WMF & Tango			★	★
Export Gerber/NC-Drill			★	★
Extended Libraries			★	★
Tango + Gerber Import				★
Update PC[illegible]hematic				★
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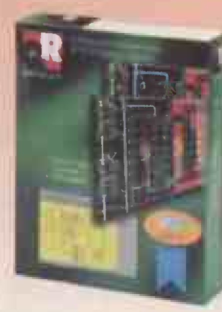
1 Simple pass/fail 2 Advanced Check

NEW Library Packs Available!



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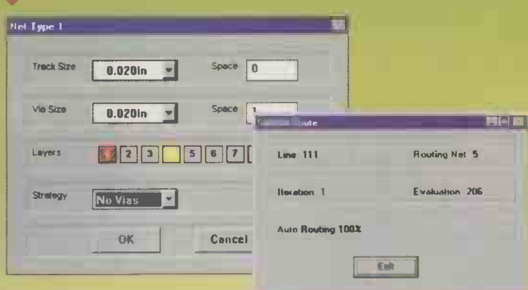

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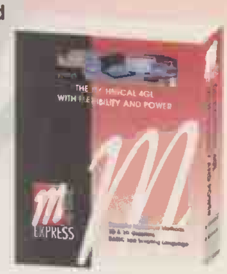

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EDITOR
Martin Eccles
0181 652 3128

EDITORIAL ASSISTANT
Mark Hefley
0181 652 8638

CONSULTANTS
Jonathan Campbell
Philip Darrington
Frank Ogden

DESIGN
Alan Kerr

EDITORIAL ADMINISTRATION
Jackie Lowe
0181-652 3614

E-MAIL ORDERS
jackie.lowe@rbp.co.uk

ADVERTISEMENT MANAGER
Richard Napier
0181-652 3620

DISPLAY SALES EXECUTIVE
Malcolm Wells
0181-652 3620

ADVERTISING PRODUCTION
0181-652 3620

PUBLISHER
Mick Elliott

EDITORIAL FAX
0181-652 8956

CLASSIFIED FAX
0181-652 8956

SUBSCRIPTION HOTLINE
01622 778000
Quote ref INJ

SUBSCRIPTION QUERIES
01444 445566
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REED BUSINESS PUBLISHING

Testing time for EMC

While most engineers would agree with Anthony Hopwood, Letters *EW* March, that there is too much pollution of the electromagnetic spectrum, the way that the European EMC laws have been drafted by our politicians is sure to stifle innovation at grass-roots level. What small company can risk such swingeing fines or what individual engineer can risk three months in prison? To a professional engineer this is comparatively more devastating than similar sentences presently being handed out to low-life rapists and muggers, so I am sure the attitude of many engineers and small firms will be 'why bother bringing a new product to the market place in Europe?'

I have never believed that membership of the EEC has been, *per se*, a good idea for UK industry. The theory that the UK would sink without EEC membership has never been proved. It must rank as one of the more nebulous political arguments promulgated by Euro-fanatics but despite this it is always trotted out on a regular basis to silence critics of the EEC as though it were irrefutable truth.

Any benefit from the EEC – if there has in fact been any – has been overshadowed by such dismal concepts as the Common Agricultural Policy and the monetary policy. Both of these have been disasters for the UK. Industry has also had an extra bureaucratic burden in the form of Value Added Tax – that most European of taxes. And now we have the EMC harmonisation laws. But if you think these were bad, wait until the Low Voltage Directive comes into effect on 1 January next year. I can see many small electronics firms just giving up when faced with both.

I expect that many of those small businessmen who voted us into the Common Market expecting to enjoy a free trade area are now wringing their hands at the never-ending avalanche of bureaucracy aimed at them from that very source.

These two pieces of legislation have all the hallmarks of having been put together by that fatal combination of big business, bureaucrats, and lawyers; fatal that is for entrepreneurs and innovation. Under this legislation, the outlook for any aspiring small electronics company in Europe is grim. The large multinational conglomerates probably had a large say in how the legislation was drafted and will not feel the pinch at all. They are sure to use the legislation against any small competitor if they attempt self-certification, but the only alternative to self-certification is the high cost of third party certification.

I recently observed the demise of two projects due to the new EMC legislation. Due to both the cost and the uncertainty associated with complying with the new EMC regulations, the plug was pulled on these specialised short-run projects. It doesn't take much imagination to see that this will be happening to a greater or lesser extent all over Europe, with many of those useful electronic gadgets and devices produced by small firms – which oil the wheels in industry, commerce and the home – not being brought to market.

One reason why this legislation has been thrust upon the industry is that engineers have never organised themselves into a quasi-political pressure group in the way that other professionals like doctors, lawyers and those running Britain's newspapers and financial institutions have done. This could explain engineers' low status in society, relatively low pay and the almost total lack of political clout that could have prevented the present predicament with the EMC laws – a situation that shows every sign of persisting indefinitely. The professions mentioned above all have self-regulation in their chosen field of operations. If it were suggested that the heavy hand of the law were applied to them – as it has been proposed often enough – there would be political uproar.

"Common sense should have dictated that the EMC problem be resolved in a different way..."

Even in the absence of such an engineering body to protest against such severe legislation, common sense should have dictated that the EMC problem should have been resolved in a different way from this big-stick approach. In particular, small companies and individual engineers should have been provided with an easier route to conformity. In their case, a type of test similar to the MoT test for cars, at a flat rate, and at government approved laboratories would be sufficient.

Such tests could be limited to interference emission only and the tests for EMI susceptibility could be omitted. A case could be made that EMI susceptibility tests are unnecessary, except in some obvious applications such as in aviation, where they may well be critical. In other areas, tests are unnecessary because at lower technical levels, market forces can sort out susceptibility offenders in the usual way. For example, hi-fi amps that are susceptible to EMI are soon picked out by reviewers in the hi-fi press. With an active consumer press – for example magazines such as *Which?* – few products which do not work because of susceptibility to EMI can escape the glare of publicity.

We often hear the maxim that 'tall oaks from little acorns grow'. And we have all seen examples of that in the pc sector of the electronics industry very recently. It is obvious that no acorn will grow in an unfavourable climate, so why have the people who are in control of the industrial climate in Europe created such hostile conditions for small electrical/electronics firms? At the root of this problem is, I believe, the almost total lack of understanding of the electronics industry by our politicians. They are in the curious position of looking enviously at the immense revenues generated by the electronics-based high-tech, relatively unregulated and bureaucracy-free tiger economies of the Far East, most of which sprouted comparatively recently from small beginnings, while at the same time putting another nail in the coffin of their own local small businesses.

How else can such oppressive pieces of legislation be explained?

Rod Cooper

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New memory technology holds more than one bit per cell

The first use of multi-level cell (MLC) technology – storing more than one bit on a memory cell – is likely to come in the form of a rom from NEC in the next few months. Early next year, SGS-Thomson expects to introduce a one-time programmable eprom based on the technology and, by mid-1997, Intel expects to have an MLC-based flash memory.

"We are developing a 64Mbit mask rom using multi-level technology for a games cartridge," Dr Hajime Sasaki, senior executive vice-president of NEC told *EW*, "the price target for a games cartridge is very tough; by using multi-level you can reduce the chip size. We already have a prototype and we are discussing it with customers." NEC's MLC technology stores two bits of memory on one cell, which in the case of a rom is made up of a single transistor.

SGS' implementation of MLC technology also uses two bits per cell. "A test vehicle has been made at Bologna University and the first product, a multi-level one time programmable eprom, will be laid out in Q4 this year", said SGS' Tony Watts. "First silicon is expected in Q1 1997."

MLC technology has been pursued by the Big Three flash suppliers – Intel, AMD and Fujitsu – as a way of increasing density without reducing process geometries. Intel demonstrated MLC-based flash at this year's International Solid State Circuits Conference (ISSCC) and, according to Anne Hall of Intel, an MLC-based product will be introduced in the first half of next year. Samsung also demonstrated MLC at the ISSCC – a 128Mbit, two bit-per-cell, memory made on a 0.4 micron process.

Peter Heinrich at AMD said MLC was some years away for them. Asked if NEC was considering using multi-level technology for flash, Sasaki laughed, replying: "It's difficult enough, for the moment, making ordinary flash."

David Manners,
Electronics Weekly

BBC sends Ceefax via digital radio

A non-interactive Internet-style information service is being broadcast to radios in the UK. The BBC is transmitting Ceefax information in HTML format over its digital audio broadcast (DAB) network.

Glyn Jones, the BBC's DAB project director, said: "We are calling the experimental transmissions BBC Digital Text, but will probably think up a snappier if we provide the service long term."

The transmission illustrates two points. Jones said: "It shows that HTML, which is universally recognised and requires no expensive licensing, can be used with DAB. It also proved we can transfer data from the Ceefax data base fully automatically through to the DAB multiplex, making broader use of our Ceefax information gathering capability.

Part of Jones' brief is to explore the possibilities of DAB. "We have also tried transmitting live RDS-type data along with programmes. This kind of service might be used to provide the 'story so far' if you switched on the radio mid-way through a play," continued Jones.

While the Ceefax information transmission is designed to be displayed on pcs linked to DAB receivers, at least one potential receiver manufacturer is thinking of incorporating a graphics display. Jones said: "DAB radios could display photographs and graphics along side station names and music titles."

A motorcycle simulator system from Virtuality is the first product to be EMC pre-compliance tested using Chloride Powerline's free service. Dr Paul Sheppard, Virtuality's senior engineering manager, said: "Powerline's free service was very useful as it allowed us to ensure that the simulator hardware would pass its formal EMC compliance at an approved laboratory." The simulator allows learner riders to experience dangerous situations without the worry of crashing a real bike.

New guidelines clear CE confusion

Confusion that exists in the CE-marking of power supplies is being addressed with the issue of new guidelines for manufacturers.

The guidelines have been drawn up by a working party of the European Power Supply Manufacturers Association (EPSMA).

EPSMA Chairman Mr Jan Tipps said: "Our objective in drawing up these guidelines was to clear up the confusion surrounding the interpretation of the regulations as far as the power supply is concerned."

The guidelines summarise the following: what a CE mark is; and how the low voltage and EMC directives apply to both stand alone and component supplies. The EPSMA represents 28 European manufacturers responsible for the sales of \$1.3bn worth of power supplies into the European market.

EMC checks down under

Our friends down under are soon to experience the joys of Euro-style EMC regulations, with a vengeance.

Based on the European EMC directive, the new Australian system will initially cover emissions only. New products must comply from 1 January 1997, older products from the start of 1999.

Even low-volume manufacturers, originally excluded from the regulations, will now have to comply.

Unlike in Europe, where the issue of enforcement is yet to be fully resolved, compliance documentation in Australia will be audited on a random basis.

The Australians' no-nonsense approach is typified by its Spectrum Management Agency, overseer of complaints of interference, which has said it will investigate any bona fide complaints received.

'Independence Day' for MPEG-4 standard

The latest multimedia hardware standard, known as MPEG-4, moved a step closer to commercial products with new component standards agreed at a meeting in Finland last month.

MPEG-4 is being developed to enable the efficient communication of, and interaction with, audio and video objects.

Paul Fellows, a project manager at SGS-Thomson involved in MPEG4 development work, said: "The encoding and decoding of various shaped video objects has already been demonstrated in MPEG-4. Now it's just a case of refining the techniques used."

According to Fellows, the standard is still on course for ratification in November 1998.

The scope of the new standard means that whereas MPEG-2 was concerned with the delivery of TV to enable more channels or reduce cost, MPEG-4 reflects the advent of multiple, separate audio and video 'objects'.

Fellows cited 'virtual' TV studios and films such as 'Independence Day' as examples of what is being done at present with composited objects. The current MPEG-4 work includes the development of verification models (VMs) for video, audio and the systems and description language. Currently over 150 contributions to the video VM are being evaluated.

The audio group is investigating an audio standard which is non-backward compatible to MPEG-2's audio standard. It uses multiple channels and offers comparable quality at a lesser bit rate. Meanwhile, the systems group is working on the definition of how the various objects are to be multiplex into a single bit-stream. The group is also defining the various Application Program Interfaces (APIs) for the various decoding and composition tools.

JPEG 2000 proposed

JPEG 2000, a new still image compression standard, is being proposed by the Joint Photographic Expert Group (JPEG) and the Joint Bi-level Image Experts Group (JBIG).

The intention is to improve on the current JPEG standard in several areas, including low bit-rate and bi-level (text) encoding performance.

JPEG is said to introduce unacceptable subjective distortion of detailed grey-level images at low bit-rates (less than 0.25bpp). It is also optimised for natural images, and does not perform well on bi-level and computer generated images. This poor performance has precluded the widespread acceptance of JPEG for use on compound documents.

In addition, JPEG 2000 will offer both lossy and loss-less compression, and feature a single decompression architecture (JPEG has 44 decompression modes, many of which are application specific).

Moves are also afoot to provide the coding tool, or tools, for JPEG 2000 compression with an interface to those proposed for use in MPEG4 video encoding.

JPEG 2000 will remove JPEG's 64,000 by 64,000 pixel limitation without tiling.

Ambulances to test linear radio

The National Health Service (NHS) is to test a new 5kHz narrow band, linear modulation, radio system for its ambulances, to replace an existing fm system before the introduction of Tetra digital systems.

The system, based on products from Securicor Linear Modulation, will replace its traditional 2.5kHz fm system in a trial in Kent.

John Burnside, chief executive of Kent Ambulance, said: "We are faced with a pressing need to replace our current radio system. In the period prior to Tetra digital systems coming on-stream, LM is claimed to offer a number of potentially useful advantages in both spectral efficiency and data transmission."

Richard Percy, a spokesman for Securicor, said: "The linear modulation technique was developed at the Bath University. It uses dsp for modulation and demodulation, relying on an 'invisible tone' introduced by the transmitter to act as a reference for the receiver." Securicor has licensed the technology through the British Technology Group.

Data relies on a variable rate modem at up to 9.6Kbit/s. Dependent on the outcome of the trial, LM may be allowed to go forward as a technology option for ambulance trusts currently procuring radio services under the government's Private Finance Initiative.

Euro trial for CDMA

Cellular mobile operator T-Mobil of Germany is to run trials of a CDMA (code division multiple access) system from Motorola – one of the first in Europe.

The 800MHz system from Motorola's European Cellular Infrastructure Division has a planned start for a technical field trial of the fourth quarter this year.

Motorola believes the trials will show that CDMA can offer competitive advantages and open up new markets worldwide.

CDMA is said to offer higher capacity and better sound quality while using less power than competing systems. However, hardware is still in the development phase.

The current European cellular system, GSM, based on TDMA (time division multiple access), is two-thirds the cost of CDMA in terms of chip content. Even though prices will reduce, the imbalance is expected to remain for some time.

Anti-terrorism ID chip from Micron

In an effort to combat terrorism, Micron Technology has introduced a new chip designed to be used as an identification device on shipping containers or luggage. Dubbed MicroStamp, the postage stamp sized chip, includes radio telemetry, processing and memory functions. The emitted signal can be detected within a range of three metres by an electronic scanner. Along with replacing bar codes, the company believes that the chip can be used to help combat terrorism through its ability track packages throughout their journey. Sources state that Micron has been awarded a research contract by the Federal Aviation Administration involving the use of MicroStamp in the development of a luggage security system.

Drop in pay rises

Pay rises are at an 18 month low in the engineering industry according to the Engineering Employers' Federation (EEF).

The EEF's July Pay Bulletin analysed 449 company's settlements, with a June average of 3.11%.

Pay settlements are continuing to fall, with 85% of rises at 4% or less and 44% of companies offering 3% or less.

New FPGA aimed at designers

A new field programmable gate array (fpga) synthesis tool from Exemplar Logic aims to convince designers to move from schematic capture to VHDL design entry. Dubbed VHDL Discovery, the new tool is a simplified version of the company's Galileo software. Priced at $4,000, the software can be updated to either Galileo or Leonardo, adding simulation, timing verification other features. ■

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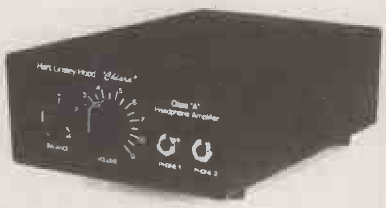

This unit provides a high quality headphone output for 'stand alone' use or to supplement those many power amplifiers that do not have a headphone facility. Easily installed with special link-through feature the unit draws its power from our new Andante Ultra High Quality linear toroidal supply. Housed in the neat, black finished, Hart minibox it features the wide frequency response, low-distortion and 'musicality' that one associates with designs from the renowned John Linsley Hood. Pre-terminated interconnecting leads and PCB mounted sockets prevent supply polarity reversal and on-board diagnostics provide visual indication of supply line integrity. Volume and balance controls are Alps "Blue Velvet" components. Very easily built, even by beginners, since all components fit directly on the single printed circuit board. The kit has very detailed instructions, and even comes with a complementary roll of Hart audiograde silver solder. It can also be supplied factory assembled and tested. Selling for less than the total cost of all the components, if they were bought separately, this unit represents incredible value for money and makes an attractive and harmonious addition to any hifi system.

K2100 Complete Kit.......... £109.50
K2100SA Series Audiophile version with selected audiophile components.......... £112.46
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K3565 "Andante" Power Supply Kit to suit "Chiara".......... £85.42
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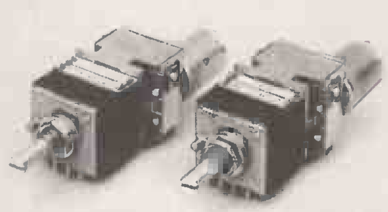

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RESEARCH NOTES

Jonathan Campbell

Gel helps take the pressure off snorers

Development of a new optical fibre transducer could mean good news for serious snorers. Researchers at Leicester University who have designed the probe hope that the transducer will be used to provide valuable feedback on the pressure profile in the upper airways. The fibre transducer is able to measure pressure at various sites in the airway simultaneously. It could indicate if the snoring is a result of the potentially serious obstructive sleep apnoea syndrome, osas.

Many of us snore at one time or another, with little harmful effect – except to the sanity of our partners. But for some, the snoring is a result of the involuntary occlusion of the airway that occurs in osas, where breathing stops for ten or more seconds. Periodic hypoxaemia and sleep fragmentation are the result.

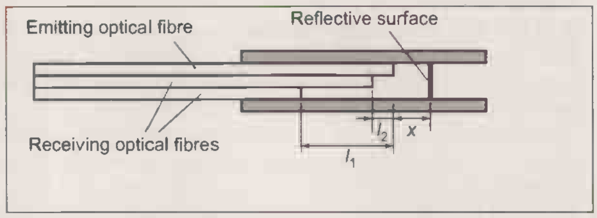
The problem for doctors is that the condition is only apparent when we are asleep, when our muscles – including those of the upper airway – relax. During respiration, the ensuing negative gauge pressure causes the airway to collapse. Then the patient awakens momentarily, tone returns to the muscles and the obstruction is overcome. The airway may be collapsing at the palate, behind the tongue or at both sides. Unfortunately, successful treatment demands that the site of the obstruction must be identified reliably.

This has been the impetus behind the work of Paul Goodyear and colleagues who have developed a seven transducer system within a single 3mm diameter catheter, allowing measurements to be taken at selected points along the airway ("The design of an optical fibre pressure transducer for use in the upper airways," IEE Transaction of Biomedical Engineering, Vol 43, No 6, pp. 601-606) .

Each transducer is less than 1mm in diameter, and consists of one emitting and two receiving fibres. The second receiving fibre sits in a slightly different location and at a different distance from the transduction element, so that when the transducer is bent on its progress through the airway, the second fibre will be available as a reference to determine signal loss.

But the real breakthrough in the design of the miniature transducer has been in development of a replacement of the normal rigid diaphragm which would be too brittle at these diameters. Here the team has used a gel coated with reflective titanium dioxide. In response to pressure changes, the meniscus deforms and modulates the intensity of light reflected back into the optical fibre system.

Contact Paul Goodyear at the Department of Engineering, University of Leicester, University Road, Leicester LE1 7RH or email at pdg@leicester.ac.uk



Three-fibre pressure transducer designed to overcome amplitude modulation problems caused by optical fibre micro-bending. The reflective surface is a coated silicone gel.

Darts in space: You're floating around with your other astro-buddies twiddling your thumbs and gently bumping around inside the confines of the multi-million rouble 'tin can' (© David Bowie) that is the Mir space station. "How about a nice game of darts?"

As unlikely as it might seem, darts is very much on the approved list of activities, as part of an experiment designed by engineers at MIT to produce a better understanding of how crew members physically affect their environment. The data could save millions in the design of future space structures like the scheduled international space station.

Currently there is very little data on the forces astronauts exert on spaceships, so engineers must over-design the racks housing sensitive experiments that could be disturbed by astronauts' movements.

As part of the experiment, the researchers will videotape crew members playing darts to study how they adapt to zero gravity. With the help of four cameras, scientists back on Earth will be able to trace out the entire arm motion to obtain three-dimensional data. The plan is to have the Mir travellers perform the experiment as soon as possible after they arrive on Mir, then at the middle and end of their time there, to show how they adapt to their new environment.

As part of the same study, data will also be collected on the forces applied as the crew uses specially instrumented footloops, a handhold, and a push-off pad to get around or anchor themselves.

Back in 1994, aboard the Space Shuttle Columbia, related experiments yielded the first data on the forces associated with astronauts' everyday activities, and showed that previous estimates of those forces were off by an order of magnitude. That study showed each astronaut had an average force value of 28N, while for the space-station models, 800N was being used for crew input, based on experiments in the 1970s with astronauts aboard Spacelab. Those studies, however, represented the 'extreme', with astronauts 'pushing off one wall and soaring to another wall as fast as they could', according to MIT.

But as anyone who has ever tottered up to the ockey in their local on a Friday night with a beer in one hand and a dart in the other will know, such behaviour is anything but extreme.

Has anyone seen my dart? MIT have put game into space to see how space travellers aboard the Mir space station react to weightlessness.

Gyroscopes that could put Einstein in a spin

Gyroscopes built to provide a reference system a million times better than the best inertial navigation gyroscopes currently available are at the heart of a space mission to be launched in year 2000 that could lead to a rethink of our understanding of time and space. Researchers at Stanford University are working with scientists at NASA on the project which some physicists believe could lead to a possible rewriting of Einstein's General Theory of Relativity.

The gyroscopes, part of the gravity probe B project, are designed to be so free from disturbance that they can provide an almost perfect space-time reference system. As such, scientists hope they will be able to measure how space and time are warped by the presence of the Earth, and how the Earth's rotation drags space-time around with it.

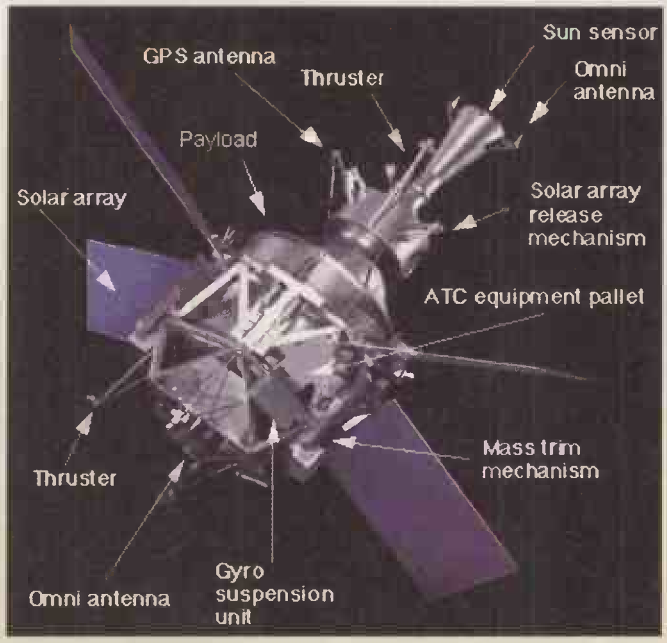
Calculations suggest that a gyroscope in polar orbit at 400 miles should turn with the Earth through an angle amounting after one year to 42milliarc-seconds. Up to now this vitally important frame-dragging effect has never been seen. But gravity probe B should be able to measure it to a precision of 1% or better.

A second, much larger change in spin direction is the geodetic effect, following from the gyroscope's motion through the space-time curvature. For a gyroscope, the predicted effect is a rotation in the orbit-plane of 6600 milliarc-seconds per year – quite a large angle by relativistic standards. Gravity probe B will measure the change to 1 part in 10,000 or better, the most precise qualitative check yet of any effect predicted by general relativity.

The Stanford team explains that the experiment itself will comprise four gyroscopes and a reference telescope sighted on Rigel, a binary star in Orion. In polar orbit, with the gyro spin directions also pointing toward Rigel, the frame-dragging and geodetic effects come out at right angles, each gyroscope measuring both.

To be able to make the measurement, the gyroscopes must provide a reference system stable to 10-11°/hour. Fortunately, two factors – space and near zero temperature – help to make the problem slightly less impossible.

Electrically suspended gyroscopes have long been among the best inertial navigation instruments but ordinarily their performance is limited by support forces. Space, enhanced by 'drag-free control', allows the support to be reduced almost to nothing. Low temperature operation greatly improves the mechanical stability of the instrument; and it also brings means of shielding the gyroscopes against non-gravitational disturbances and of reading their directions of spin.



Gyroscopes aboard the Gravity probe B mission could answer a lot of questions posed by Einstein's theories on gravity as a field.

The complete Gravity Probe B instrument is made of a core of fused quartz 530mm long, bonded to a quartz telescope and containing the four gyroscopes plus the drag-free proof mass.

The gravity probe B Mission is planned for launch aboard a Delta II rocket from Vandenberg Air Force Base in October 2000.

● *Information on the gravity probe-B mission, a great deal of interesting background on relativity and Einstein, can be found on the Internet World Wide Web at http://stugyro.stanford.edu/RELATIVITY/GPB/GPB.html*

Weeds get the robot treatment

How do you tell a plant from a weed? It's sometimes difficult for the ordinary person (and impossible for the Research Notes office gardener). So how do you lay down the rules to enable a robot to make that distinction? R Brivot and J A Marchant at the Silsoe Research Institute think they have found the answer, and hope they have the basis of a robot that can move along lines of plants, selectively picking out the weeds to spray them with chemicals.

Motivation for the work is the huge amount of chemicals currently used in crop protection programmes, and pressure from consumers and environmentalists to make reductions. Using a robot sprayer to put the chemicals only and precisely where they are needed could help achieve that goal.

But first the robot has to be able to see the difference between the weed and plant. Brivot and Marchant have developed an infrared-based system that, under the right conditions, is showing good results ("Segmentation of plants and weed for a precision crop protection robot using infrared images", R Brivot and J A Marchant, IEE Proc – Vis Image Signal Process, Vol 143, No 2, pp. 118-124).

The system relies on a high resolution sensor in the form of a ccd camera, permitting the use of grey-level distribution of the infrared images as well as texture information. The camera is fitted with a near-infra-red filter and is linked to a data acquisition system which stores 256 x 256 pixel image sequences.

Key to successful discrimination is the strength of the algorithms used to process the images and these are based on a number of hypotheses – for example plants are defined by single blobs which do not touch each other. Most of the time the grey level distribution is sufficient for discriminating plants and weeds (and certainly good enough for discriminating plants and soil). But where it isn't, texture information can be used, because the grey-level surface of the plants is more constant than the weeds and the plants appear brighter than their centres.

Results so far show a 92% correct classification with "good" images and up to 72% with "bad" images. The processing can be carried out in real-time too as most of the algorithms do not need a knowledge of the whole image so multiprocessors can be used.

Unfortunately, there is some way to go yet before a robot can be built to keep the Research Notes garden free of weeds – and in that case it would need to be fitted with a flame thrower rather than a chemical spray. For instance, the Silsoe study was carried out on the specific problem of tending cauliflowers transplanted from greenhouses into lines in a weed-free bed. The plants are nearly always bigger than the weeds, but the situation does reflect commercial practice. The work was also carried out in diffuse lighting conditions rather than direct sunlight. Even so, with 23,000tonnes of chemicals used for treating crops last year, the incentives for continuing with the work are high.

More information from Biotechnology and Biological Sciences Research Council, Silso Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS, UK.

Rocket engine shows promise

Tests on the prototype of NASA's xenon ion engine, which fires electrically-charged atoms from its thruster, are reportedly progressing well at the Jet Propulsion Laboratory, Pasadena, California. Once validated by the test, a similar engine will power the first New Millennium mission, called Deep Space-1, to an asteroid and a comet in 1998. The comet will be West-Kohoutek-Ikemura and the asteroid will be McAuliffe, named after the school teacher Christa McAuliffe who died in the Challenger accident.

In space, the 300mm diameter engine will use xenon gas as fuel and be powered by more than 2000 watts from large solar arrays provided by the Ballistic Missile Defence Organisation. The actual thrust comes from accelerating and expelling the positively-charged ions. The thrusting action is similar to that of chemical propellant engines which expel burning gases, except that such engines can produce up to millions of pounds of thrust.

The roaring engines in rockets that lift the Space Shuttle quickly lift the Shuttle to more than 17,000mile/h. An ion engine, however, starts with only about 20-thousandths of a pound of thrust and there is no roar, just an eerie blue glow. While the atoms, charged by an electric arc which removes one of the 54 electrons around its nucleus, are fired in great numbers out the thruster at more than 70,000 miles an hour, their accumulative mass is so low, the spacecraft moves only millimetres per second in its early stages of flight.

However the advantage of ion propulsion is that is more propellant-efficient than chemical propulsion because it expels molecules from the engine at a much higher speed.

DSP slows speech – and speeds understanding

It makes sense to speak a little more slowly to elderly people who are hard of hearing – particularly in the light of studies that have shown that temporal processing factors other than peripheral hearing loss can be involved.

Pressing a button on the speech rate selector allows speech to be slowed down so that it is easier to understand.

Now Japanese researchers have used recent improvements in digital-signal processing technology, dsp, to design a portable speech converter that can be used by a listener to slow down speech in real time conversation – without affecting pitch.

A user simply operates the device by pressing a button, to cause speech signals to be recorded into memory while previously-recorded signals are being slowed and generated. A 16Mb random-access memory allows two to three minutes of speech to be recorded at once, which should be enough for normal conversation.

To keep the size of the device small and reduce the complexity of dsp operation, a simplified pitch-synchronous time-scaling algorithm has been developed. Time scaling expands only the duration of those signals above a certain power level and does not change the duration of signals below that level – such as consonants. This dynamic processing feature helps minimise extra distortion in the output device.

The device's hardware, which has been squeezed into a unit that fits in the hand, consists of a 33Mflops 32bit dsp, the 16Mb memory and 14bit 13.3kHz analogue-digital interface circuits specially designed for the dsp. The dsp program itself is stored in a 256K eprom.

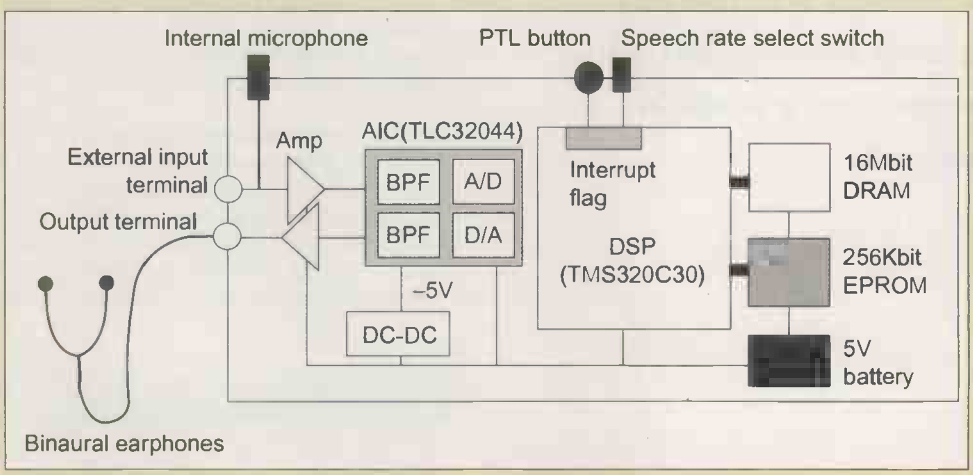
Initial results (A portable digital speech-rate converter for hearing impairment," Yoshito Nejime et al, IEEE Transactions on Rehabilitation Engineering, Vol 4, No 2, pp. 73-83) showed improved understanding by seven out of ten elderly subjects who had hearing difficulties and were allowed to use the device.

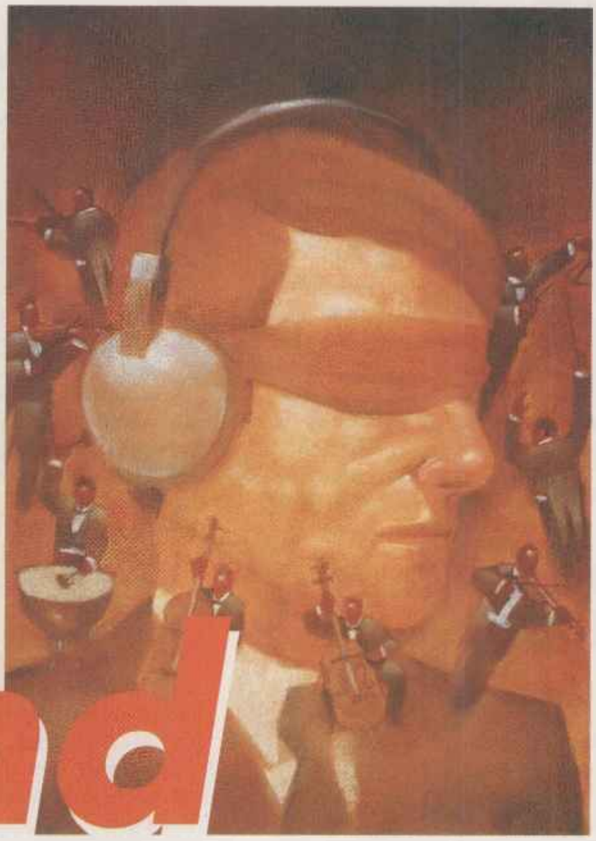
The researchers say the results suggest that speech-rate conversion can be used to overcome the deterioration of peripheral ability by helping auditory memory processing. In this it may have a function complementary to that of conventional hearing aids and could be used in conjunction with them.

A smaller version of the device, with lower power consumption and using a low-voltage risc chip is currently under development. ■

Contact J Nejime at the Central Research Laboratory, Hitachi Ltd, Kokubunji, Tokyo 185, Japan or email at nejime@crl.hitachi.co.jp

16Mb dram gives enough storage to handle two-three minutes of speech which should enable listeners to get through a normal conversation.





Music in mind

A problem with headphones is that when you move your head, the sound source moves with you. As an exercise in applying a low-cost gyroscope, Ian Hickman has designed a headphone rig that emulates a stationary sound source – but why does it only work in mono?

Listening to music through headphones has several advantages, perhaps the main being that you can have the volume as loud as you like without disturbing anyone else. But the main disadvantage is perhaps that the music sounds as though it is inside your head.

Many years ago, I was told by a colleague that this is because there is no differential change in the phase of the signals reaching the ears when the head is turned. Normally, there would be, this being the mechanism that allows you to determine which direction a sound is coming from.

I had long wanted to check out whether adding delays to the signals to the left and right earpieces – delays which varied whenever the head was turned – could 'externalise' the sound. But the opportunity to do so had not arisen. Doubtless the experiment has been performed before, but that is no reason for not trying it oneself. Besides, implementing such a concept presents some very interesting design problems.

Recently I saw an advertisement for a miniature all solid-state gyroscope. Here surely was a solution in search of a problem. One of the uses envisaged by the manufacturer is automobile navigation systems. Clearly there are many others – among them the aforementioned psychoacoustic experiment. The gyroscope could be used to sense rotation of the head, and this signal used to adjust the delays in the left and right channels.

Gyroscope details

The piezo-vibrating gyroscope uses a triangular prism of Elinvar metal, to which are attached piezo-electric transducers. These transducers are maintained in a flexural mode oscillation by an oscillator operating at the assembly's resonant frequency, **Fig. 1a)**. Vibration is maintained by a set of three electrodes, Fig. **1b)**, two of which are also used as sensors. When the unit is rotated about the longitudinal axis of the prism, an additional component of force is applied to the piezo-electric material, Fig. **1c)**. This results in a differential component in the voltage at the two detection electrodes as in Fig. **1d)**. The differential component is picked off and synchronously detected, filtered and smoothed, providing a voltage proportional to the rate of change of direction.

Figure 2 shows an application circuit from the manufacturer's data sheet for the device. Note that the signal output is ac coupled. This is to allow for a possible standing offset between the signal output and the reference voltage to which it relates – in particular for temperature variation of this offset. There is

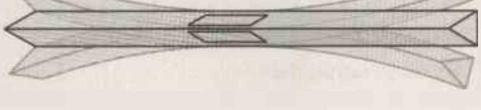


Fig. 1a) Murata's piezoelectric vibrating gyroscope uses a triangular prism, maintained in a flexure-mode vibration.

also a temperature coefficient of the nominal 1.11mV/°/s scale factor.

In an automotive navigation system, it is assumed that the vehicle will return to a straight-line course after each turn before the high-pass filter introduces too much signal loss. If you were to drive round and round a roundabout however, the system might presumably lose track of the vehicle's direction. Since the device produces a signal output relative to the reference, which indicates the rate of turn, this signal must be integrated to obtain an output giving the actual direction of travel.

It is however possible to engineer a 3dB corner frequency much lower than the 0.3Hz, Fig. 2, avoiding this problem while still blocking the much slower variations in output offset due to temperature variations.

Head-mounting gyroscope

For the purposes of the psychoacoustic experiment, I fixed the gyroscope to the headband of a pair of earphones, to detect head movements. The gyroscope was mounted on a small piece of 0.1in matrix copper strip board. A couple of metres of screened lead was used for the signal and earth connections, and two other wires, for the +5V supply to the unit and its reference output V_{ref}. Signal output was passed through an ac coupling with a time constant of 300s, giving a low-frequency cut-off of about 0.0005Hz.

Figure 3 shows the arrangement, in which the gyroscope output is applied via a low-pass filter to the input of a unity gain buffer stage A_1. Designed to further suppress switching ripple in the signal output, the filter before the buffer comprises a 100kΩ resistor plus 10n capacitor.

The 10MΩ resistor at the non-inverting input of A_1 is returned not to V_{ref}, but to a point at 97% of A_1's output. This effectively multiplies its value by a factor of 30, giving in conjunction with the 1µF capacitor, a time constant of 300s.

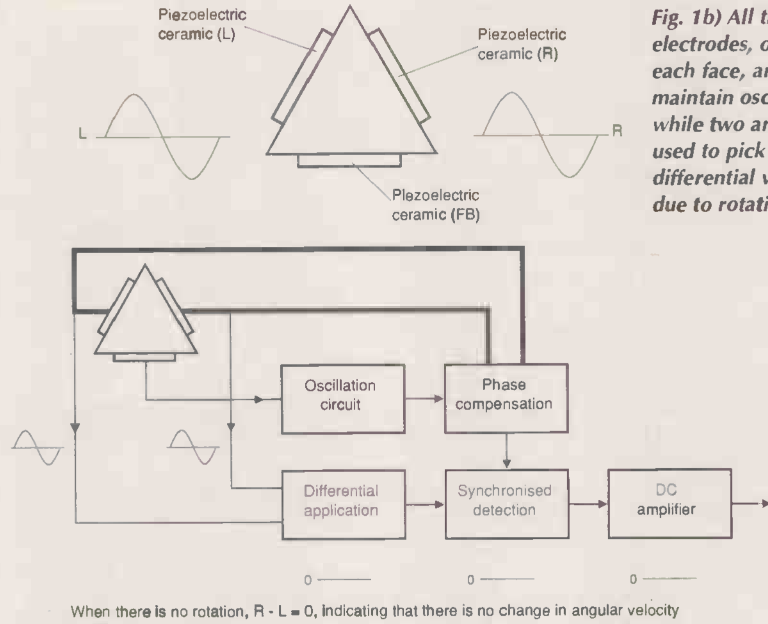


Fig. 1b) All three electrodes, one on each face, are used to maintain oscillation, while two are also used to pick off any differential voltage due to rotation.

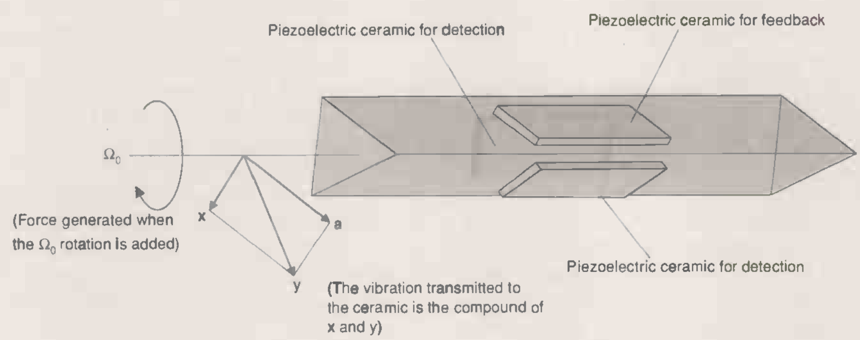


Fig. 1c) When rotation about the longitudinal axis occurs, force transmitted to the prism contains extra component 'a'.

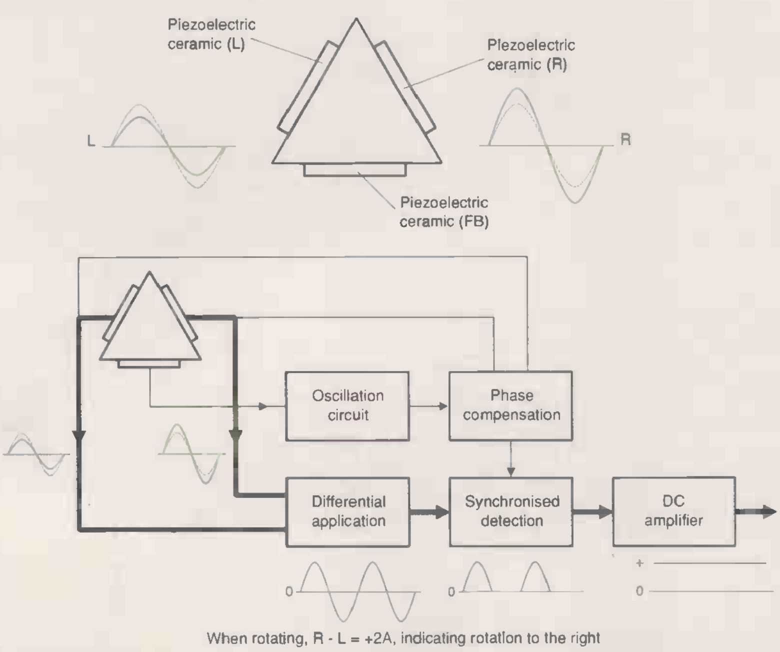


Fig. 1d) This results in a corresponding differential voltage between the detection electrodes, proportional to the rate of rotation.

For A_{1-4}, I used a *TLE2064* quad op-amp on account of its low bias current I_b of 3pA and offset current I_o of 1pA – both typical values, at 25°C. Buffered high and low-passed signal output, together with the reference output, are applied to A_2. This op-amp is connected as a bridge amplifier providing rejection of the common-mode reference voltage. Its output is thus ground referenced, adequate common mode rejection being obtained due to the use of 1% metal film 100kΩ and 270kΩ resistors.

Op-amp A_2 provides a gain of ×2.7. A further gain of ×10 is raised in A_3, at which stage an offset adjustment is introduced, to allow for offsets in A_1 and A_2.

In practice, at switch-on, it was necessary to temporarily short the 10MΩ resistor at the non-inverting input of A_1, to avoid a very long wait for the dc conditions to settle. On removing the short, there was still an offset due to I_b flowing in 10MΩ rather than a short circuit. So a 10MΩ resistor was included in the inverting input also, bypassed by a 330pF capacitor, to maintain stability.

A normally-open two-pole switch was used to short both 10MΩ resistors at switch-on, to allow for settling. Even so, drift of the output of A_1 was still experienced. I finally removed the 1μF capacitor and the resistors, and reconnected A_1 as a simple dc coupled unity gain buffer.

Offset between the signal and reference outputs of the gyroscope turned out to be only a few millivolts, and could thus be nulled with the offset adjustment at A_3's input. As ambient temperature changes in a domestic environment are small and slow-acting, this proved acceptable for the purposes of this experiment.

To obtain the absolute rotary position of the headphones, the output of A_3 was integrated. But here there is a problem; integrators have an annoying but unavoidable habit of heading off, over the long term, to one or other of the supply rails. This is because in practice, the input voltage never remains exactly at zero.

The solution used was twofold. Firstly, when the listener's head is stationary, giving no output from the gyro and hence none from A_3, the 27kΩ resistor at the integrator's input is effectively disconnected by the two diodes.

Furthermore, to prevent the integrator from integrating its own input bias current, a 3GΩ resistor was connected across the 1μF integrating capacitor. Actually, a 10MΩ resistor was used, but since only one thirtieth of the integrator's output is applied to it, its effect is that of a 3GΩ resistor. This means that, in the absence of head movements, the 'sound stage' will over a period of many minutes, revert to straight ahead. This is where it should be of course, assuming that you will not want to spend long periods with your head cocked uncomfortably to one side or the other.

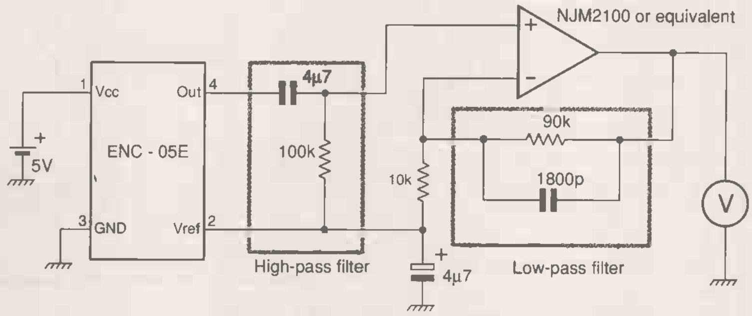
Note that considerable gain has been used ahead of the integrator. As a result, even comparatively small, slow movements of the head produce a large enough output from A_3 to turn on one or other diode. This effectively reconnects the 27kΩ resistor at the integrator's input.

Checking the delays

Output of the integrator, indicating the rotational position of a listener's head, was used to control the relative time delay of the sounds reaching the ears. To find out what this should be, some simple measurements and calculations were needed.

With the aid of a ruler and a mirror, I determined that my ears were about 14cm apart. Thus, when the head is turned through an angle of 45° to left or right, one ear moves to a position, in the fore-aft direction, 10cm ahead of the other. So each channel needs to be able to produce a delay equivalent to ±5cm, or, given the speed of sound is about 1100 feet per second, ±150μs, **Fig. 4**.

Bucket-brigade devices were used to produce a delay in the signal to each earphone. The delay was varied by altering the clock frequency used to drive the bucket-brigade devices. The 1024 stage bucket-brigade chips used, namely Panasonic *MN3207*s, were each



The high-pass filter's cut-off frequency is approximately 0.3Hz
The low-pass filter's cut-off frequency is approximately 1kHz

Fig. 2. Sample amplifier circuit from the ENC-05EA1 solid state gyro data sheet. Note that the base diagram shown is confusing; V_{ref} is actually on the same side of the device as V_{cc}.

driven by a matching *MN3102* cmos clock generator/driver. This generator contains a string of inverters which are usually used in conjunction with an external *R* and *C*, setting the clock frequency.

For this application, the *R* and *C* were omitted, and the first inverter driven by an externally generated clock. The two clock generator/drivers were driven by two voltage-controlled oscillators, or vcos. These in turn were controlled by an long-tailed pair, driven from the output of the integrator in Fig. 3.

Initially, an elegant vco using an operational-transconductance amplifier and a *TL08x* op-amp was designed and tested. This had the advantage of providing a unity mark/space ratio independent of output frequency. However, I abandoned the transconductance amplifier as it would not run fast enough. Drive to the clock generator/driver chips has to be at twice their clock output frequency. So a pair of simple vco circuits, using two sections of a *CD4093* quad two-input schmitt nand gates, were used, **Fig. 5**. These gates run at about 230kHz, providing a clock frequency of around 115kHz from the *MN3102*s for each bucket-brigade device.

The output waveform of the vcos is distinctly asymmetrical, and varies with the long-tail pair control input. But the *MN3102* device turns this into two antiphase non-overlapping clock waveforms with near unity mark/space ratios.

Differential delays

The long-tail pair provides differential control by subtracting a greater or lesser amount from the available charging current via the 27kΩ

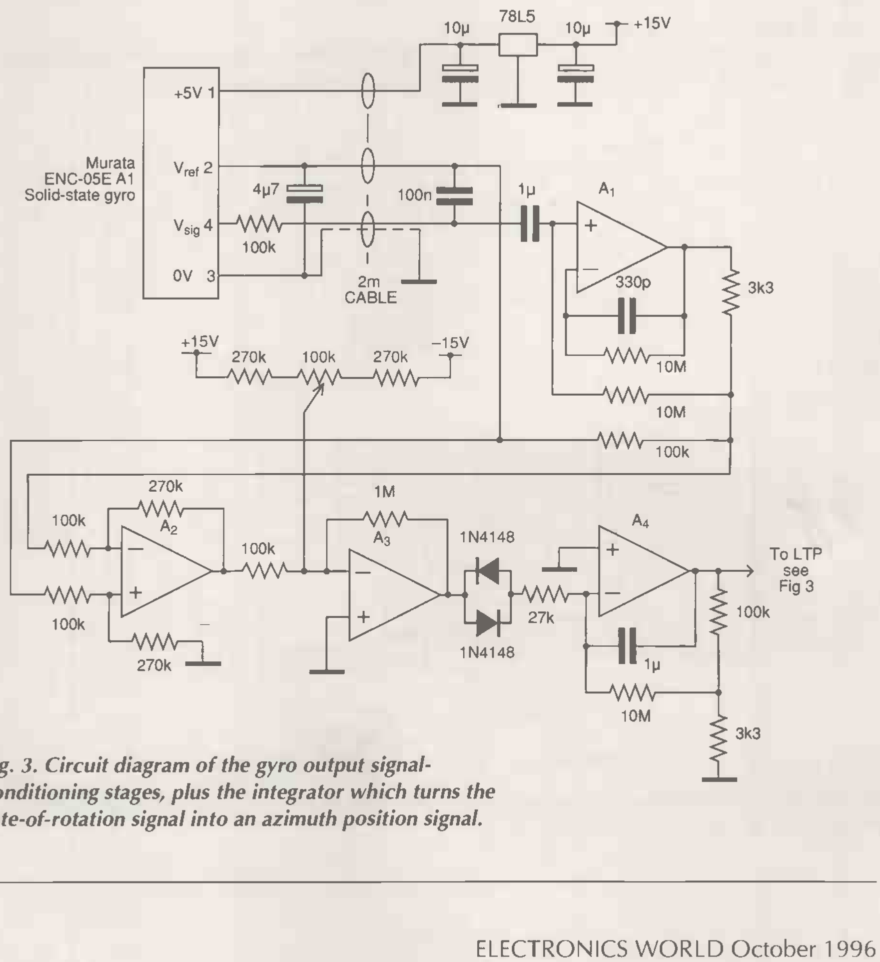


Fig. 3. Circuit diagram of the gyro output signal-conditioning stages, plus the integrator which turns the rate-of-rotation signal into an azimuth position signal.

resistor, at the input of each vco. In this way, as one vco frequency increased, the other reduces by the same percentage – at least, to a first approximation – Fig. 5. The bucket-brigade device provides delays of 2.56 to 51.2ms for clock frequencies in the range 200kHz down to 10kHz. As a result, at the 115kHz clock frequency used, the delay is nominally 4.45ms. So to provide the required ±150µs delay variation for a head movement of 45°, the frequency of the voltage-controlled oscillators must be varied 0.15/4.45, or about ±3.4%.

As this is but a small variation, the integrator output is attenuated before being applied to the long-tail pair, the transconductance of which is adjustable by means of a 10kΩ potentiometer between the emitters. This potentiometer provides an adjustment for the spacing between the ears of a listener. A fat-headed person will require a lower resistance setting of the potentiometer than a narrow-minded type.

Non-overlapping clocks from each *MN3102* are applied to the corresponding *MN3207* bucket-brigade device. These also each receive an audio input, see **Fig. 6a)**. Delayed audio output from each bucket-brigade device is applied to a three-pole Chebychev filter, to suppress the clock ripple which appears in the bucket-brigade device outputs.

The filters are of a slightly unconventional kind, taking into account the output impedance of the bucket-brigade devices, the input capacitance of the opamps, circuit strays etc.. As a result, the capacitor values are not what you would obtain from the usual tables of normalised filters. Nevertheless, the response is flat to within 1dB to beyond 15kHz, 4dB down at 20kHz and already 33dB down at 50kHz.

The output filter op-amps could not be expected to cope well with the loads imposed by 32Ω headphones, so a dual audio amplifier was added. This was a National Semiconductor *LM4880* dual 250mW audio power amplifier, which operates on a single supply rail in the range 2.7-5.5V. On a 5V supply it provides 85mW continuous average power into 32Ω or 200mW into 8Ω, at 1kHz with 0.1% thd. It features a shut-down mode, which reduces current drain from a typical 3.6mA no-signal quiescent drain, to around a microamp.

For speed and convenience, I used National's 'Boomer' evaluation board, carrying the small outline version of the device. Its circuit is shown in Fig. **6b)**. Output coupling capacitors C_o are each two 100µF electrolytics in parallel. Strapping the shut-down input to V_{DD} activates the shut down feature, but as this was not required, the SD pad was strapped to ground.

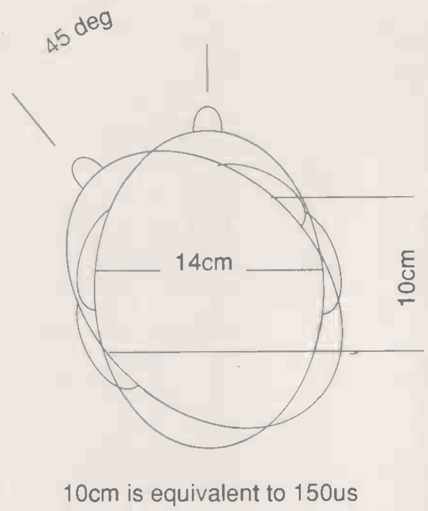


Fig. 4. Showing the differential delay to binaural sounds as a function of head rotation. 10cm is equivalent to 150µs.

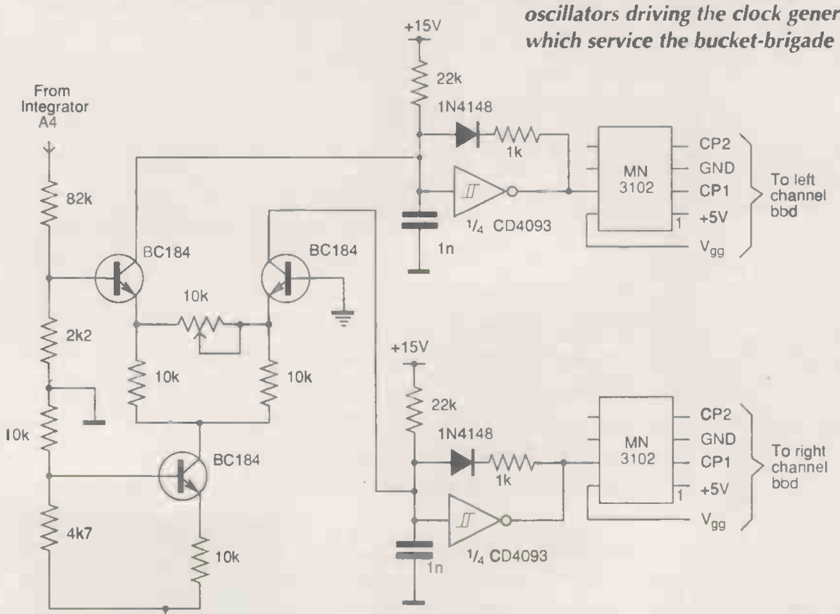


Fig. 5. Showing the differentially controlled voltage-controlled oscillators driving the clock generators which service the bucket-brigade chips.

Testing the prototype

During design and implementation – which proceeded in parallel – each section of circuitry was tested for functionality as it was added, starting with A_1 and working through to the audio output stage. But any serious overall evaluation of the scheme was obviously not possible until the whole equipment was complete.

As I mentioned earlier, the ac coupling at A_1 was discarded due to extended settling problems, the alternative dc coupling being adequate for an experimental set-up.

With the circuitry complete, a 250Hz sinewave was applied to the two audio input channels strapped in parallel. The offset potentiometer had been set up for zero output at A_3 while the gyroscope was stationary, and the integrator output zeroed. Strapping the two inputs together provided a path for a little leakage of bucket-brigade chip clock frequency between devices. This resulted in some low level 'birdies' being audible in the background, which were ignored at this stage.

On turning my head to either side, a most bizarre effect was noted. The pitch of the sound in the advancing ear, i.e.the right ear when turning the head to the left, momentarily rose while that in the other ear fell. At this point I realised that the attenuator between the integrator output and the long-tail pair input had been omitted. The result was an enormous transient delay, i.e. phase change, in the signal, resulting in Doppler effect shifting of the frequency. This would indeed occur on turning your head provided that your ears were a few tens of metres apart.

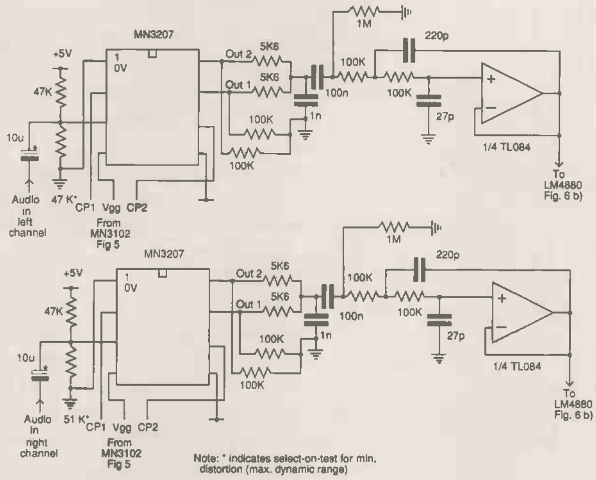
With a suitable degree of attenuation added, as shown in Fig. 5, the long-tail pair emitter potentiometer was adjusted to give ±0.15ms delay in one channel and ±0.15ms in the other for a 45° rotation of the head. The result was quite distinct. While facing front, the sound appeared to be arriving centrally, but from the right as the head was turned to the left and *vice versa*.

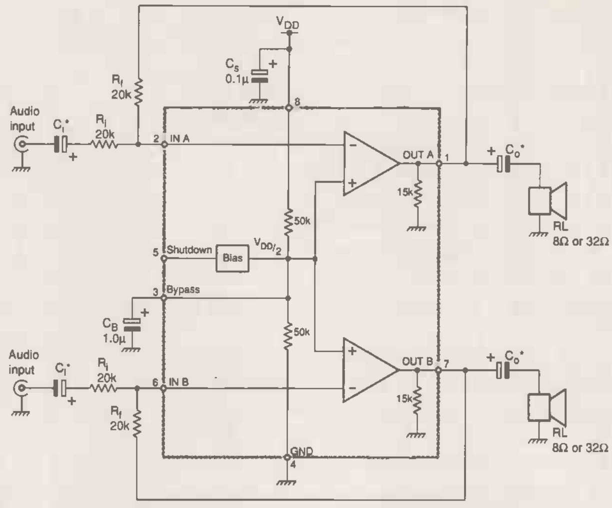
Interestingly, the sound in the ear nearest the front actually sounded louder than that in the other ear, although of course the two signals were identical, except for their phase. Evidently the ear/brain system is quite capable of resolving differential times of arrival of sound of the order of 100µs.

Next, tests were carried out using program material, from an fm radio. The signal was taken via a couple of two-pin DIN speaker plugs from the set's external speaker outlets. Taking the signal from two separate low impedance outputs like this largely suppressed the birdies mentioned earlier.

With reception switched to mono, program material of all sorts behaved in exactly the same way as the continuous sinewave, the 'direction' of the source being readily identifiable. Much the same applied to speech in stereo, but since a microphone is usually used

Fig. 6a) The BBD audio delay stages, followed by three pole Chebychev low pass filters to remove clock ripple from the output of the BBDs.





* see text for information on selection of input and output coupling capacitors

Fig. 6b) The audio output stage, using an LM4880 dual 250mW audio power amplifier with shutdown mode (not used in this application). Note, if the sound stage moves to the left instead of the right when the head is turned to the left, the audio connections between a) and b) should be interchanged.

which is near – or actually on – the speaker, stereo speech is usually virtually mono anyway.

Why no effect on stereo?

Disappointingly, results with an extended sound source, such as orchestral music in stereo, were not noticeably amenable to 'externalisation' by the gyroscope system. The sound stage remained doggedly stuck to the head, turning with it. The reason for this is not clear to me, so I hope that one of you is able to provide enlightenment.

Possibly the ear/brain system is so dominated by the abundance of positional information cues contained in a stereo signal, that it cannot but hear the sound as coming from a sound stage fixed relative to the head. Whatever the explanation, the scheme is virtually ineffective on stereo material.

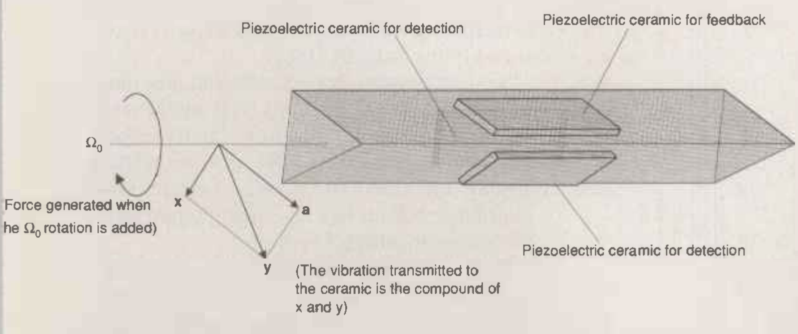
But that's engineering for you; the results of an experiment are what they are, not what one might like them to be. Hypotheses have to fit the facts, not the other way round. ■

Solid-state gyroscope – 15% reader discount

Until 31 December, Willow Technologies is offering Murata's ENC-05E solid-state gyroscope for the discount price of £70 instead of the normal price of £82, excluding VAT and delivery.

Measuring 21.5 by 8.5 by 7.6mm, the ENC-05E gyroscope handles up to 50 changes in direction a second and a maximum angular velocity of ±90°/s. This velocity produces a swing of about ±200mV dc about the zero angular velocity output reference of 2.3V dc. Requiring a maximum of 5mA, the ENC-05E is suitable for portable navigation systems.

Rotational sensing applications of the ENC-05E include camera stabilisation, model-aircraft control, virtual-reality headsets and robotics. Willow Technologies Ltd is at Shawlands Court, Newchapel Road, Lingfield, Surrey RH7 6BL, tel. 01342 835234, fax 01342 834306.



In common with all viratory gyroscopes, the ENC-05E relies on the Coriolis effect, where rotation of a vibrating beam about the vertical axis produces a force perpendicular to applied rotation.

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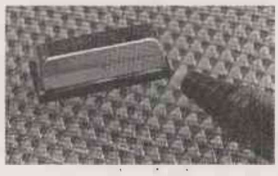
Please make your cheque payable to Willow Technologies Ltd and send it to Willow at Shawlands Court, Newchapel Road, Lingfield, Surrey RH7 6BL, tel. 01342 835234, fax 01342 834306. Note that this offer is limited to five units per reader. Please allow 28 days for delivery.

Measuring 21.5 by 8.5 by 7.6mm, the ENC-05E gyroscope handles up to 50 changes in direction a second and a maximum angular velocity of ±90°/s.



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A-to-D via the COM port

Interfacing via the pc's COM port and accessible using simple Basic routines, David Gains' a-to-d converter can log up to four differential sensors with fast sampling.

My requirements were for a data acquisition system that would acquire analogue signals from transducers such as temperature sensing integrated circuits. The system had to use my PC's unused COM2 port, and it had to be capable of sampling a single channel at, say, 1-2kHz, or a few channels on demand at infrequent intervals. Further, to accommodate signals of different voltage levels, and to improve resolution, each channel had to have software programmable gain.

The resulting design, **Fig. 1**, provides the following features:

- four differential input channels,
- four gains of 1, 2, 4, and 8,
- single-conversion, or free-running conversion mode, and
- single-channel, or scanning channel mode.

All of the above features are software programmable. In addition, the capture module can be configured for either unipolar or bipolar input signals.

Serial interface

The *MAX232* line driver-receiver, IC_1, provides the communications interface between the computer and the data acquisition system. Ostensibly, it converts signals between RS-232 compatible levels of ±12V and 5V ttl levels, but only requires a single 5V rail.

A single byte-long character command is passed to the *CDP6402* universal asynchronous receiver-transmitter, IC_3. This uart takes the serial data from the receiver input RRI and converts it into a parallel word. Provided that this word has been received correctly, it then appears at the receiver buffer register output, RBR_{1-8}.

In my design, if a framing error or an overrun error occurs, it is ignored. In any case, if an error does occur, the RBR_{1-8} outputs adopt a high impedance state. The RBR_{1-8} outputs are then decoded to provide the functions shown in **Table 1**.

The uart is configured for a data format of eight data bits, and one stop bit, **Table 2**. In addition, there is no parity bit; the parity inhibit PI input is held high.

The serial data rate is set by programmable oscillator, IC_2, which is an *EXO-19.6608*. This device allows data rates of 4800baud up to 1228800baud. However, the *MAX232* supports RS-232C standard, and this is only guar-

Table 1. Receiver output bits from the uart are used to configure the a-to-d conversion circuitry.

RBR_8 Unused	RBR_7 Unused	RBR_6 Conversion	RBR_5 Scan	$RBR_{4,3}$ Gain	$RBR_{2,1}$ Channel
x	x	0=single	0=off	0,0=×1	0,0=channel 1
x	x	1=running	1=on	0,1=×2	0,1=channel 2
x	x			1,0=×4	1,0=channel 3
x	x			1,1=×8	1,1=channel 4

Table 2. Three bits configure the uart serial data framing as follows.

CLS_1	CLS_2	SBS	Format bits data	stop
0	0	0	5	1
0	0	1	5	1.5
1	0	0	6	1
1	0	1	6	2
0	1	0	7	1
0	1	1	7	2
1	1	0	8	1
1	1	1	8	2

Table 3. Programmable oscillator – applicable bit-rate settings.

Input S_3	S_2	S_1	Frequency kHz	Data rate bps
1	1	1	76.8	4800
1	1	0	153.6	9600
1	0	1	307.2	19200

Listing 2. Object-oriented implementation of the functions used to interface to pc and a-to-d converter, in Turbo C++

```
// Standard libraries
#include <bios.h>
#include <conio.h>
#include <dos.h>
#include <process.h>
#include <stdio.h>

// Function key codes
#define F1 0x3B
#define F2 0x3C
#define F3 0x3D
#define F4 0x3E
#define F5 0x3F
#define F6 0x40
#define F7 0x41
#define F8 0x42
#define F9 0x43
#define F10 0x44

// COM port settings
#define COM2 1
#define DATA_READY 0x100
#define SETTINGS
(_COM_9600 | _COM_CHR8 | _COM_STOP1 | _COM_NOPARITY)

// Implementation of interface to unit. No error checking.
class serial {
private:
  unsigned _port;      // Port identity
  unsigned _settings; // Port settings
  // Configuration
  unsigned _channel, _gain, _scan, _run;
  char str[40];
public:
  // Constructor - Configures serial port
  serial(unsigned p, unsigned s) : _port(p), _settings(s) {
    _bios_serialcom(_COM_INIT, _port, _settings);
    _channel=_gain=_scan=_run=0;
  };

  // Change run mode
  void run() {
    _run=!_run;        }

  // Change scan mode
  void scan() {
    _scan=!_scan;
  }

  // Change gain
  void gain(unsigned g) {
    _gain=g;
  }

  // Change channel
  void channel(unsigned c) {
    _channel=c;
  }

  // Get port status
  int status() {
    unsigned s=_bios_serialcom(_COM_STATUS, _port, 0);
    return s;
  }

  // Read value from port
  unsigned read(unsigned& v) {
    return v=_bios_serialcom(_COM_RECEIVE, _port, 0);
  }

  // Write a value to port
  void write() {
    _bios_serialcom(_COM_SEND, _port,
      _channel | _gain<<2 | _run<<4 | _scan<<5);
  }

  // Get a-to-d unit's configuration
  char* config() {
    sprintf(str, "Channel:%1x Gain:%1d %s %s", _channel, 1<<_gain,
      _scan?"Scanning":"Fixed", _run?"Running":"Single");
    // If scanning, keep track of channel
    if (_scan) {
      _channel++;
      _channel%=4;
    }
    return str;
  }
}; // End of class definition
```

Listing 3. Turbo C++ routine applying the objected-oriented software, Liting 2.

```
void main(void) {

unsigned in, out;
class serial s(COM2, SETTINGS);
// Define and setup port

clrscr();
for(;;){
  if (s.status() & DATA_READY)
   // Print unit's configuration and
value read
   cprintf ("%s %3d\r", s.config(),
s.read(in));

  if (kbhit()) {
   out=getch();
   if (out=='\x1B')
    // Escape key pressed. Quit.
    exit(1);
   else {
    if (out=='\x00') {
     // Extended key pressed
     out = getch();
     switch (out) {
       case F1: s.channel(0); break;
       case F2: s.channel(1); break;
       case F3: s.channel(2); break;
       case F4: s.channel(3); break;
       case F5: s.gain(0); break;
       case F6: s.gain(1); break;
       case F7: s.gain(2); break;
       case F8: s.gain(3); break;
       case F9: s.run(); break;
       case F10: s.scan(); break;
     }
     s.write();
    }
   }
  }
 }
}
```

anteed to work up to 19200baud. Switches, $S_{1\text{-}3}$, program the oscillator, **Table 3**.

Selecting channels

Selection of the analogue channel is carried out by the *MPC509* four-channel differential multiplexer, IC_6. This device offers up to $70V_{p\text{-}p}$ over-voltage protection, and should it lose power, it does not cause problems for the signal sources.

Channel addressing for the multiplexer is produced by the asynchronous presettable two-bit counter-latch formed by the JK bistable devices, IC_{10} and the steering logic, IC_{11}. Operation is as follows.

When scan mode is off, i.e. RBR_5 is low, the JK bistable device clocks are disabled, and the channel address on $RBR_{1\text{-}2}$ is used to preset the counter-latch outputs. The PRESET signal, created by data-received signal DR going high and triggering monostable IC_{8b}, enables the NAND gates, IC_{11}. These then derive suitable logic levels for the bistable clear and set inputs. These inputs are clock independent, or asynchronous. Since the multiplexer's ENABLE line is tied high, the analogue input channel is immediately selected.

In channel scanning mode, with RBR_5 high, the counter-latch is preset with the channel address, as before. In this case, however, after each conversion has completed, the counter is incremented by the NEXT pulse. This pulse is derived from the BUSY signal going inactive, and enabled by the inputs $RBR_{5\text{-}6}$ on NAND gate IC_{12c}. It results in the next analogue channel being selected.

Programmable-gain amplifiers

The *PGA205* programmable amplifier, IC_5, provides fixed programmable gains of 1, 2, 4, and 8. Its gain-selection inputs are ttl-compatible and bits $RBR_{3\text{-}4}$ are connected directly. With the a-to-d converter configured with a reference voltage of 2.5V, the *PGA205* gives the system the full scale ranges and resolutions shown in **Table 4**.

Conversion mode

The conversion mode allows the unit to make either a single conversion when requested, or continually provide conversions, i.e. free run, at a rate governed by the uart.

If the single conversion mode is selected, i.e. RBR_6 is low, the a-to-d converter starts converting the selected channel shortly after

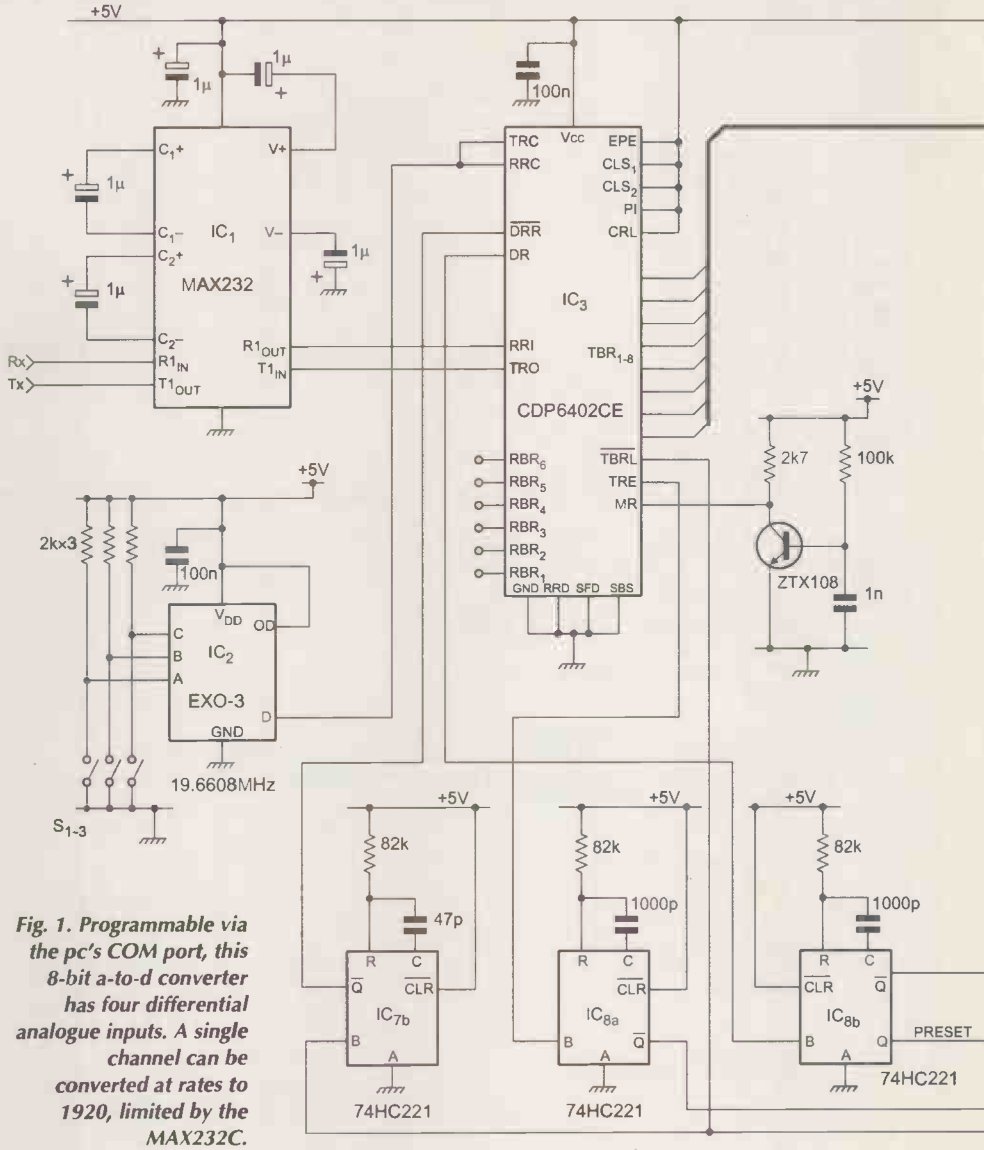


Fig. 1. Programmable via the pc's COM port, this 8-bit a-to-d converter has four differential analogue inputs. A single channel can be converted at rates to 1920, limited by the MAX232C.

the command is received from the computer. The data received status line DR goes high, and edge-triggered monostable IC_{8b} provides a low level pulse of about 82µs duration to the WRITE input of the a-to-d.

On the rising edge of the same low-level pulse, the a-to-d converter starts converting. The duration of the pulse is long enough to ensure the *PGA205* gain network and multiplexer have settled. It is also fast enough for conversions to be performed and transmitted at up to about 19.2 kilobaud, i.e. the sampling rate is about 1.9kHz.

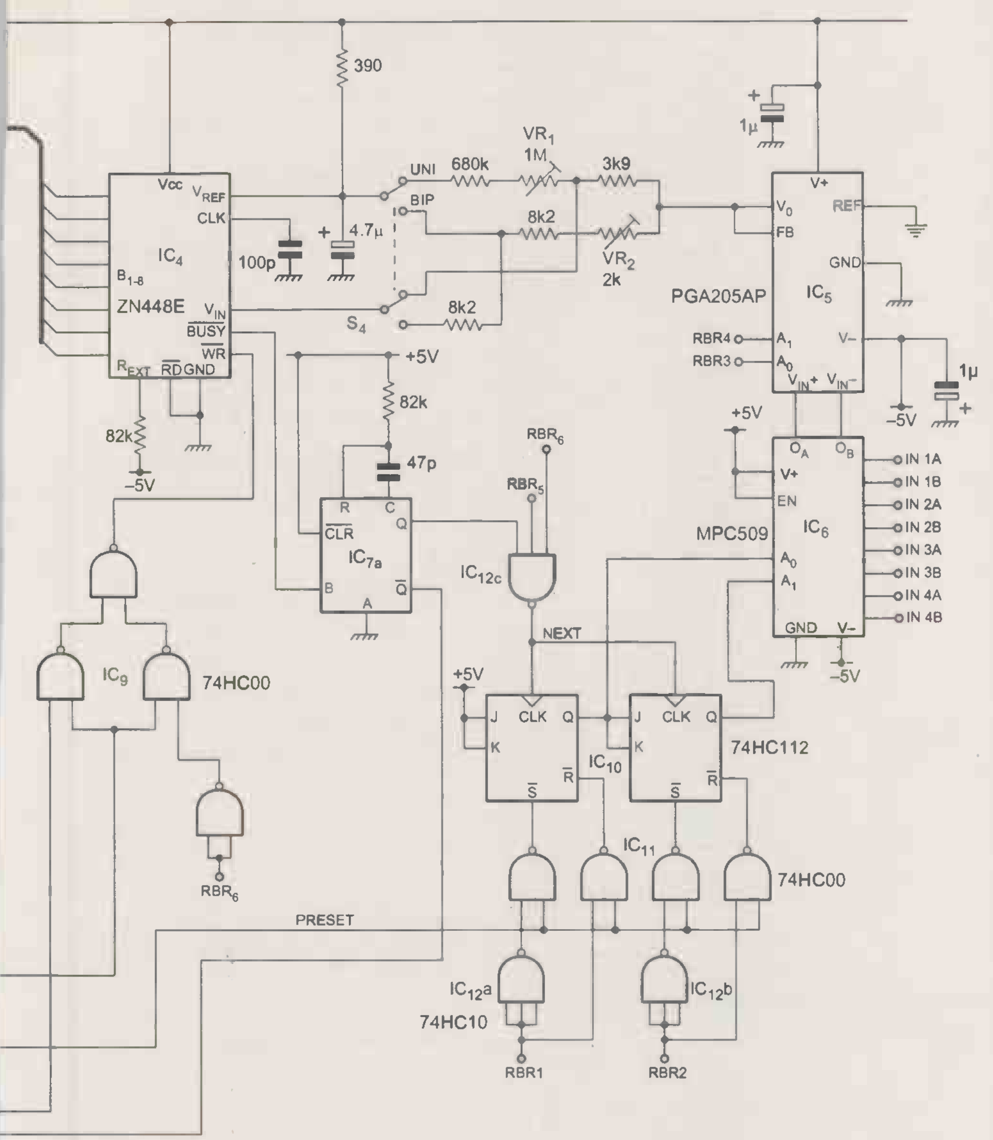
NAND gates within IC_9 select the source to be used for the start conversion signal. With RBR_6 low, only DR is used as the basis for the WRITE signal. When RBR_6 is high however, the start conversion signal is derived initially

Table 4. Full scale range, or fsr, and resolution at different gains.

Gain	Unipolar FSR	Unipolar Resolution	Bipolar FSR	Bipolar Resolution
1	2.5V	9.8 mV	±2.5V	19.5 mV
2	1.25V	4.9mV	±1.25V	9.8 mV
4	0.625V	2.4mV	±0.625V	4.9mV
8	0.3125V	1.2mV	±0.3125V	2.4mV

Listing 1. QuickBasic routine showing how simple it is to grab an analogue sample from channel 0.

```
REM Continually poll channel 0 (unity gain)
CLS : PRINT "Press any key to stop."
OPEN "COM2:9600,N,8,1" FOR RANDOM AS #1
A$ = ""
WHILE (A$ = "")
   PRINT #1, CHR$(0);
   LOCATE 2, 1: PRINT "Channel 0: "; ASC(INPUT$(1,
1))
   A$ = INKEY$
WEND
CLOSE #1
```



from DR, but then from the transmitter register empty, TRE, status flag of the uart. This signals that the last conversion has been sent to the computer, and that the UART is ready for new data. Again, the pulse is about 82µs duration.

Analogue-to-digital conversion

The a-to-d converter, IC_4, is a *ZN448* 8-bit successive approximation converter with internal band-gap reference and clock.

The converter is configured, by connecting the 100pF capacitor to the clock input, pin3, for conversion times of about 100ns. The input to the a-to-d converter can be either unipolar or bipolar according to the position of switch S_4. The resistor network sets the input voltage range to either 2.5V for unipolar operation or ±2.5V for bipolar.

During a conversion, the BUSY signal, active low, goes low, and when finished it goes high. On this rising edge, monostable multivibrator IC_{7a} creates a pulse that:

- automatically increments the channel address of the multiplexer,
- load the converted data into the uart's TBRL transmitter buffer register,
- reset the data received status flag of the uart, by taking DRR low.

Configuration and control

When the unit is powered up, the transistor, Tr_1 and associated passive components apply a low going pulse of 15µs to the uart's master reset MR input, and so ensures all the error/status flags, and transmitter buffers are reset.

The unit is easily configured and controlled by outputting byte commands – or appropriate ASCII characters – to the serial port.

An example *Quick-Basic* program is given in **Listing 1**. It shows how samples can be acquired from one channel, namely channel 0 with unity gain.

A further example is given by way of an object-oriented program using Borland *Turbo C++*, **Listings 2, 3**. Listing 2 gives the class implementation of the functions used to interface with the unit, while Listing 3 is an example of the class being used. The pc's function keys are used to configure the unit's operation, and the escape key exits the program.

Neither of these examples check for framing errors nor overrun errors, which would be necessary to ensure samples are not missed, or, if scanning channels, that the channel being sampled does not become misaligned with what the program thinks is being sampled.

The serial communications functions provided by *Turbo C++* are implemented with hardware handshaking. In this case, a null modem can be used; link the request-to-send line RTS and clear to send, CTS, together, and link data set ready DSR, data carrier detect, DCD, and data terminal ready, DTR. In *Quick Basic*, setting parameters in the OPEN statement that ignore handshaking is possible.

Setting up

The only setting up required is that of the *ZN448*. This is easily achieved with either of the above example programs, set to sample a channel continually.

Zero adjustment is required for the unipolar range. This is done by applying 5mV to a channel, and adjusting VR_1 until the most significant bit flickers between one and zero with all the other bits at zero. No gain adjustment is provided in this design.

Only offset adjustment is required for the bipolar range, as this design offers no gain adjustment. In a similar way to the unipolar zero adjustment, apply –2.49V to a channel, and adjust VR_2 until the most significant bit flickers between one and zero with all the other bits at zero.

Further development

There are two bits of the uart's received data word spare, namely $RBR_{7\text{-}8}$. These could easily be used to expand the unit's capability. Obvious enhancements are to provide eight channels of differential input, or 16 channels of single-ended input, or to make the unipolar/bipolar modes software selectable.

If greater accuracy is required, gain adjustment for both unipolar and bipolar input ranges could be added to the *ZN448*. ■

Further reading

MAXIM Integrated Products, *MAX230-241* Data Sheet, pp 2-25 to 2-40.

Universal asynchronous receiver transmitter, RS Data Sheet 4046, March 1985.

Crystal Oscillators – KSS Kinseki, *KSS-EXO-3* Series Data Sheet.

MPC508A, Burr Brown Data Sheet.

8-bit A to D converter *ZN448*, RS Data Sheet 5291, March 1985.

PGA205, Burr Brown Data Sheet, pp 4.175 to 4.187.

MM74HC221A Dual Non-retriggerable monostable mulitvibrator, National Semiconductor Data Sheet, pp 3:204-3:208.

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Free circuit design software
TINA for Windows

This month's cover disk* is a working, interactive version of TINA for Windows. Newly launched, this comprehensive package is an electronics toolkit integrating all the functions needed for the design, development and test of electronic circuits. TINA makes it easier and faster to simulate circuits with realistic characteristics.

TINA comprises a software simulation and analysis package, together with a complete range of 'virtual' test and measurement instruments for testing design theories as well as breadboards, prototypes or any other electronic product.

The demonstration version of TINA presented free with this issue of *Electronics World* allows circuits of any size to be constructed but analysis only works on a limited number of nodes. Save and print facilities are also disabled.

PSpice compatibility

Unlike many circuit design systems, TINA can save your designs as an industry standard PSpice format netlist – which means that design concepts are based on the specifications of actual components. This makes simulation more realistic and the identification of faults easier. It also simplifies 'what if' questions, and allows different components to be tested quickly, easily and without the need to build breadboards. This obviously saves considerable time, as well as the cost of components.

Comprising all the necessary hardware and software, Tina is a complete system which allows digital, analogue or mixed-mode circuits to be simulated. Tina is also a powerful analytical tool and can perform AC, DC or transient analysis as well as noise, tolerance and Fourier analysis.

Comprehensive library

A comprehensive library of components contains power supplies, resistors, capacitors, inductors, amplifiers, switches, etc. Using familiar Windows-style commends, these are simply selected, dragged and dropped into the desired circuit diagram. Component values can then be changed to create and test the feasibility of the ideal circuit.

The library features digital components, including a large selection of TTL and CMOS standard devices.

Low price

Tina, is very cost effective. A single copy of the software costs only £299 and a 20-user site licence is only £1,800, excluding hardware. Special discounts are available for educational establishments.

For further information contact: Tandem Technology Limited, Breadbare Barns, Clay Lane, Chichester, West Sussex, PO18 8DJ, telephone: 01243 576121 fax: 01243 576119, e-mail 101626.3234@compuserv.com.

*Available to UK readers only.

Virtual instruments – supplied with the Tina circuit design tool is a complete range of test and measurement 'virtual instruments' – including a function generator, multimeter, power supply and oscilloscope. These are used to analyse test circuit designs as well as providing real time test and measurement of actual circuits, prototypes and breadboards. The benefit of these 'virtual' instruments is that they operate via the PC. This makes it easy to incorporate measurement values into calculations and analyses.

£100 voucher

Until 4 October, this voucher is worth £100 off TINA's normal price of £299 excluding VAT and delivery. Simply send this voucher together with £237.93 – fully inclusive – to Tandem Technology Limited, Breadbare Barns, Clay Lane, Chichester, West Sussex, PO18 8DJ. Telephone: 01243 576121 fax: 01243 576119, e-mail 101626.3234@compuserv.com.

Loading your free software

Full instructions on loading the demonstration version of Tina are given in the README.TXT file on the disk. This file is accessed by inserting the disk in drive A and double-clicking on the file under Windows' File Manager. Once the software is installed, this read-me file appears as a Windows icon.

The route to pcb cad

Rod Cooper's second set of reviews covers *Ranger2* and *Electronics Workbench*.

PCB CAD review subjects

This review, which began last month and continues next, covers the following ten products.

PCB Designer: Niche Software Ltd, tel. UK 01432 355414. £49 inclusive (see September issue).
PIA: AW Software, tel. Germany +49 89 6915352. PIA std 99DM: extended 171DM 32bit 286DM inc tax (see September issue).
Easytrax: Protel International pty, tel. Australia 408 437 7771, UK PDSL, tel. 01892 663298 (see September issue). £6 copying charge.
Ranger2: Seetrax CAE Ltd. 01705 591037, £150 exc £10 p+P and VAT.
Electronics Workbench: Interactive Image Technologies Ltd (Canada), tel. 0014169775550. UK Robinson Marshall, tel. 01203 233 216, £199 exc p+p and VAT.
Quickroute 3.5 Pro+: Quickroute Systems Ltd.
CircuitMaker: MicroCode Engineering.
Propak: Labcenter Electronics.
Proteus: Labcenter Electronics.
EasyPC Pro XM: Number 1 Systems.

Note that although it started last month with a couple of smaller packages, this review is not in any order of complexity or competence.

A common drawback in computer-based pcb design programs is that the small crt screens often used are not an ideal drawing board. This fact is never mentioned in the glossy brochures. A standard 14in screen on a typical pc does not give you 11in by 8in to draw on. Do not be surprised if you find that you have a drawing area of 7in by 6in or less; you are not going to get much circuitry in that area.

The rest of the screen is taken up with program controls, and most irritating, the program maker's name, logo or other useless clutter. Fortunately, some programs give a much better performance in this region than others, as detailed in the individual reviews.

Most programs use a large sheet for drawing on – A3 for example – and you are supposed to pan around with your small viewing window if you want to see the rest of the circuit. This illustrates the importance of having auto-pan or a good manual panning method.

Larger circuits will have more than one page which will of course be out of sight altogether until you make a page-change request. This is not as easy as turning over a page of a circuit diagram, although some people would have you believe otherwise.

Because components appear small on a small screen, you will have to zoom in to get resolution of the parts and their pads, and zoom out again to see the circuit. This makes it essential to have an efficient method of zooming and panning.

I think relative to having the circuit drawn out before you on real paper, all methods of representing the circuit on screen are inferior if are planning a circuit from scratch – ie actually designing rather than just drafting. You could of course buy a larger monitor – say 17in or 21in, with higher resolution – but these are still very expensive and very bulky compared to the common 14in model and you still will not solve the problem completely.

Neither is the mouse a good drawing tool; a pencil and paper is much better than a mouse and mat if you are experimenting. Some people prefer a digitising tablet. Proponents of the tablet system say that it is more accurate than a mouse, easier to use in CAD, faster, and comes more naturally to someone used to drawing with a pen and paper.

I use a digitising tablet for CAD, and a mouse for everything else, and I have to agree. However, on the down side, tablets are at least twenty times more expensive than a mouse and it will come as no surprise to learn that some programs that work well with a mouse do not work well with a digitising tablet. I tried every program with both mouse and tablet.

Standards and formats – or not

Unfortunately, there is not much standardisation in this branch of computer-aided design. Each maker has its own way of presenting component outlines, drawing schematics, etc. etc. Few commands or menus are standard. This means that if you take the time and effort to learn a program produced by one company, you will have to go through the same time-consuming process all over again if you change to another.

The good news is that there is a trend towards standardisation in the output format for net lists and component lists and for computer-aided manufacturing although there is a long way to go in this respect.

Windows or dos?

The choice between dos and Windows will be of prime interest to the prospective buyer, with many opting for Windows simply because that is the trend. Much of what is presently available runs under dos. The many advantages of running a program in Windows that apply to business and accounting programs and the like, is to a large extent lost on pcb design software.

Free of the constraints of Windows, dos programmers can sometimes come up with a superior user interface. You can expect Windows programs to be more intuitive initially. But this will not enable you to operate a Windows system straight away unless it is very simple or small. You will find that you still need to read the manual, just as with a dos program. Although I am a Windows enthusiast myself, when it comes to pcb design, I regard dos as a viable alternative.

Programs written solely for dos are usually much cheaper, often have modest ram requirements, and take up less hard disk space than the equivalent Windows program. In addition, dos programs are nearly always quicker, for a given hardware setup.

Another good reason for choosing a dos program is that XT, AT, and 286 pcs that have been left behind in the Windows revolution will probably run it perfectly well. The money you save may be better spent on a 21in monitor and a digitising tablet.

Finally, most dos programs are mature products with the bugs and snags already designed out. If you buy a newly-produced Windows program it would be unreasonable to expect no bugs at all.

Printers or plotters?

Windows 3x provides a wider range of printer drivers than dos programs but on the other hand, pen plotters are not as well supported. Ironically this may provide a good reason for sticking to dos if you want to use your existing plotter.

With a few exceptions, most popular pen plotters,laser printers and matrix printers are well supported by the dos programs under review, so a list for every product is not included. Such lists are regularly updated so it is best to check that your printer is supported with the software distributor before buying.

Regarding the speed relationship between dos and Windows, if you want a bench-mark, then try screen redraws. These are fast in dos, and annoyingly slow in Windows. In fact, you need a very fast pc to make a Windows redraw to equal a dos redraw. Redraws are very important because they occur all the time in computer-aided design; for example, every time you pan, zoom or refresh.

■

Next month – Rod presents more reviews and explains what to watch out for with autorouters.

Review 1 –

Ranger 2 by Seetrax

Ranger2 is another dos-based product that will run on any pc from an XT upwards. The minimum requirements are modest – an IBM PC XT, 640kB of RAM, 20MB hard disk, EGA card and monitor. To test this, I ran it on a 286, and found no problem. It ran very well on the 386SX.

Ranger2 consists of a schematic drawing program with schematic capture, and an autorouter. The two are fully integrated and there is not much scope for connecting to another system. However, there is a facility to import a net list in the Futurenet format, and if you wanted to connect to a simulation program, you can export a net list in the PSpice format. For the latter, it is necessary to type in the PSPICE model types for each component before compilation.

A very good evaluation package is available which is fully-operational and will allow circuits with up to 64 components or 128 pins to be completed. The evaluation obtained via Seetrax is just £5 but, unusually, includes an excellent short-form printed manual. This is a sound marketing technique – Seetrax clearly realise that people starting out in CAD, such students and fledgling engineers, will use the full process of their evaluation package to make real boards, get to like the system and then go on to buy the full product.

This contrasts sharply with some other makers, whose evaluation packages are either of the non-usable or slide-show variety, or sometimes so cut-down and disabled that they cause more irritation than desire to buy the product. The manual for Ranger2 is comprehensive and well-written. The order in which subjects are placed is a little odd, but then most other manuals were like this.

The schematic drawing part of Ranger 2 has a large working area, about 8.5in by 6.5in on a 14in monitor. You can chose a page size from A1 to A5 to work on, and combine up to 8 pages in one design. The system is partly menu-driven by full-screen menus to start the job, leading to the drawing screen with a single vertical 17- button bar on the left with an abbreviated name of the control on each button.

You quickly get to know the buttons from their names, and personally I think this is a much better system than using icons, even if the icons have pop-up help text added. It has been said that a well-designed GUI for dos can beat a poorly-designed Windows presentation. If so, then Ranger2 is a good example of this.

A second horizontal sub-bar can be generated from the first bar as required to give various options. I found this to be a very acceptable operating method, giving maximum drawing area without sacrificing control. The drawing method is a proper orthogonal system with automatic junction dot placement.

One excellent feature of Ranger 2 is that the drawing of any one connection is not enabled until you have located a component pin or pad, and then the drawn line is not fixed until you have connected it to another permitted point. A good snap-to system means that you do not have to hit the pin exactly as required in some

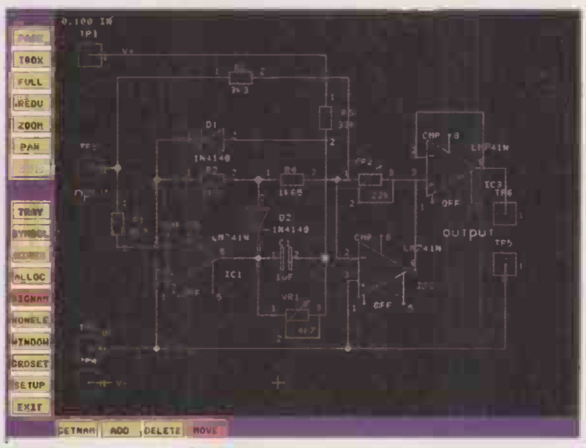

Fig. 1. Schematic of the test circuit. The lower horizontal button bar is generated from one of the vertical buttons on the left.

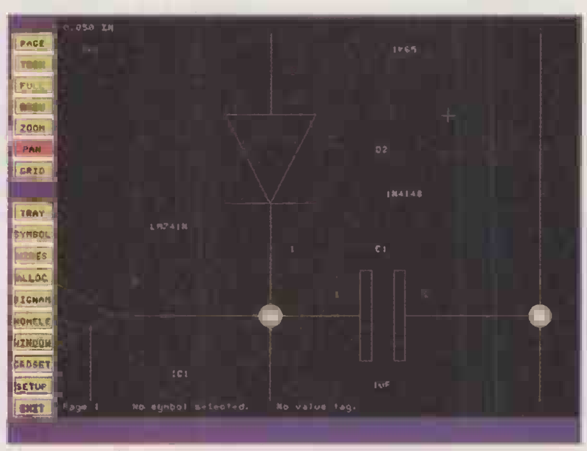

Fig. 2. Close-up of part of schematic showing clarity and definition of symbols.

other systems. This ensures the connectivity of your schematic.

You cannot hang lines in space by accident, your drawing cannot wander off to tie you in knots, and you cannot go wrong. This type of system, which is used in other programs as well as Ranger2, is a boon.

Power lines to ics are not shown in the schematic, just like most conventional circuit diagrams, but are automatically added later in the process.

Locating parts from the library system is easy and quick once you have read how to do it. Until you become familiar with the library, you have to refer to the manual to find out which volumes contain which parts. There is no on-screen help, but the manual provided with both the evaluation disk and full package is clear and concise.

The library size is adequate for general-purpose use. Parts are transferred to a parts bin on the screen which can be turned off to give more screen area; normally you would do this once the parts are on the screen. This is akin to the practice you would use on the real bench. Parts are described in text and only assume graphic form (ie as a symbol) when they are in the drawing area.

Moving the symbols around the drawing was smooth and precise. Text moves with the symbol and stays upright if the symbol is rotated, and can be moved anywhere independent of the symbol in order to tidy up the diagram. There is no autopan, but pan is easily selected by a single click and works well. Autosave is included and the time between saves is adjustable.

Generating a net list

Generating a net list from the schematic (which incidentally Seetrax call a parts/wiring list) was a simple one-step operation. The parts/wiring list can be readily viewed to check for mistakes, but with Ranger2's connection-confirmation drawing program there are unlikely to be any errors arising from the processing system.

Defining the board profile was easy compared to other programs, but what impressed me was the way in which Ranger2 generates the rat's nest. Many programs dump a pile of components in a corner of the screen, and on big circuits it can be difficult to sort them out. Not so with Ranger – the parts are fed in one at a time and in another smooth and precise mouse manoeuvre you place them into the position you want. When all the components have been fed in, a message tells you so. This is one of the better rat's nest systems of the systems I have inspected, in my opinion.

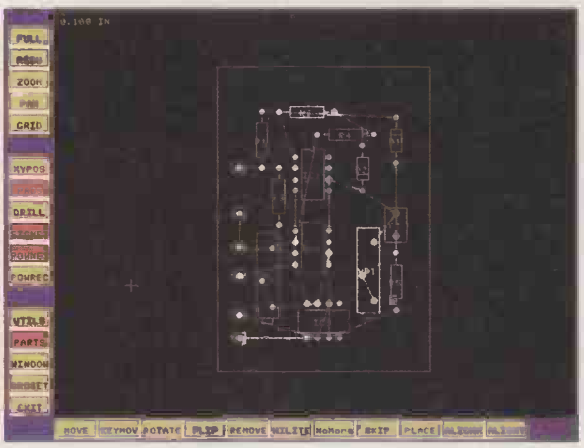

Fig. 3. Typical Ranger2 rat's nest, used for above autorouter tests. Note power rat-lines in blue.

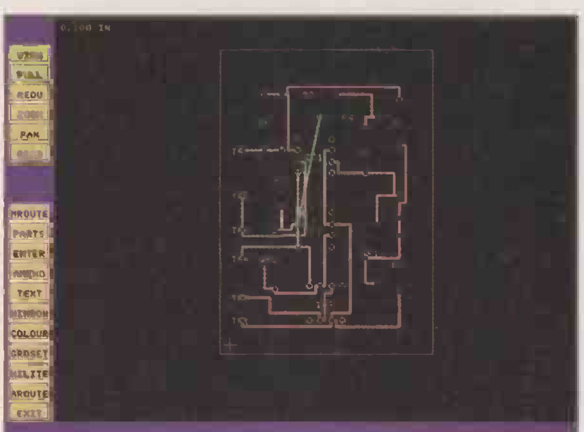

Fig. 4. Results of standard autorouter on single-sided test circuit. Note incomplete rat-lines in green.

The rat-lines move with the component, except for the power lines which are treated separately in Ranger 2. However, they can be reconnected by a single mouse-click on the appropriate button, and it is a method you soon get used to. Rat-lines self-optimise as you move components, ie they choose the shortest route, which is a considerable help.

Having arranged the rat's nest, the next step is to digitise the lines and pads prior to autorouteing. This is an extra step peculiar to Ranger2 and it is hard to see why it has not been designed out. It is required less if you have the more powerful Specctra autorouter. In most circuits being routed in Ranger2 you would digitise and then autoroute the power lines first, then repeat the process for the signal lines. You could autoroute all the lines at once if you wanted but the Ranger2 approach gives the power lines priority, which in most cases is the correct way.

Pre-run configuration of the autorouter is reasonably comprehensive, but was easy to understand and perform. The operation of the autorouter can be biased for or against such things as the number of vias, 45° tracks, and tracks going in the 'wrong' direction, ie away from the direct-line route. Interestingly, one of the parameters you can specify is how long the autorouter is allowed to take for each track it attempts. This feature is not seen on many autorouters, and on large boards it can be useful to limit overall run time. The grid size could be also varied.

One would suppose that such an autorouter would have problems with the amount of memory it would use on large boards. The notorious dos memory problem is side-stepped in Ranger2 by dividing the board into windows and doing each window in turn. This takes more time and it would be better if the autorouter utilised expanded or extended memory like other dos programs.

Routeing double-sided boards

The standard autorouter does a fair job on double-sided boards. The performance on single-sided boards was not so good, despite a type of Lee's algorithm being listed as one of the autorouter's strategies. An example is shown in **Fig. 4**. Here, it has failed to route some of the tracks even though they are obvious to a human, and despite a generous time allowance being provided at the programming stage. This is not to single out Seetrax for criticism, because none of their competitors' autorouters at this price level were any better on single-sided boards. This autorouter falls into category C. For category system see next review.

The big advantage of the Ranger2 standard autorouter is its speed – it was comparatively quick even on large boards. Another advantage is that if a large number of un-connectable tracks is reported by the autorouter, it is particularly easy in Ranger2 to delete just the autorouter artwork, re-arrange the rat's nest and have another go.

Manually routeing of the tracks that the autorouter failed to connect is performed by the rubber-banding technique. I don't think Ranger 2 is intended for making boards by manual routeing – it is really meant as an fully automated program with a manual routeing option for completing boards.

Summary

Ranger2 is an excellent product for double-sided and multilayer boards and is recommended. At only £150 it represents the best value for money for a full system, of the programs reviewed. It is easy to learn how to operate, and is relatively vice-free. There are two ways to upgrade, as follows.

As well as the standard autorouter, another type called the 386 Rip-up autorouter is available to purchasers of Ranger2, in an optional utilities bundle priced at £50. This bundle includes Autocad in/out and Gerber import. As the name suggests, this autorouter needs a 386 or better to make it work, as it uses the 386 protected mode to access extended memory. I used it firstly with 4MB of extended memory, but it ran better with 8MB.

It uses rip-up-and-retry strategies which improve its efficiency over the standard autorouter very considerably, but does not have push-and-shove. It can autoneck, and can route

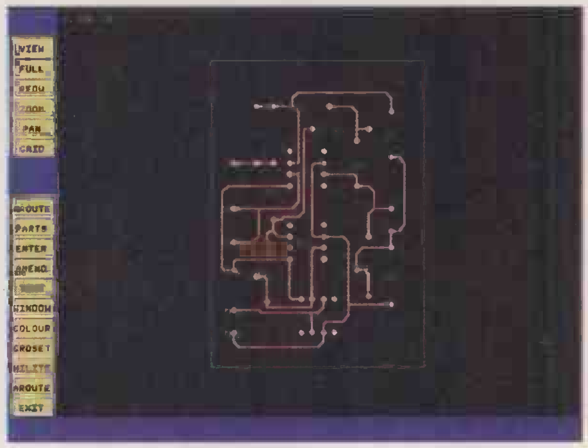

Fig. 5. Results of Specctra autorouter on the same rat's nest – 100% completion at first attempt.

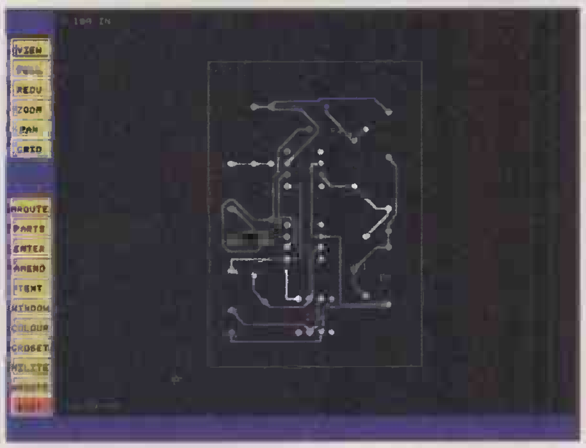

Fig. 6. Results of 386 Rip-up autorouter. Again, 100% completion.

at angles as well as in the usual orthogonal mode. It is a grid-type autorouter with an adjustable grid size. There are comprehensive means to configure it, much more so than with other autorouters in this review, and although the set-up therefore takes longer to perform than the standard Ranger2 autorouter, it is time well spent, as the results produced are much more satisfactory.

The 386 Rip-up autorouter has no difficulty in routeing 100% on double-sided boards. In addition it can route small single-sided boards 100% given a good rat's nest layout, and the test circuit results put it in category A. It can be a little slow, but this can be used to advantage as you can see where it is having trouble routeing – ie on a 386 the process is not so fast that it is too quick for the human eye.

This can help with re-arranging the rat's nest if you decide to re-route. I would rate the power of this 386 autorouter as lying well above the standard Ranger2 autorouter but a little below the Specctra product which is dealt with next.

The manual for the 386 Rip-up is supplied on the disk and is 34 pages of A4. Because Seetrax have fully incorporated the Specctra autorouter into Ranger2, they say they are doing no more development work on the 386 Rip-up autorouter.

Besides these two autorouters and perhaps in recognition that the standard autorouter, albeit capable, is a medium power router, Seetrax offer Ranger2 coupled to a much more powerful autorouter for £250 extra. This is the well-known Cooper (no relation) and Chyan gridless, re-entrant Specctra autorouter. Again, this is good marketing technique since someone starting out in CAD with Ranger2 has a well-defined path if he wants to up-grade.

With other systems, there is often no option for a more powerful autorouter, and if one is required (perhaps for a especially tough job) the only way forward is to buy a complete new system and undergo the relearning process, or buy a third-party autorouter, with the attendant problems with transfer of information between systems.

How much better is this autorouter? Amongst its many features Specctra has rip-up-and-retry, plus push-and-shove, and I quickly discovered these make it probably the most efficient autorouter in this price bracket, being able to route 100% on double-sided boards, with the fewest vias, and in very reasonable times. Specctra is one of the few autorouters that could route small to medium single-sided boards 100%, and to achieve this it is only necessary to put in just a little extra work on the rats-nest to get optimum parts placement.

This autorouter requires a 386DX and a coprocessor and 8Mb of RAM minimum, 80MB of hard drive and at least MS-DOS 5.0. Even with this it will still page to disk on medium sized boards due to lack of RAM. If you increase RAM to 16Mb or more this becomes less noticeable. 32MB is recommended for large boards.

Protected autorouter

Unfortunately this autorouter is protected against piracy by a dongle. If you have not come across this device before, it is a small gadget which plugs into the pc's parallel port and without it you cannot run Specctra. It should (in theory) be transparent to printers, plotters and other devices that use the parallel port. Dongles got themselves a bad name in the early days for unreliability, so you don't see many of them around today. However, the Specctra dongle seems to work quite well.

The snags the dongle brings with it are threefold. First, it is inconvenient to scrabble about at the back of the pc just to get one program to work. This may be acceptable if you have only one dongle, but it can become a nightmare if you have two or more to contend with from other programs.

Secondly, like any exposed piece of hardware fixed to the outside of the pc, it is vulnerable to damage, either physical or electrical. Snapping or bending a pin is a favourite. You then have to go cap-in-hand to the supplier for a new one.

Thirdly, I have found that it is very easy to misplace or lose completely such a small item as a dongle, and you are then in the same position as if you had damaged it. This isn't too bad if the supplier is still in business, at least you can buy a new one, but if the firm has been taken over or has ceased trading it means your program is then useless. There are other ways to secure software against piracy, many of them better than a dongle and cheaper too; dongles add a significant amount to the cost of software. This autorouter is the only product in this review that is routinely supplied with a dongle.

The Cooper and Chyan autorouter has extensive and flexible configuration controls. The instruction book at 120 pages long is larger than some manuals describing full systems. Most unusually, a manual on the Specctra design language – intended for use by programmers – is also provided. All this may appear daunting to those who are not fully computer-literate or who have turned their back on dos.

However, to Seetrax's credit they have provided their own Ranger2 interface and short-form configuration for Specctra, and this gets round any possible objections to the complexity of the autorouter. In addition, this approach eliminates one of the main objections to using a third-party autorouter, and that is having to learn another set of rules, another terminology, another screen format and another programmer's foibles.

In operation, Specctra is configured for routeing in Ranger2, the work is done in Specctra, then a file is automatically passed back to Ranger2, so the results are viewed in Ranger2 format and processed from then on in the normal Ranger2 system – all very straightforward. Indeed, using the Seetrax interface you would not notice you are using a third-party autorouter were it not for the Specctra pages flashing past during routeing.

I found Ranger2/Specctra combination easy to operate, which, considering the whole thing is in dos, and from two different sources, is remarkable. The version of Specctra provided by Seetrax gives improved manufacturability by putting an optional mitre on track corners and also by spreading tracks out to take maximum advantage of available space. This gives a very satisfactory finished product.

Summary of 386 and Specctra routers.

The 386 autorouter is a worthwhile and inexpensive addition to the standard Ranger2 package and is recommended.

The Cooper and Chyan autorouter gives even better results, and is much quicker than the 386. It is altogether a superior autorouter – perhaps the best of this review. However, there is the dongle aspect to consider.

Review 2 – *Electronics Workbench*

This is a essentially a simulation product, ie a schematic drawing and capture program with integrated digital, analogue and mixed simulations, but there is the capability to connect it with a third-party pcb-design program. There is no specific pcb package allied to it, but an add-on program at £49.95 translates the schematic into Orcad, Tango, Eagle, Protel, Ultimate and Layo1 net lists for export. (This add-on is sometimes provided free – contact Robinson Marshal for details) Another add-on at £49.95 transfers SPICE net lists in and out. I tested the Tango and SPICE transfers – see later.

There are various versions of Electronics Workbench which can run under Windows 3.1 (4MB) as a 16-bit program, or as 32-bit program under Windows 3.1 (6MB) with Win32s, or under Windows 95 (4MB) or NT (12MB). The figures in brackets indicate the minimum amount of RAM you will need for each version. Of course, more RAM will help whichever version you choose. They are all supplied on the same set of three disks, which incidentally include Win32s if you don't already have it. The recommended minimum pc is the 486, with co-pro if you have the 486SX cpu, but I ran both 16 and 32 bit versions with Windows 3.1 on a 386SX with co-pro and 8MB of RAM and they both performed well.

Two books are supplied, one a user guide, the other a technical reference. These are well-written, but include large sections that refer to a dos version, and these can be a little distracting as they constantly get in the way. A third booklet is available as a teachers' guide with the educational version of Electronics Workbench, a version which enables faults to be set for student exercises. Of particular interest to teachers will be the many sample circuits already drawn and set up with instruments, ready to go. There is comprehensive on-line Help including a very good itemised explanation of the symbols in the generic libraries.

At first glance, Electronics Workbench may appear to be very similar to CircuitMaker. Indeed, they are both aimed at the same sector of the market, and both include facilities like fault injection for educationalists. However, both style and operating modes are different in many ways.

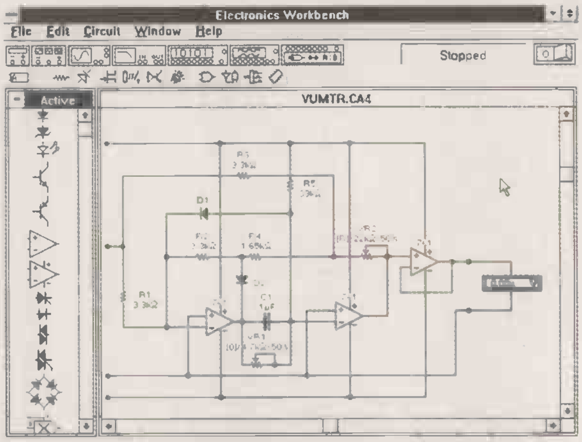

Fig. 7. Shows manually generated schematic. Note the active parts bin, how the voltmeter is connected and how readings are presented on it, and the realistic on/off switch at the top r.h.s.

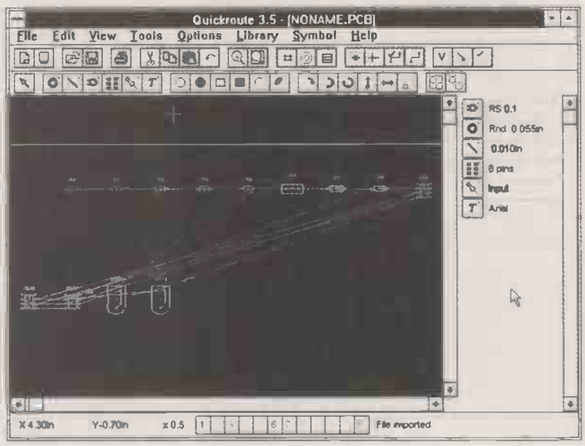

Fig. 8. This is a screen from Quickroute after a TANGO net list has been imported from Electronics Workbench for subsequent pcb artwork production. Note the ratlines to the missing connector footprint are absent – see text for explanation.

Using Workbench

The screen drawing area is about 9in by 5in without the parts bin, and about 7.5in by 5in with it. The actual drawing area is about four times bigger than this, with no support for multi-sheet schematics. There is a dot grid to assist drawing but I did not find it very useful because it did not appear well defined and the pale green dots did not show up well against the grey-white background. There are no colour options for the grid.

However, use of the grid is not a high priority and is confined mainly to part placement because there is an automatic orthogonal drawing facility – you just point the mouse at the pins you want to join and the rest is done for you. This is a system similar to Propak's WAR and CircuitMaker's SmartWire. Unlike those two, there is no alternative facility for manual drawing to the automatic system.

If you do not like the results – and this can happen frequently as the schematic grows in size and density, and the auto-wiring program finds it harder to route – then you edit the connections using a technique very similar to rubber-banding, except in this case the results remain orthogonal. I prefer to have both methods at hand, using the auto-wire on small diagrams for speed, then reverting to manual if the diagram gets congested or large, because even if you are only moderately skilled at diagrams this combination saves on time otherwise spent editing. However, I should emphasise this is a personal preference.

Improved button bar?

Electronics Workbench does not use the familiar button-bar style to access functions like delete, pan, rotate etc. Where you would normally find the button-bar there is a row of simulated instruments such as signal generators and 'scopes. Underneath this there is a type of button bar, but the buttons do not implement tools; instead each of ten buttons opens a library volume. Most of the other functions you would expect to find in a button bar are in the drop-down menus. In practice, I found this a good arrangement.

The library of generic symbols is presented, one volume at a time, in a parts bin on the left-hand side of the screen, which can be scrolled to reach those symbols not on view. The method used here is to select a generic part, position it on the drawing area using drag and drop, then open the Circuit Menu and select the specific label, value and simulation model for that part.

This is repeated for each individual part – you cannot specify a group of identical parts such as resistors of the same type, for example. Although a logical system, and though I liked it, I found it to be rather slow. A few of the common symbols have default values, such as the op-amps, which are assumed to be 741 type unless re-labelled manually. The labels and values usually stay upright during rotation, although the manual advises some may rotate.

There are a little over a hundred or so generic symbols and 350 models in the basic version of Electronics Workbench. This is

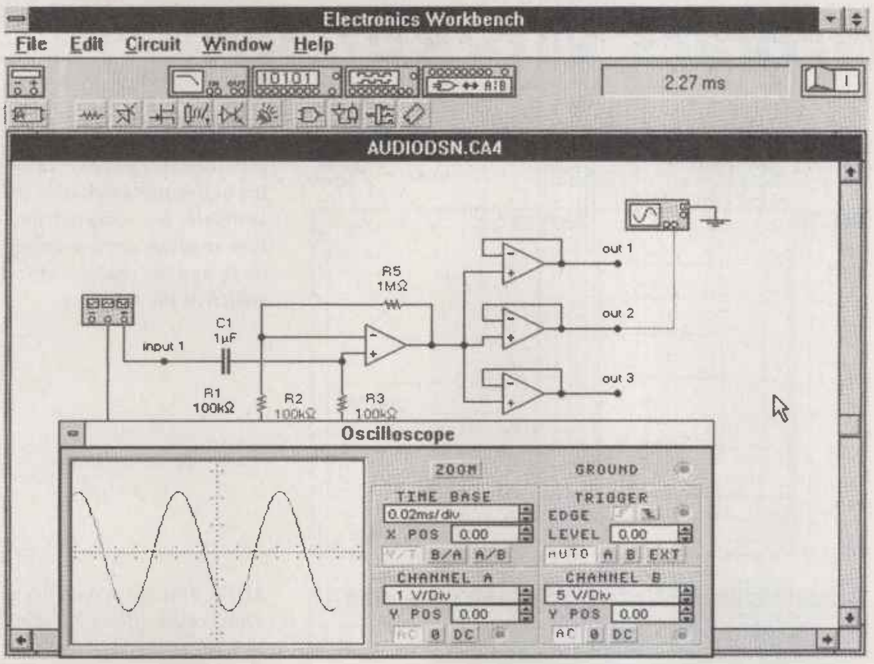

Fig. 9. Shows schematic automatically generated from imported SPICE net list from Quickroute. Note how instruments have been removed from instrument bar and connected. The 'scope window has been maximised.

probable sufficient for schematic drawing for making pcbs and for general-purpose usage as a simulation tool. An option of a further 2,100 models is available on a separate disk costing £99. A significant omission in the libraries was a volume on connectors. This does not matter in simulation, but it is of major importance when it comes to transferring a net list to a pcb program, because most circuits have connectors of one sort or another. This limits the usefulness of Electronics Workbench outside the simulator field as it stands at present.

To start drawing a connection you click on a component pin with the left mouse button. This button is also used to select symbols for editing, and at first I found it was all too easy to select symbols instead of drawing connections. It needed some practice until I was able to sort out one from the other. I would prefer to see the right-hand mouse button used for selecting symbols for edit, as in other programs. There is inhibition of bad connections and automatic junction dot placement, so it is easy to avoid making connectivity errors.

Panning the drawing area is done with the usual Windows scroll-bars. I was mildly surprised to discover there is no zoom feature for magnifying/reducing the diagram in the drawing area. The menu item called Zoom is used for something else – opening up instrument or circuit icons. With a 14in 640×480 16-colour screen, the symbols are just about sufficient in size and resolution to get away without zoom, and after a while I discovered I could carry on reasonably well, but I am sure someone with less than good eyesight would experience difficulty – they would need a larger monitor. Zoom is included with so many programs for good reasons. Apart from this, the schematic drawing program was intuitively easy and pleasant to use.

Virtal instruments

Using the 'instruments' from the instrument bar bears an uncanny resemblance to taking a real instrument down from the shelf and making real connection to an actual circuit. The instruments in Electronics Workbench are designed to look something like the real thing, and connection to a circuit (although idealised) is also intended to re-assure the designer, and this is a success. As an added touch of realism, any plots or readouts on the 'scopes, dvms etc., appear on the actual instrument itself instead of in a window on the monitor screen.

This graphical technique is so easy and intuitive that anyone accustomed to working with proper instruments would feel at home with it. There are nine instruments provided in Electronics Workbench; voltmeter, ammeter, dual-beam oscilloscope, signal generator, d.v.m., word generator, logic analyser, logic converter and bode plotter covering the usual digital, SPICE-based analogue and mixed simulations. Like CircuitMaker, there is no plot of input/output impedance in the analogue section, and no pcb simulation such as Nol's Layan.

Creating a net list in one of the formats mentioned above for export to a pcb drawing program is also straightforward. I generated a Tango net list in Electronics Workbench and exported it to Quickroute 3.5 Pro+. I chose Quickroute for this because the net list transfer is particularly easy as both products are in Windows, and if you look at the Quickroute data, you will see that Tango is the preferred format for imports.

As **Fig. 8** shows, this was successful except for the connectors; no fault of Quickroute's – I expected the connectors to be missing as there is no connector library in Electronics Workbench, as mentioned earlier, so no connector footprint can be transferred. No doubt you could overcome the connector problems by making up your own connector symbols for Electronics Workbench and then tying them in with the connector libraries in Quickroute but this is a lot of work.

You could also try adding the missing connectors by editing the rat's nest, but this is also fraught with difficulty. I think many designers would say – why go to this trouble when there are packages that are fully integrated and where these difficulties do not exist?

If you already had a schematic capture/pcb package and wanted a simulator, you might consider using Electronic Workbench as an add-on package. I tried exporting a SPICE net list from Quickroute (although I could equally well have used Propak) into Electronic Workbench, and it worked well. The schematic came out a little awry, but it was intact, and you could easily re-arrange it if you wanted to. But by adopting this system you would end up with two schematic drawing programs, one of which would be mainly redundant.

Summary

As this review is about pcb artwork production it may seem unusual to include Electronic Workbench, which is really a simulator, but as part of a pcb producing program Electronics Workbench has good potential, hence the provision of a net list exporter. The lack of a connectors volume in the symbols library is an impediment at present.

What Electronics Workbench would need in order to be considered seriously for pcb artwork production is a fully integrated Windows pcb program with autorouter, preferably with rip-up-and-retry strategies, or alternatively an alliance at the technical level with an already established pcb product. It comes so very close to meeting these criteria when allied to Quickroute3.5 (with the new AR3 autorouter) that it would be astonishing if the omission in Electronic Workbench's library was not put right. Such a combination would make a very attractive proposition indeed to a much wider group of engineers and designers.

As a simulation program, Electronics Workbench has many good points, but the absence of the zoom feature will not please many people, and this needs to be corrected. The lack of plots for input and output impedance make the analogue simulation less attractive to the serious engineer, and this feature really needs to be added. These points excepted, the presentation style of simulations is excellent for educational and demonstration purposes. ■

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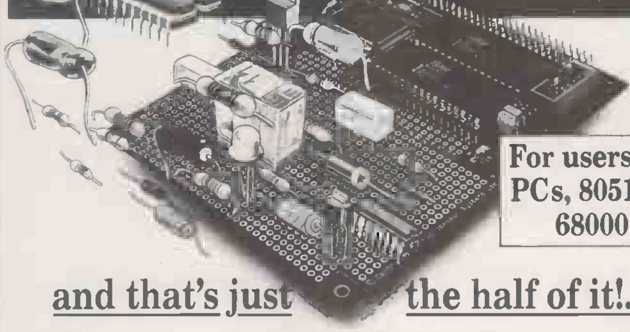

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CIRCLE NO. 113 ON REPLY CARD

12-bit analogue i/o via LPT

Although simple, Yongping Xia's LPT analogue interface resolves to 12 bits.

Equipped with a-to-d and d-to-a converters, a pc can perform many measurement and control functions. **Figure 1** shows an easy way of providing 12-bit a-to-d and d-to-a conversion. Driven by the software below, the circuit interfaces with the pc through its printer port.

The *MAX176* is a complete serial 12-bit a-to-d converter with a built-in track/hold circuit and a voltage reference. Two signals – clock and convert start – are needed to drive the chip. Once started, the a-to-d conversion result is sent out through the DATA pin in two's complement, high-to-low serial order. Analogue input is buffered by IC_{1B} with range of –5V to +5V. The *MAX176* needs +5V and –15V power supplies and provides a –5V reference output.

The *MAX543* is a 12-bit serial d-to-a converter. Its current output is converted to voltage by IC_{1A}. Required –5V reference is provided by a *MAX176*. Resistors $R_{1,4}$ adjust the d-to-a converter offset and gain respectively. The d-to-a converter's output range is also –5V to +5V.

The a-to-d and d-to-a conversion procedures shown are in C. In this application, two printer port addresses (0×37c and 0×37d) are used. One is for output and the other input. Note that the base address may differ between computers. You should find details in your user guide.

The d-to-a conversion procedure converts 12-bit data in serial order and sends it to *MAX543* through the printer port pin 5. Conversion data is stored in 'data out'. An output register named 'out' is used to map the base address printer port. The a-to-d conversion procedure generates *MAX176* required CL(oc)K and CONV(ersion start) signals through pins 2 and 3 of the printer port, reads serial data via printer port pin 15, and returns the reorganised a-to-d conversion result.

These procedures can be included in any C-based application program. If an a-to-d conversion is needed, call the a-to-d procedure and it will return the result. If a d-to-a conversion is required, simply call the d-to-a procedure and pass the data to the procedure. Conversion time depends on the type of pc is used. It takes around 75µs for a-to-d and 68µs for d-to-a on a 50MHz 486 machine. ■

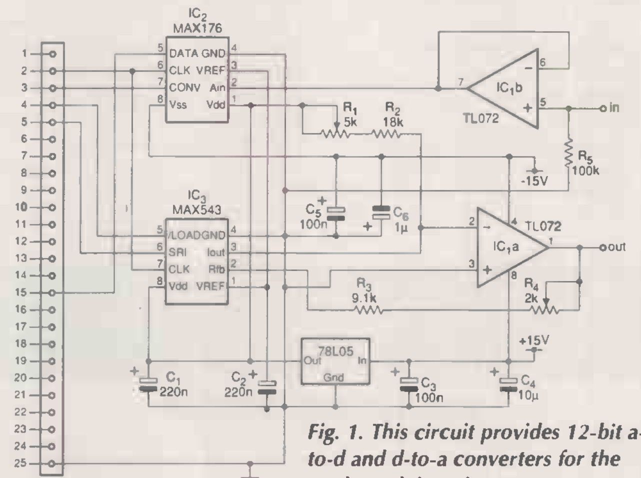

Fig. 1. This circuit provides 12-bit a-to-d and d-to-a converters for the pc through its printer port.

Assembly language for reading and writing the analogue data converters via the pc's LPT port.

```
#include cstdio.h~
#include <dos.h>
#include <conio.h~
#define OUT PORT     0x37c        /* base address */
#define IN PORT      0x37d        /* base address + 1 */
#define CLOCK HIGH 0x01           /* set clock bit high */
#define CLOCK LOW 0xfe            /* set clock bit low */
#define CONVST HIGH 0x02          /* set start conversion bit high */
#define CONVST LOW 0xfd           /* set start conversion bit low */
#define LOAD HIGH 0x04            /* set load bit high */
#define LOAD LOW 0xfb             /* set load bit low */
#define DAC HIGH 0x08             /* set data out bit high */
#define DAC LOW 0xf7              /* set data out bit low */
void dac(int data out);
int adc(void);

/* D-to-A conversion procedure */
void dac(int data out)
{
  int i, out;
  out = 0x04;             /* set DAC's LOAD to be high */
  for (i=0; i<12; i++)    /* send out 12-bit DAC data */
   {
    if (data out < 0x800)          /* if bit 11 is low, */
     {
     out = out & DAC LOW;          /* set output bit = 0 and */
     data out *= 2;     /* double DAC data */
    else      /* if bit 11 is high, */
     out = out | DAC HIGH;         /* set output bit = 1 and */
     data out = (data out-Ox800) * 2; /* double DAC data after set */
     }        /* bit 11 to be 0 */
    outportb(OUT PORT, out);       /* send out */
    out = out | CLOCK HIGH;        /* turn CLOCK high */
    outportb(OUT PORT, out);       /* send out */
    out = out & CLOCK LOW;         /* turn CLOCK low */
    outportb(OUT PORT, out);       /* send out */
   }
  out = out & LOAD LOW;           /* turn LOAD low */
  outportb(OUT PORT, out);        /* send out */
  out = out | LOAD HIGH;          /* turn LOAD high */
  outportb(OUT PORT, out);        /* send out */
}
/* A-to-D conversion procedure */
int adc(void)
{
 int i, data, out;
 data=0;    /* clean data                */
 out = 0x04 | CLOCK HIGH;        /* set CLOCK and DAC's LOAD high */
 outportb(OUT PORT, out);        /* send out */
 out = out & CLOCK LOW;          /* turn CLOCK low */
 outportb(OUT PORT, out);        /* send out */
 out = out | CLOCK HIGH;         /* turn CLOCK high */
 outportb(OUT PORT, out);        /* send out */
 out = out | CONVST HIGH;        /* turn A/D CONVERT START high */
 outportb(OUT PORT, out);        /* send out */
 out = out & CLOCK LOW;          /* turn CLOCK low */
 outportb(OUT PORT, out);        /* send out */
 out = out & CONVST LOW;         /* turn A/D CONVERT START low */
 outportb(OUT PORT, out);        /* send out */
 out = out | CLOCK HIGH;         /* turn CLOCK high */
 outportb(OUT PORT, out);        /* send out */
 out = out & CLOCK LOW;          /* turn CLOCK low */
 outportb(OUT PORT, out);        /* send out */
 for (i=0; i<l2; i++)            /* get 12-bit conversion data */
  {
   out = out | CLOCK HIGH;       /* CLOCK high */
   outportb(OUT PORT, out);      /* send out */
   data = data * 2 + (inportb(IN PORT) & 0x08) / 8; /* update */
   out = out & CLOCK LOW;        /* CLOCK low */
   outportb(OUT PORT, out);      /* send out */
  }
 return (data);          /* return A/D conversion result */
}
main()
{
/* your application */
```

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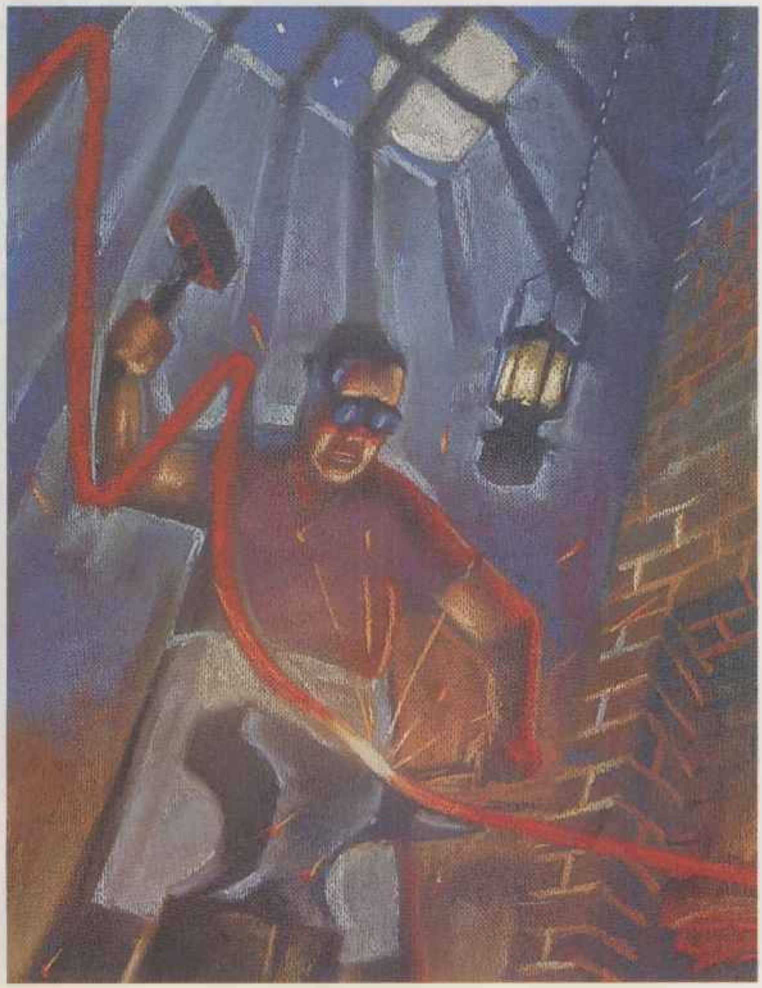
Thermal dynamics in audio power



Douglas Self explains how to achieve lower power amplifier distortion by improving bias accuracy.

The first part of this series demonstrated how quite complex problems in thermal dynamics could be simply solved by using electrical analogues and a circuit simulator; the second part showed how this approach could be used to produce techniques for power amplifier thermal compensation that were much faster and more accurate than the conventional methods. These methods explicitly assumed it would be possible to design a bias-generator with a temperature coefficient either higher or lower than the standard result[1].

Fig. 1 shows two versions of the classical V_{be}-multiplier bias-generator. Each has its lower rail grounded to simplify the results. The first (Fig. **1a**) is set up for an emitter-follower output stage, where the voltage V_{bias} is $(4 \times V_{be})+V_q$, which comes to +2.93V. Voltage V_q is the small quiescent voltage across the emitter resistors R_e; it is this quantity that must be kept constant, rather than the quiescent current, as is usually assumed. The optimal V_q for an emitter-follower stage is about 50mV.

The second (Fig. **1b**) is suitable for a complementary-feedback-pair output stage, for which the required V_{bias} is less at $(2 \times V_{be})+V_q$, or about 1.30V. Note that the optimal V_q is smaller for the complementary-feedback pair, at about 5mV.

It is assumed that V_{bias} is trimmed by varying R_2, which will in practice be a preset in series with an end-stop resistor that limits the maximum V_{bias} setting. This is important, because a preset normally fails by the wiper becoming disconnected, and if it is in the R_2 position the bias will default to minimum. In the R_1 position an open-circuit preset gives maximum bias, which may damage the output stage.

Since the emitter-follower version of the bias generator has a higher V_{bias}, there must be a larger V_{be}-multiplication factor to generate it, and this is reflected in the higher temperature coefficient, see **Table 1**.

Raising temperature coefficient

There are many approaches possible, but the problem is complicated because the bias generator may have to work within two rails only 1.3V apart. Additional circuitry outside this limit can be accommodated by bootstrapping, as in the Trimodal amplifier biasing system[2], but this adds complexity.

Often the thermal losses to the temperature

Table 1. The emitter follower needs a larger V_{be} multiplier.

	V_{bias}	$R_1(\Omega)$	$R_2(\Omega)$	$R_3(\Omega)$	Coeff.(mV/°C)
Emitter follower	2.93	120	470	22	–9.3
Complementary feedback pair	1.30	470	470	150	–3.6

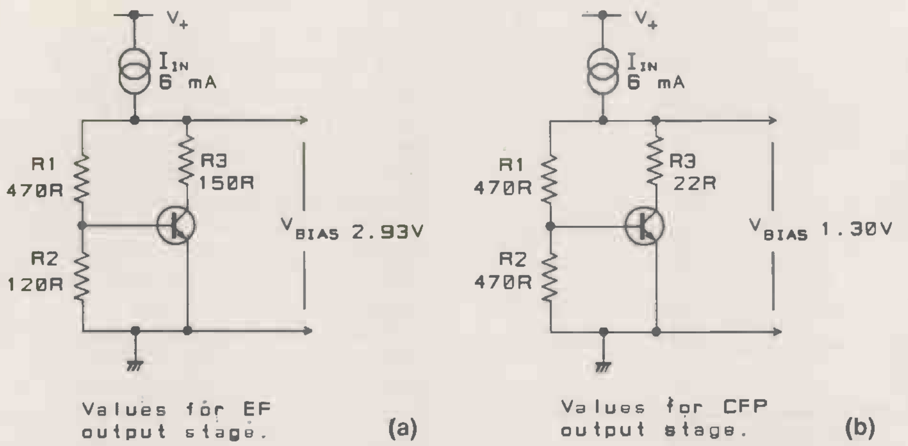


Fig. 1. Classical V_{be}-multiplier bias generator. Two versions are shown, for biasing emitter follwer (at 1a) and complementary-feedback-pair output stages (at 1b). The emitter-follower requires more than twice the bias voltage for optimal crossover performance.

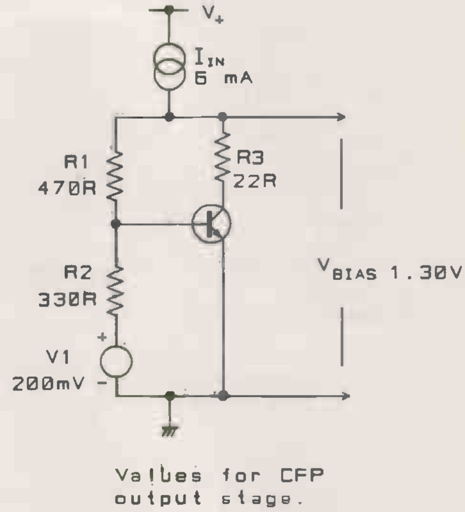


Fig. 2. Theoretical basis of V_{be} multiplier with increased tempco. Adding voltage-source V_1 means the voltage-multiplication factor must be increased to get the same V_{bias}. The temperature coefficient is therefore also increased, here to –4.4mV/°C.

sensor are the major source of steady-state V_{bias} error, and to reduce this a tempco is required that is larger than the standard value given by: 'V_{be}–multiplication factor times –2mV/°C'.

A simple new idea is shown in **Fig. 2**. The aim is to increase the multiplication factor – and hence the negative temperature coefficient – required to give the same V_{bias}. The diagram shows a voltage source V_1 inserted in the R_2 arm. To keep V_{bias} the same, the value of R_2 must be reduced, and since the multiplication factor $(R_1+R_2)/R_2$ is increased, the tempco is similarly increased.

In **Table 2**, a complementary-feedback-pair bias circuit has its temperature coefficient varied by increasing V_1 in 100mV steps; in each case the value of R_2 is then reduced to bring V_{bias} back to the desired value.

Table 2. Complementary feedback pair bias data, showing increasing temperature coefficient.

V_1	V_{bias}	R_2	Coeff
mV	V	Ohms	mV/°C
0	1.287	470	–3.6
100	1.304	390	–4.0
200	1.287	330	–4.4
300	1.286	260	–5.0
400	1.285	190	–6.9

A practical circuit is shown in **Fig. 3**, using a 2.56V band-gap reference to generate the extra voltage across R_4. This has to work outside the bias generator rails, so its power-feed resistors R_7, R_8 are bootstrapped by C from the amplifier output[2].

Ambient temperature changes

Power amplifiers must be reasonably immune to ambient temperature changes, as well as changes due to dissipation in power devices. The standard compensation system does this pretty well, as the V_{be}–multiplication factor is inherently almost the same as the number of junctions being biased.

This is no longer true if the tempco is significantly modified. Ideally we require a bias generator that has one increased tempco for power-device temperature changes only, and another standard temperature coefficient for ambient changes affecting all components.

One approach to this is Fig. 4, where V_1 is derived via R_6, R_4 from a silicon diode rather than a bandgap reference, giving a voltage reducing with temperature. The tempco for temperature changes to Q_1 only is –4.0mv/°C, while the tempco for global temperature changes to both Q_1 and D_1 is lower at –3.3mv/°C.

Table 3. Reducing temperature coefficient.

V_1	V_{bias}	R_1	Coeff.
mV	V	Ω	mV/°C
0	1.287	470	–3.6
100	1.304	390	–3.3
200	1.287	330	–3.1
300	1.286	260	–2.8

Lowering temperature coefficient

In Part I[1], I showed that an emitter-follower output stage can show 'thermal gain' in that the changes in V_q make it appear that the tempco of the V_{bias} generator is higher than it really is. This is because the bias generator is set up to

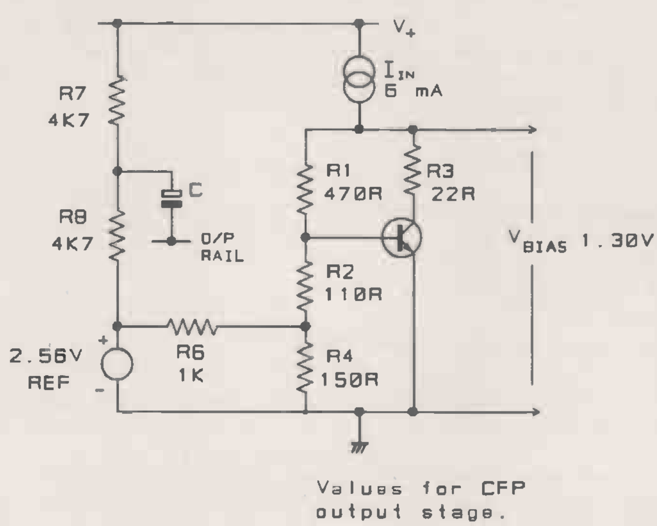


Fig. 3. Shows a practical version of a V_{be} multiplier with increased tempco. The extra voltage source is derived from the bandgap reference by R_6, R_4, and the tempco is increased to –5.3mV/°C

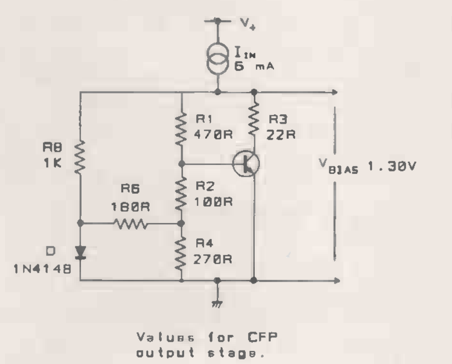


Fig. 4. Practical V_{be} multiplier with increased tempco, and also improved correction for ambient temperature changes, by using D_1 to derive the extra voltage.

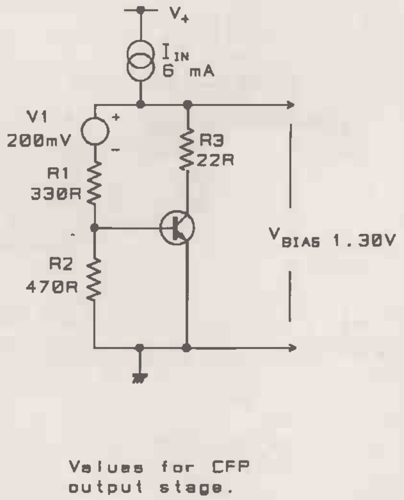


Fig. 5. The principle of a V_{be}-multiplier with reduced temperature coefficient. The values shown give –3.1mV/°C.

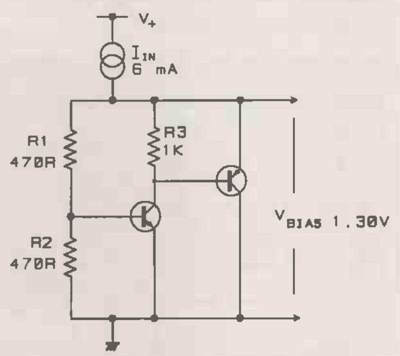


Fig. 7. Circuit of a two-transistor V_{be}-multiplier. The increased loop gain holds V_{bias} more constant against current changes.

compensate for four base-emitter junctions, but in the emitter-follower output configuration the drivers have a roughly constant power dissipation with changing output power, and do not change much in junction temperature.

The full benefit of the temperature coefficient is thus felt by the output junctions, and if the sensor is placed on the power device itself rather than the main heatsink, to reduce thermal delay, then the amplifier is likely to be seriously over-compensated for temperature. In other words, after a burst of power V_q will become too low rather than too high. We now need a V_{bias} generator with a lower temperature coefficient than the standard circuit.

The principle is exactly analogous to the method of increasing the temperature coefficient. In **Fig. 5**, a voltage source is inserted in the upper leg of potential divider R_1, R_2; the V_{be}–multiplication factor is reduced, and so therefore is the temperature coefficient.

Table 3 shows how this works as V_1 is increased in 100mV steps. Resistor R_1 has been varied to keep V_{bias} constant, in order to demonstrate the symmetry of resistor values with Table 2; in reality R_2 would be the variable element, for safety reasons described above.

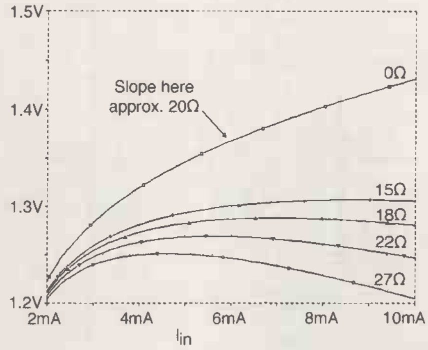


Fig. 6. Simulation results for standard V_{be} multiplier, showing how current-compensation resistor R_3 is chosen. When R_3 is fitted, V_{bias} peaks very broadly at a particular current, giving much smaller variation with current.

Fig. 8. The two-transistor configuration gives a consistently lower series resistance, and hence V_{bias} variation with current, compared with the standard version without R_3.

Current compensation

Both bias-generators in Fig. 1 are fitted with a current-compensation resistor R_3. The V_{be}–multiplier is a very simple shunt regulator, with a low loop gain, and hence a significant series resistance. Resistor R_3 is therefore added to give first-order cancellation of V_{bias} variations caused by current changes, by subtracting a correction voltage proportional to this current.

Rather than complete cancellation, this gives a peaking of the output voltage at a specified current, so that current changes around this peak value cause only minor voltage variations. This peaking philosophy is widely used in IC bias circuitry.

Resistor R_3 should never be omitted, as without it mains voltage fluctuations can seriously affect V_q. Table 1 shows that the optimal value for peaking at 6mA depends strongly on the V_{be} multiplication factor.

Figure 6 shows variation of V_{bias} with current for different values of R_3. The slope of the uncompensated, R_3=0, curve at 6mA is ≈20Ω. This linear term is cancelled by making R_3 18 or 22Ω.

Current through the bias generator varies because the voltage amplifier current-source is not a perfect circuit element. Biasing it with the usual pair of silicon diodes is not sufficient to make it wholly immune to supply-rail variations. I measured a generic amplifier (essentially the original Class-B Blameless design) and varied the incoming mains from 212V to 263V, a range of 20%. This, in these uncertain times, is perfectly plausible for a power amplifier travelling around Europe. The voltage-amplifier stage current-source output varied from 9.38mA to 10.12mA, which is a 7.3% range.

Thanks to the current-compensating resistor in the bias generator, the resulting change in quiescent voltage V_q across the two R_e's is only from 1.1mV (264V mains) to 1.5mV (212V mains). This is a very small absolute change of 0.4mV, well within the V_q tolerance bands. The ratio of change is greater, because V_{bias} has had a large fixed quantity (the devices' V_{be}) subtracted from it, so the residue varies much more. Variation in V_q could best be further suppressed by making the current source more stable against rail variations.

The finite ability of even the current-compensated bias generator to cope with changing standing current makes a bootstrap voltage-amplifier stage collector load much less attractive than the current-source version; from the above data, V_q variations will be at least three times greater.

A wholly different approach to reducing V_{bias} variations increases the loop gain in the V_{be}-multiplier. **Fig. 7** shows the circuit of a two-transistor version that reduces the basic resistance slope from 20 to 1.7Ω. The advantage is that V_{bias} variations will be smaller for all values of voltage-amplifier stage current, and no optimisation of a resistor value is required. The drawback is slightly greater complexity in an area where reliability is vital. **Figure 8** compares the two-transistor configuration with the standard version, without R_3.

Conclusion

This final part of the 'Thermal Dynamics' series shows how to build simple V_{bias} generators with temperature coefficients ranging from –2.5 to –6.9mV/°C.

This, in combination with the techniques described in the earlier parts of this series, should allow you to design of Class-B amplifiers with greater bias accuracy, and therefore lower crossover distortion. ■

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1. D. Self, 'Thermal Dynamics In Audio Power' *Electronics World*, May 1996, p411.
2. D. Self, 'Trimodal Audio Power' Part 2 *Electronics World*, July 1995, p585.
3. D. Self, 'Distortion In Power Amplifiers, Part 7' *Electronics World*, Feb 1994, p139 (Peaking effect of current-compensation).

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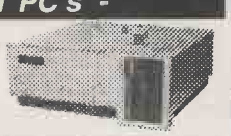

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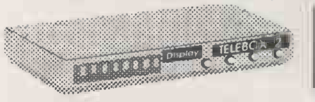

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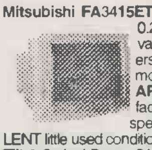

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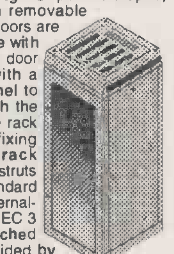

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CIRCLE NO. 116 ON REPLY CARD

A rationalised *phono preamplifier*

Simon Bateson's RIAA preamplifier is economical *and* offers benefits over existing designs.

A great number of phono preamplifier designs have been published over the years. Perhaps this is because the subject can span any realisation between the very cheap and the outrageously expensive, or because there are interesting design features hidden within an apparently simple function.

One trend was the preoccupation in the early 1980s with low noise and RIAA accuracy, another was the move from series to shunt feedback, widely promoted by John Linsley-Hood.

John has published several excellent reviews and designs of amplifiers and preamplifiers and it will be clear that the circuitry described here is but a rearrangement of his work. However there are a couple of worthwhile advantages in this configuration. I am not about to launch into a defence of vinyl discs, but I do have a number of records and this preamp seems to make the best of them.

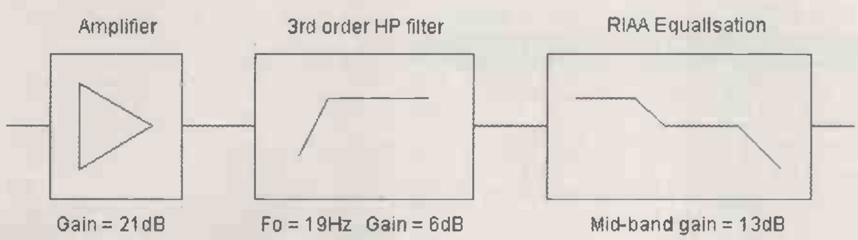


Fig. 1. There are no electrolytic capacitors in the signal path of the preamp and its noise is low.

Circuit elements

Figures 1 & 2 are the design's block diagram and circuit. The first stage is a straightforward dc-coupled amplifier with a stage gain of 21dB. This is followed directly by a third-order Butterworth rumble filter based on a standard equal value Sallen-Key circuit with a gain of 6dB. The filter is in circuit permanently. I have large, accurate speakers, namely ATC *SCM50A* active monitors, and it is sad to see the woofer wobbling about without the filter. After some experimentation the I set the turnover frequency at 19Hz.

The third part of the filter is formed by C_4 and R_9 which feed the RIAA equalisation stage. Although this is a shunt feedback stage,

Advantages of this RIAA preamplifier configuration

The unusual aspect of this design is the rearrangement of conventional circuit blocks so that the rumble filter appears before the RIAA equalisation. Several advantages accrue from this arrangement:

- No electrolytic capacitors appear in the signal path and the low-frequency characteristic is closely defined. Additionally, since there are no high-value capacitors to charge, the circuit settles almost immediately on switch-on.
- Large low-frequency rumble signals never reach the RIAA stage so do not compromise headroom. The mid-band gain is 40dB giving an input clip point of about 130mV with ±15V supplies. In any case, it is a trivial matter to adjust the gain of IC_1 to suit whatever cartridge is in use, including moving coil types.
- The rumble filter is not a configuration subject to excess noise due to high impedances, since the capacitors C_2 and C_3 present a low impedance at high frequencies. $1/f$ noise from the op-amp is reduced due to the high-pass characteristic of C_4/R_9. Meanwhile, ordinary amplifier noise is reduced because the filter is followed by the low-pass RIAA stage.
- The input amplifier does not suffer a high dc offset due to mismatched input terminal resistances since the dc cartridge resistance is fairly close to that of R_3 and the gain is low. Therefore there is no need for a high value electrolytic in series with R_3, or in series with the input. I do not believe that a minute bias current passing through the cartridge causes a problem although this might upset owners of £3000 handcrafted banana wood and platinum specimens.

DC feedback resistance of the RIAA stage is fairly high, at 100kΩ, so although the overall stage dc gain is zero due to C_4 it is better to use a fet op-amp such as the excellent *OPA2604*. Under these conditions there is no significant output offset voltage so the output coupling capacitor is not needed. The RIAA stage needs to achieve quite a high maximum gain, but only at low frequencies where, of course, the op-amp has the greatest open-loop gain available.

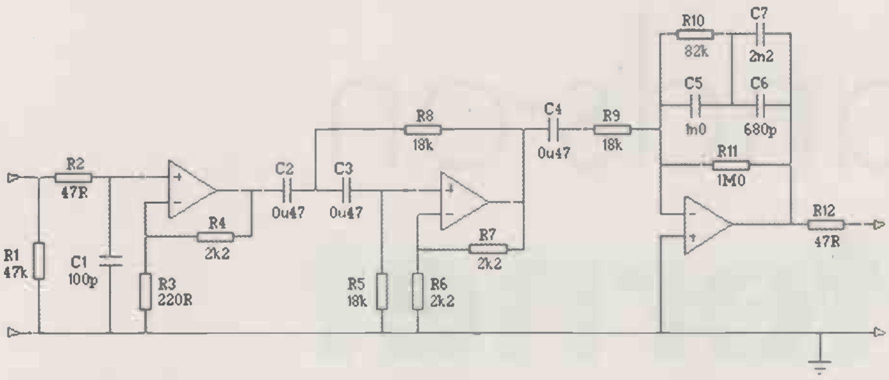


Fig. 2. The unusual aspect of this RIAA preamplifier is the rearrangement of conventional circuit blocks so that rumble filtering appears before RIAA equalisation.

it operates at a high signal level. As a result, small-value capacitors can be used in a relatively high-impedance network without any noise penalty.

This is an inverting configuration. If absolute phase is considered important, it is a matter of moments to reverse the phono cartridge connections. Concerning component choice; the rumble filter capacitors should be the 5% tolerance miniature polyester film types (available from RS), while the RIAA network uses cheap and accurate Philips 1% polyester types.

Using integrated operational amplifiers such as the *NE5532*, the circuit is easily constructed on a small pcb, the layout of which is available from the editorial office. I recommend this pcb as carefully laid out and tested. I suspect poor pcb layout is responsible for far more under-performing equipment than is popularly thought.

Details to note are that low-value resistors are provided at the input and output to ensure stability with capacitive loads, while a single electrolytic is placed across the supply rails close to IC_1. High-performance op-amps do not take kindly to poor power supply decoupling and will oscillate at several megahertz to vent their feelings.

In summary

When the configuration first came to mind, my satisfaction at its economy and effectiveness was a little dampened by the thought that it came to mind about twenty years too late. Still, it probably won't be the final RIAA design to be published. There are a few possibilities which come to mind, such as using an *SSM2015* differential amplifier for the first stage. This would offer slightly lower noise along with zero offset current through the cartridge and the usual benefits of balanced operation – which are inherently available from the cartridge if you rearrange the turntable wiring. Its surprising that balanced operation never came into fashion. You could use discrete instrumentation amplifiers and military grade capacitors. ■

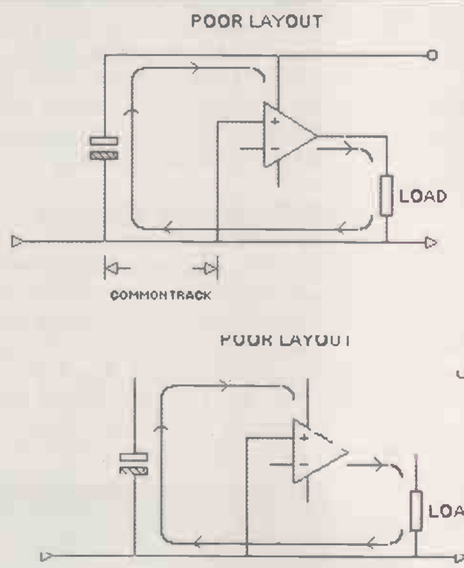
Thoughts on power supply decoupling

Power rails should not be decoupled to the local earth with the usual pair of large electrolytics. Decoupling is a frequently misunderstood subject and the heavy-handed application of capacitors actually couples power rail disturbances into the ground rail.

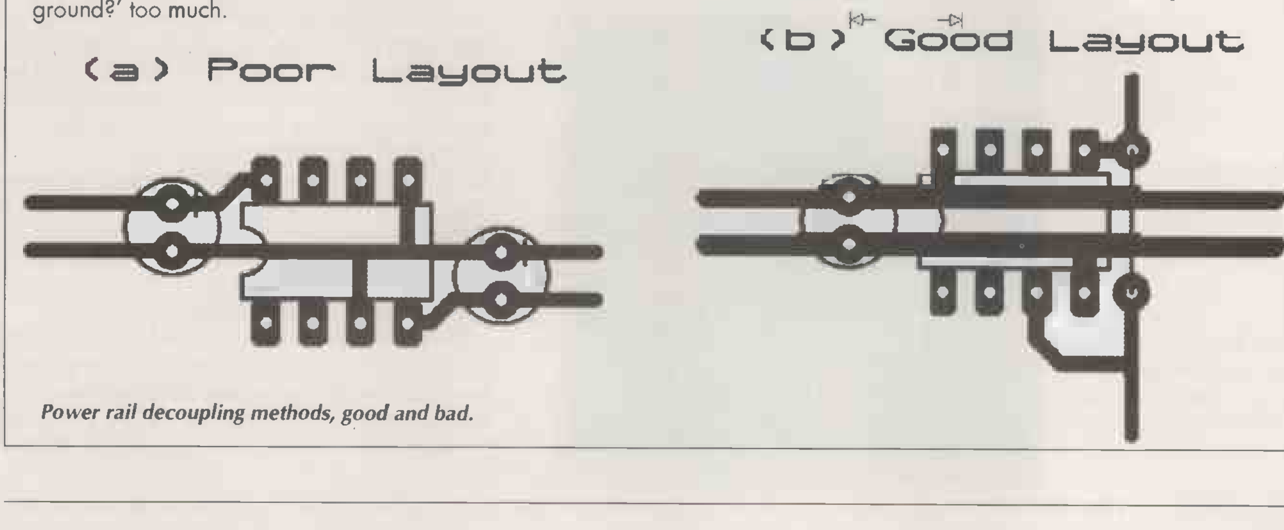
The major problem with all practical circuit layout is that the ground line is simultaneously an input signal reference point, an output signal reference point and a power ground. When the op-amp delivers transient current into a load, the current is drawn from the nearest source – the decoupling capacitor – hence output current flows in the local earth line. This line acts as a reference for the input signal and if badly laid out the earth current couples back to the op-amp inputs, inducing instability or even oscillation.

One mode of coupling back is shown above, right, where the earth connections are simply in the wrong order. A good way to induce op-amp hysteria is the pcb layout below right. Similar comments apply to non-inverting configurations. The better the op-amp, the more important it is to get the earth layout correct.

I have found the best arrangement to be rail-to-rail decoupling adjacent to the IC, with rail-to-ground decoupling at the power connection to the board; this lowers the power-supply impedance at high frequencies without confusing the issue of 'what is ground?' too much.



Earth currents in an amplifier physical layout are frequently misunderstood.



Power rail decoupling methods, good and bad.

Hands-on Internet

Cyril Bateman looks at mirrors, electronics design data, and new ways to search old services.

With the ever growing dominance of the World Wide Web, it is easy to overlook the original Internet uses; e-mail, FTP and News Groups. While for regular use, dedicated software is preferred, most Web browsers now provide working access to these functions.

While the Web browser search methods covered in my previous articles are targeted to Web page and FTP searches, Deja_News[1] searches only within the Usenet News Groups, eliminating the time consuming manual searching previously needed to locate a topic, **Fig. 1**.

Growing interest in emc has caused the formation of a specialist news group – sci.engr.electrical.compliance – which is dedicated to emc and safety compliance. Maintained by Bill Lyons of Claude Lyons Ltd[2], this group's FAQ contains much essential reading.

Closely related to emc, Texas Instruments[3] recently issued an application report detailing the Bergeron Graphical Method, used to determine line reflections during transient phenomena.

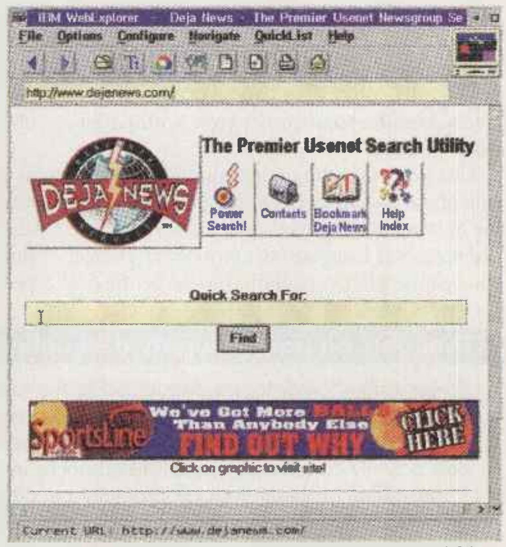


Fig. 1. Using Deja News to search for topics within Usenet. Some claim the Usenet archives hold the largest information base in Internet.

Reflections on Windows

Two FTP software download sites catering for Windows systems are widely mirrored, i.e. backed up and available via different sites. Winsite[4] has 44 mirrors while Simtel.Net[5] has 64 mirrors. Winsite – formerly the CICA Windows FTP archive – went live on 13 October last year, **Figs 2, 3**.

For the UK, the Hensa[6] archive at Lancaster University and Sunsite North Europe[7] at Imperial College London, are particularly good FTP sources.

Fig. 2. The WinSite home page stakes its claims. This site used to be known as Cica, some archives continue to use the Cica name. Especially within their hard disc directory structure.

Both carry Winsite and Simtel.Net mirrors for pcs and also hold Amiga, Atari, Apple, Archimedes RiscOS and OS/2 software archives. Note external access to Hensa is not permitted during normal working hours.

Software for downloading is freely available from all mirror sites, but software for uploading is only accepted at parent sites. Uploads not conforming to the published instructions is rejected. Accepted software will be available from all mirrors after a few days delay and the Archie servers will automatically be advised.

With the enormous amounts of data and software already available, your unpublicised upload will raise little interest. By way of example, in early June I uploaded evaluation copies of my EMCFiltr.zip software, used to illustrate the 'Understanding emi filters' article[8], to three sites. These were Winsite, Simtel.Net and Funet.Fi[9]. Within two days, archie.funet.fi located this file, but four weeks later several Archie servers remained unaware. On acceptance of the software, the upload site administrator posts an Internet announcement. However, it is advisable to seek further publicity. Send mail to net-happenings[10] and try Submit It[11] to advise the popular search engines.

While Netscape 2.01 incorporated improved security features, the latest Beta version 3.0, available by download[12], adds features and further enhances security. It also provides support for SSL3.0 and permits 'personal certificates' to prove your on-line identity.

Fig. 3. Simtel.Net is part of Walnut Creek cd-rom. For those with slow Internet access, much of this software collection is available on cd-Rom.

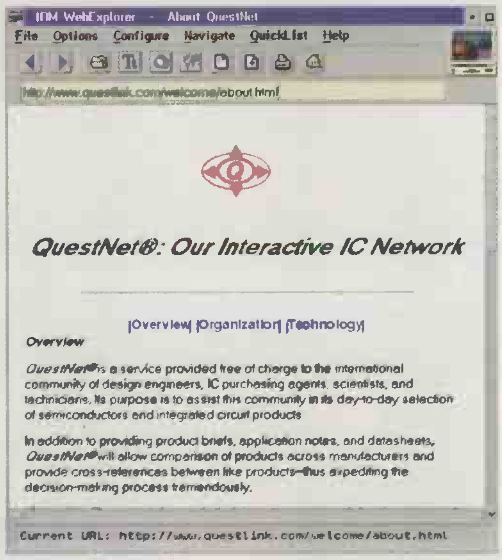


Fig. 4. Dedicated to searching for semiconductor sources world wide. Also can provide product briefs, application notes and datasheets.

Sourcing semis

QuestNet[13] helps designers to select and source semiconductors or integrated circuits world wide. It provides product briefs, application notes and datasheets. In addition, there are Internet facilities for semiconductor houses not yet having a Web page. Present searches are by product function, search by manufacturer and part number is being implemented, **Fig. 4**.

Continuing the on-line support theme, Motorola[14] has an extensive Web presence. With its vast product ranges, the site is full of information and should be visited.

Elantec[15] provides its full range of application notes for download and has a page devoted to interactive technical support and samples request.

Electric Library[16] has now been sampled. Unlike other search methods listed, it is only available by a $9.95 monthly subscription. And you can take advantage of the free trial offer. If sufficient of the 780 magazines and journals listed prove useful, the subscription fee can easily be recovered. This resource is similar to a conventional library of books and journals, except that it is electronically searchable using plain English. Having found the relevant document, click and it is downloaded. Unlike other search tools, you are not linked to Internet resources, it delivers the document to you, **Fig. 5**.

While all search engines covered to date have been US based, if all else fails, you can perhaps try a UK one[17] which has an appropriate if irreverent address. While the present Web page differs, this version noticed recently, has a certain artistic appeal, **Fig. 6**. ■

The battle of OS

Expect more clashes in the operating system war, now that the latest Beta version of OS/2 Merlin has been shipped to testers for hands-on evaluation. Available to registered OS/2 users is a demo compact disk for Merlin. With built in support for Java, object-oriented technology and voice input/control allowing hands-off and eyes-off operation, Merlin claims to set the standards for ease of use.

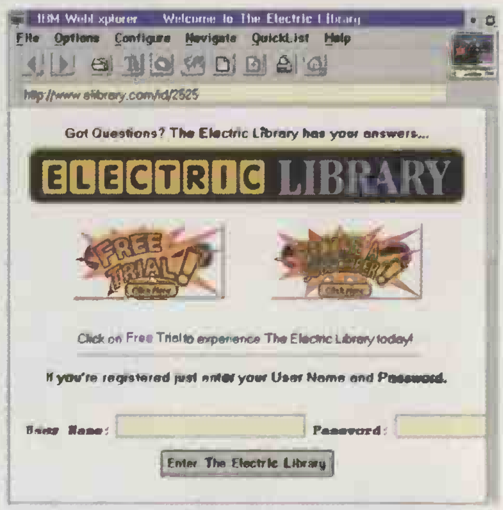


Fig. 5. Maintains its own database of material but requires your regular subscription. Register by e-mail to gain a month's free access, without needing a credit card number. Maintains its own knowledge base and unlike some, does not pass you on to other Web links.

Fig. 6. Lord knows what this is. The site is organised rather differently from the established US search engines.

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HIGH DIRECTIVITY RF COUPLER

Paolo Antoniazzi has developed a method of producing couplers usable at gigahertz frequencies using standard low-cost fibreglass printed circuit.

At the beginning of the 1950's, a transmission line corresponding to a flattened coaxial with the sides removed was described[1]. While yielding configurations that were somewhat simpler to fabricate, this approach still required that close tolerances be maintained as in the case of coaxial construction. The relative simplicity of the parallel-line system – or stripline – suggested further study of this type or of some equivalent open system.

This work has resulted in an interesting variation of the parallel-line system which avoids the requirements for extreme accuracy and dimensional symmetry. Because of the ease of manufacture and the apparent similarity to conventional wiring, the generic name of microstrip has been given to this transmission system[2]. A cross section of the wire-above-ground system, as well as a cross section of the variation using a strip conductor – microstrip in place of the round wire – are shown in **Fig. 1**.

In the idealised case using a simple uniform dielectric and a lossless conductor, the type of transmission corresponds to the TEM mode[3,4]. This has been confirmed approximately by theoretical work and by measurements performed on practical microstrip circuits comprising composite dielectrics and finite conductor dimensions.

As the frequency is increased, however, the dispersion effect becomes more obvious, and the characteristic impedance and the phase velocity defined under the quasi-TEM analysis, **Inset 1**, must be modified.

Inset 1. TEM – Transverse-ElectroMagnetic waves. These waves are characterised by the fact that both the electric vector (E vector) and the magnetic vector (H vector) are perpendicular to the direction of propagation. This is the mode commonly excited in coaxial and open-wire lines. It cannot be propagated in a waveguide.

An important characteristic of the microstrip circuits is the power-flow distribution between the conductor and ground plane. **Figure 2** gives the calculations of the ratio of power-flow in a particular cross section to the total flow of power for a given b/h (b=width of the microstrip conductor, h=thickness of dielectric substrate).

While the distribution shown is approximate, it is possible to conclude that most of the power-flow is adjacent to the conductor. Essential characteristics necessary to design a microstrip system are shown in the box, **Figs. 3-5**. In particular using the information in Fig. 4 it is possible to design the correct length of the near λ/4 coupler, for fibreglass material about 0.5 referred to air.

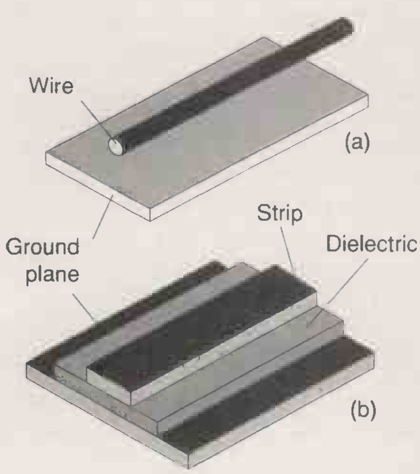

Fig. 1. Cross section of transmission systems: (a) shows the wire above ground and (b) illustrates the microstrip.

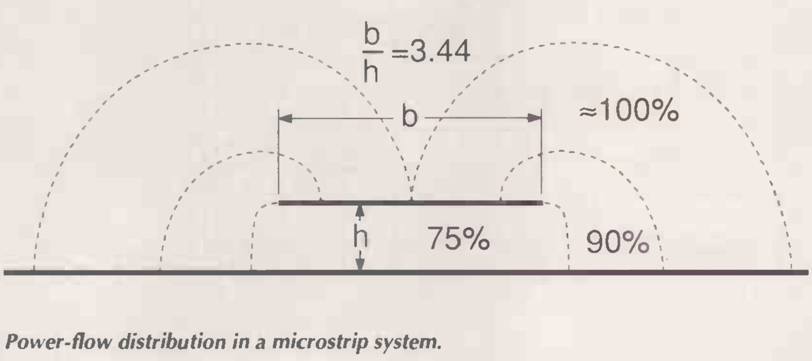

Fig. 2. Power-flow distribution in a microstrip system.

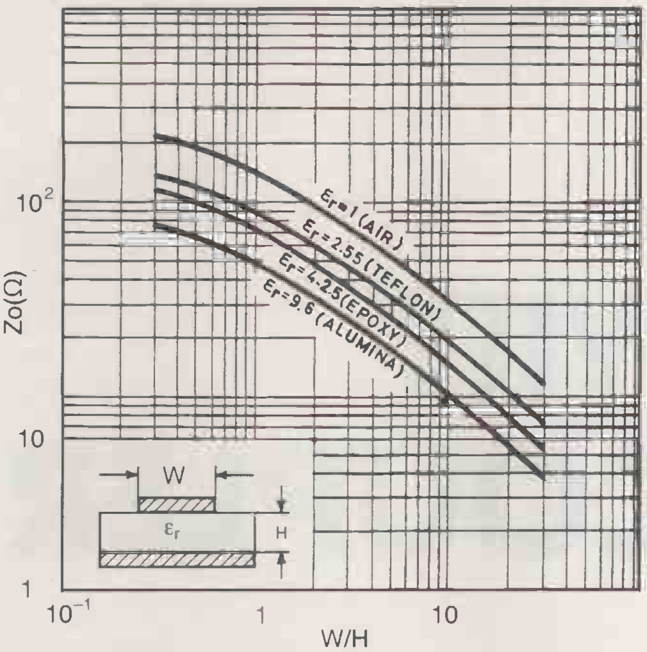

Fig. 3. Characteristic impedance versus E and W/h.

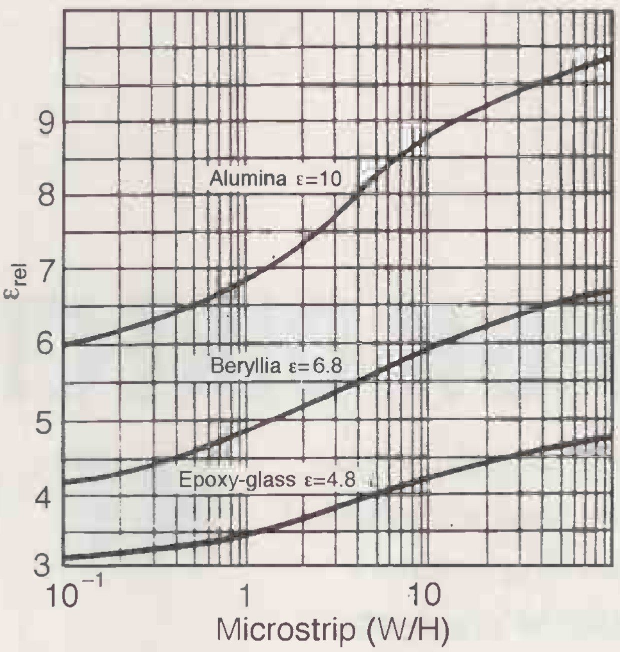

Fig. 4. Effective dielectric constant.

The directional coupler

A directional coupler is ideally a lossless reciprocal four-port device. It normally provides two unequal amplitude outputs when a signal is fed to one of its inputs. Depending on which port is fed, the outputs may be in-phase or out-of-phase (90° or 180°).

Directional couplers are usually described by indicating the coupling ratio of the low signal level output. Thus a 20dB directional coupler will provide a 'coupled' output which is 20dB below the input, while the through path (main line) has only a little loss, 0.04dB in this case. Naturally the main line loss increases for lower coupling ratios as indicated in **Table 1**.

Directional couplers can be used effectively in systems to monitor power or match, branch signals, feedback power in amplifiers and for signal injection. Designer who understand the unique features of directional couplers will find many other applications where coupler properties can solve particular system problems.

Table 1.

Coupling ratio (dB)	Coupled output (dB)	Main line loss (dB)
3	–3	3.00
6	–6	1.25
10	–10	0.46
20	–20	0.04

A directional coupler has the ability to separate and sample signal components based on the direction of signal flow. Referring to **Fig. 6**, the diagram shows a 20dB directional coupler with a signal source at Port (1).

Ports (2) and (3) are terminated in Z_o while Port (4) is loaded with an unknown impedance Z_l. We can see that if Z_l=Z_o the return loss of Z_l becomes infinite and no signal reaches Port (3). This, of course, should follow from the consideration that Ports (1) and (3) and (2) and (4) are isolated when the directional coupler is terminated with Z_o.

Practical directional couplers have finite isolation and this introduces an error in the comparative levels at Ports (3) and (2). Directional coupler directivity is a limiting parameter in the ability to accurately measure the return loss of a unknown load. As an example, if isolation (S31) is 43dB and coupling (S21) is 13dB, then directivity is 43–13, or 20dB.

The calculated error limits for a given directivity of coupler are shown in **Fig. 7** and the following Table[5]. For example, if a coupler with 25dB directivity is used to measure the return loss of an antenna for wireless LAN systems and the measured value is 22dB, then the true return loss value can be anywhere between 17.3 and 32.7dB. Inserting different lengths of cable between the coupler and the antenna quickly shows that the match is not perfect, since the readings will change. The need for higher values of directivity by simple

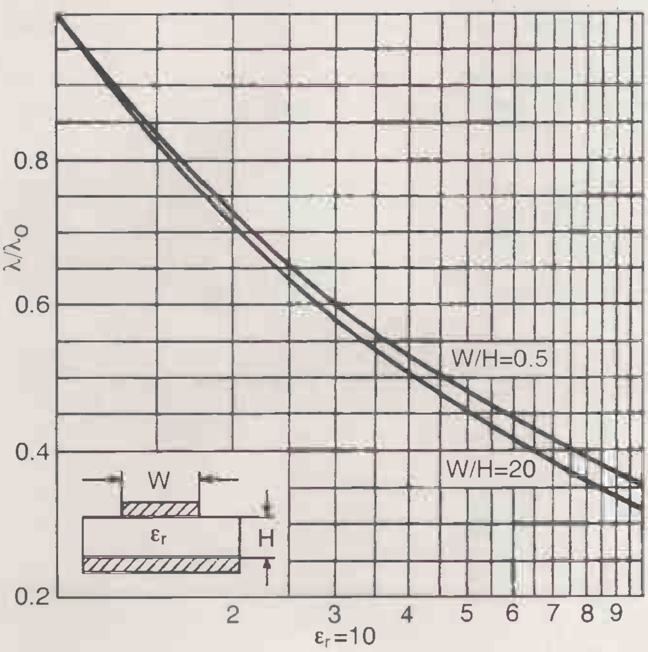

Fig. 5. Ratio of line wavelength to free space wavelength.

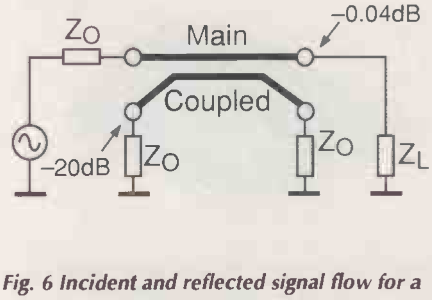

Fig. 6 Incident and reflected signal flow for a 20dB directional coupler.

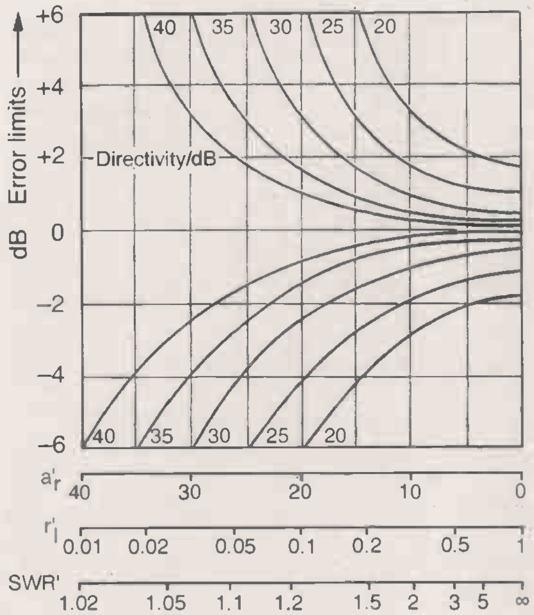

Fig. 7. Error limits due to insufficient directivity.

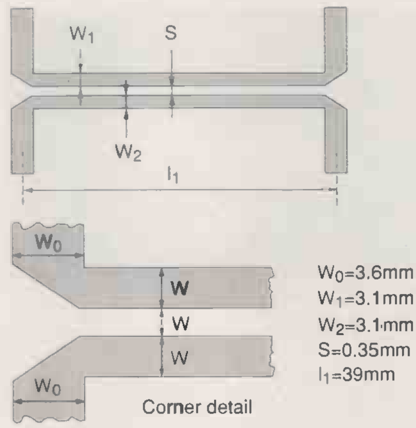

Fig. 8. Layout of the side coupled 13dB directional coupler realised with standard 1.6mm fibreglass printed circuit – dual sided.

couplers was the starting point for our experiments.

Measured return loss (dB)	Range of true return loss (dB) with 20dB Directivity	with 25dB Directivity
10	7.6 to 13.3	8.6 to 11.7
14	10.5 to 20.0	11.8 to 16.9
18	12.9 to 31.7	15.0 to 23.1
22	15.0 to 33.7	17.3 to 32.7

High directivity via standard pcb

A difficulty with stripline couplers in homogeneous dielectric, where the centre board has a lower dielectric constant than the outer boards, is that the even-mode circuit will be electrically longer than the odd-mode circuit. For side coupled microstrip directional couplers of the type shown in **Fig. 8**, the well known even-and-odd-mode theory shows different phase velocity for the even mode (E) and odd mode (O) of propagation[6].

Figure 9 shows the electric field of the two modes. The system has different values of E for the different modes of propagation, since their fields are not distributed in the same way between air and dielectric. In this way, the two modes have different phase velocity.

Taking this effect into account, we can design simple high directivity couplers. A conventional microstrip 13dB directional coupler has only 26 to 28dB of isolation (directivity of 13 to 15dB) according to our tests at 900–1200MHz, **Fig. 12**.

The measured values are in good agreement with the theory. More expensive directional couplers realised with triplate techniques or meander-folded coupled lines[7] have better directivity because of symmetrical distribution of the electric field. However, for microstrip circuits that also contain other passive or active components, this design is not practical.

The improved directivity of the coupler described in this article, with the layout of Fig. 8 and shown in photos of **Figs 10, 11**, is obtained simply by covering the central coupler structure with an unmetallized dielectric layer that consists of the same material as the microstrip substrate. This assumes standard 1.6mm fibreglass copper-clad circuit board.

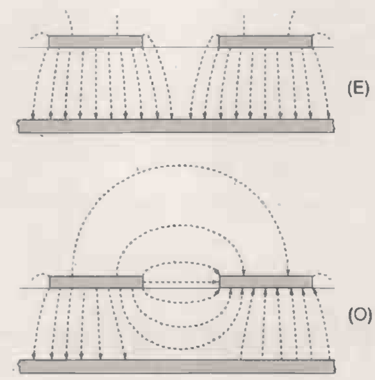

Fig. 9. Even mode (E) and odd mode (o) propagation. Electric field of the two modes.

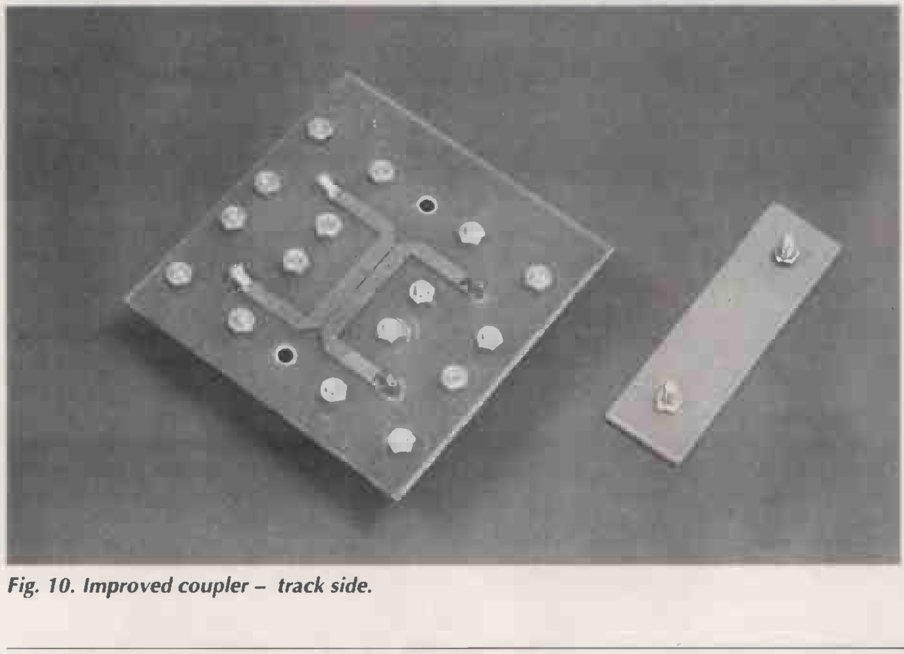

Fig. 10. Improved coupler – track side.

Owing to this 'overlay substrate', of about 12×50mm, the electric field propagates almost entirely in an homogeneous dielectric and therefore the even and odd modes show nearly the same propagation velocity.

A comparison between conventional and 'overlay' couplers (with the same layout) is shown in Fig. 12. The reverse coupling was plotted against frequency after various adjustments of the side coupling space (s) and linewidth in the coupling zone (W_1 and W_2).

The final optimised 'overlay' coupler design shows high directivity, with reverse coupling better than 35dB in the range 950–1200MHz. The four type-N connectors – used only to permit a special high-power test – passed through the ground plane and made contact to the microstrip conductor. Compensation aluminum transitions are used in the mounting of the 'big' connectors. ■

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Fig. 11. Improved coupler, showing the connector layout.

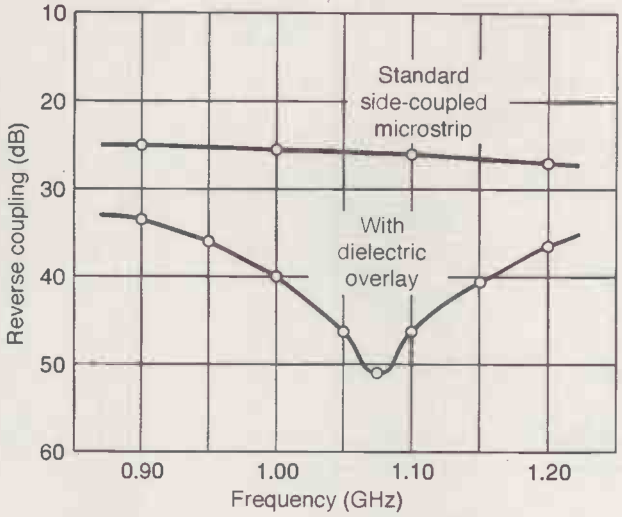

Fig. 12. Comparison between standard and 'overlay' coupler (1.6mm fibreglass, layout of Fig. 8.).

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CIRCLE NO. 119 ON REPLY CARD

Ian Hickman introduces aspects of passive filter design that are important yet frequently omitted from standard descriptions.

Filter VARIATIONS

Many applications call for the filtering of signals, to pass those that are wanted, and to block those that are outside the desired passband. Sometimes digital filtering is appropriate, especially if the signals are in digital form already, but oftentimes, analog filters suffice – indeed are the only choice at rf. At lower frequencies, where inductors would be bulky, expensive and of low Q, active filters are the usual choice. Some of these are documented in every text book, but there are some useful variations upon the them which are less well known. This article explores one or two of these.

A basic active filter

Probably the best known active filter is the Sallen and Key second order circuit, the lowpass version of which is shown in **Figure 1**. Interchanging the Cs and Rs gives a highpass version. There has been considerable discussion recently of its demerits, both in regard to noise and distortion, from Dr D. Ryder and others in the Letters section of this magazine, see the November 1995 to April 1996 issues inclusive. But for many purposes it will prove adequate, having the minor advantage of very simple design equations. Moreover, the circuit is canonic - it uses just two resistors and two capacitors to provide its two-pole response.

Being a second order circuit, at very high frequencies the response falls away forever at 12dB per octave, at least with an ideal opamp. In practice, opamp output impedance rises at high frequencies, due to the fall in its open loop gain, resulting in the attenuation curve levelling out, or even reversing. In the maximally flat amplitude response design, at frequencies above the cutoff frequency, the response approaches 12dB/octave asymptotically, from below. At dc and well below the cutoff frequency, the response is flat, being 0dB (unity gain), again a value the response approaches asymptotically from below. The corner formed by the crossing of these two asymptotes is often called, naturally enough, the 'corner frequency'. The corner or cutoff frequency f_o is given by $f_o=1/(2\pi\sqrt{\{C_1C_2R_1R_2\}})$ where, usually, $R_1=R_2$.

The dissipation factor $D=1/Q$ where $Q=0.5\sqrt{(C_1/C_2)}$ and for a maximally flat amplitude (Butterworth) design, $D=1.414$, so $C_1=2C_2$. The Butterworth design exhibits no peak, and is just 3dB down (ie $V_{out}/V_{in}=0.707$, or equal to Q) at the corner frequency. If $C_1>2C_2$, then there is a passband peak in the response below the corner frequency, being more pronounced and moving nearer the corner frequency as the ratio is made larger. This permits the design of filters with four or six poles, or of even higher order, consisting of several such stages, all with the same corner frequency but each with the appropriate value of Q.

It is easy to see that the low frequency gain is unity, by simply removing the capacitors from Figure 1, for at very low frequencies their reactance becomes so high compared to R_1, R_2, that they might as well simply not be there. At a very high frequency, way beyond cutoff, C_2 acts as a near short at the non-inverting (NI) input of the opamp, resulting in the lower plate of C_1 being held almost at ground. As C_1 is usually greater than C_2, it acts in conjunction with R_1 as a passive lowpass circuit well into its stopband, resulting in even further attenuation of the input. At twice this frequency, both of these mechanisms will result in a halving of the signal, which thus falls to a quarter of the previous value, ie the roll-off rate is 20log(1/4) or –12db/octave. But what about that peak in the passband, assuming there is one?

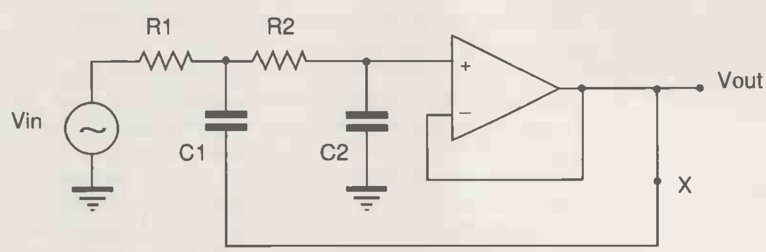


Fig. 1. The Sallen and Key second order lowpass active filter. Cut-off 'corner' frequency is given by $f_o=1/(2\pi C_1C_2R_1R_2)$ and $Q=0.5\sqrt{(C_1/C_2)}$ and dissipation D=1/Q. For a maximally flat amplitude (Butterworth) design, D=1.414, so $C_1=2C_2$. The Butterworth design exhibits no peak, and is just 3dB down at the corner frequency.

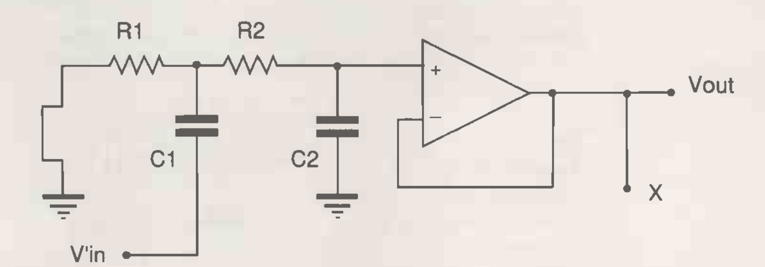


Fig. 2. Breaking the loop and opening it out helps to understand the circuit action (see text).

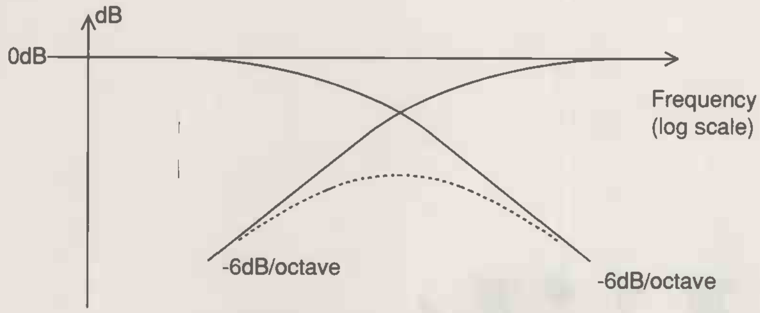


Fig. 3. Cascaded lowpass and highpass CR responses, and their resultant, (dotted).

The best way to approach this is to break the loop at point X, in Figure 1 and consider what happens to a signal V'_{in}, going round the loop, having removed the original V_{in}. Note that as the source in Figure 1 is assumed to have zero internal resistance, it has been replaced by a short circuit in **Fig. 2**. To V'_{in}, C_1 with R_1 now forms a passive lead circuit – highpass or bass-cut. The resultant voltage across R_1 is applied to C_2, R_2, a passive lag circuit – lowpass or top-cut.

Each of these responses exhibits a 6dB/octave rolloff in the stopband, as shown in **Fig. 3.** Thus the voltage reaching the NI input of the opamp at any frequency will be roughly the sum of the attenuation of each CR section (actually rather more, as C_2R_2 loads the output of the C_1R_1 section), as indicated by the dotted line in Figure 3. At the frequency where the highpass and lowpass curves cross, the attenuation is a minimum, and the phase shift is zero since the lag of one section cancels the lead of the other.

If C_1 is now made very large, the bass cut will only appear at very low frequencies – the highpass curve in Figure 3 will shift bodily to the left. If in addition, C_1 is made very small, the top cut will appear only at very high frequencies – the lowpass curve will shift bodily to the right. Thus the curves will cross while each still contributes very little attenuation, so the peak of the dotted curve will not be much below 0dB, unity gain. Consequently, at this frequency the voltage at X is almost as large as V'_{in}, and in phase with it. The circuit can almost supply its own input, and if disturbed in any way will respond by ringing at the frequency of the dotted peak, where the loop phase shift is zero.

But however large the ratio C_1/C_2, there must always be some attenuation, however small, between V'_{in} and the opamp's NI input, so the circuit cannot oscillate, although it can exhibit a large peak in its response, around the corner frequency. In fact, if the peak is large enough, the response above the corner frequency will approach the –12dB/octave asymptote from above, and below the corner frequency will likewise approach the flat 0dB asymptote from above.

Variations on a theme

The cutoff rate can be increased from 12dB/octave to 18dB/octave by the addition of just two components; a series R and a shunt C to ground between V_{in} and R_1. And such a third order section can be cascaded with other second order section(s) to make filters with 5, 7, 9 poles etc. Normalised capacitor values for filters from 2 to 10 poles for various response types (Butterworth, Chebychev with various passband ripple-depths, Bessel etc.) have been published in Refs. 1 and 2, and in many other publications as well. However, these tables assume R_1=R_2 (= the extra series resistor in a third order section), with the Q being set by the ratio of the capacitor values. This results in a requirement for non-standard values of capacitor, which is expensive if they are specially procured, or inconvenient if made up by parallelling smaller values.

While equal value resistors is optimum, minor variations can be accommodated without difficulty, and this can ease the capacitor requirements. Ref. 3 gives tables for the three resistors and three capacitors used in a third order section, with the capacitors selected from the standard E3 series (1.0, 2.2, 4.7) and the resistors from the E24 series, for both Butterworth and Bessel (maximally flat delay) designs.

The Kundert filter

The formula for the Q of the Sallen and Key filter is $Q=0.5\sqrt{(C_1/C_2)}$, so given the square root sign and the 0.5 as well, one finishes up with rather extreme ratios of C_1 to C_2, if a high Q is needed, as it will be in a high order Chebychev filter. In this case, the Kundert circuit of **Fig. 4** may provide the answer. The additional opamp buffers the second CR from the first, so that the attenuation at any frequency represented by the dotted curve in Figure 3 is now exactly equal to the sum of the other two curves. Removing the loading of C_2R_2 from C_1R_1 removes the 0.5 from the formula, which is now $Q=\sqrt{(C_1/C_2)}$ – assuming R_1=R_2. And due to the square root sign, the required ratio of C_1 to C_2 for any desired value of Q is reduced by a factor of four compared to the Sallen and Key version.

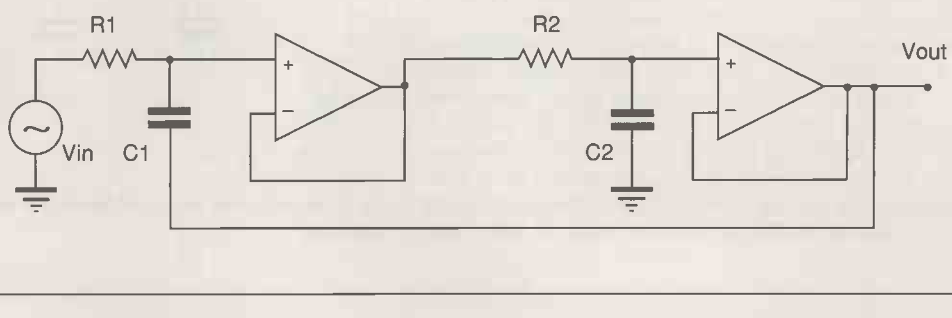
A further advantage of this circuit is the complete freedom of choice of components. Instead of making R_1=R_2 and setting the Q by the ratio of C_1 to C_2, the capacitors may be made equal and the Q set by the ratio of R_1 to R_2, or both Cs and Rs may differ, the Q being set by the ratio of C_1R_1 to C_2R_2. Given that dual opamps are available in the same 8 pin DIL package as single opamps, the Kundert version of the Sallen and Key filter, with its greater freedom of choice of component values, can come in very handy for the highest Q stage in a high order filter.

The equal C filter

In addition to filtering to remove components outside the wanted passband, signals also frequently need amplification. The basic Sallen and Key circuit only provides unity gain, and with this arrangement, equal resistors are optimum. For, due to the loading of the second stage on the first, if R_2 is increased to reduce the loading, then C_2 will have to be even smaller, whilst if R_2 is decreased to permit a larger value of C_2, the loading on C_1R_1 increases.

Where additional signal amplification is needed, there is no reason why some of this should not be provided within a filtering stage and **Fig. 5** shows such a circuit. Clearly the dc and low frequency gain is given by (RA+RB)/RB. A convenience of this circuit is that the ratio RA to RB can be chosen to give whatever gain is required (within reason), with C_1, C_2, R_1 and R_2, chosen to give the required corner frequency and Q. An analysis of this most general form of the

Fig. 4. The Kundert filter, a variant of the Sallen and Key, has some advantages.



circuit can be found in Ref 4. If there were a buffer stage between R_1 and R_2 as in Figure 4, and the two CR products were equal, then at a frequency of $1/(2\pi CR)$ there would be exactly 3dB attenuation round the loop due to each CR.

So if RA were to equal RB, giving 6dB gain in the opamp stage, there would be no net attenuation round the loop and the Q would equal infinity – you have an oscillator. Without the buffer opamp, the sums are a little more complicated due to the second CR loading the first. But the sums have all been done, and the normalised values for R_1 and R_2 (values in ohms for a cutoff frequency of $1/2\pi$Hz, assuming C=1F) are given in Ref. 5 for filters of 1 to 9 poles, in Butterworth, Bessel and 0.1dB- 0.5dB- and 1dB-Chebychev designs.

For odd numbers of poles, this reference includes an opamp buffered single pole passive CR, rather than a three pole version of the Sallen and Key filter, as one of the stages. To convert to a cutoff frequency of, say, 1kHz, regard the ohms figures in the tables as Mohms and the capacitors as 1μF. Now divide the resistor values by 2000π. As the values are still not convenient, scale the capacitors in a given section down by say 100 or any other convenient value, and the resistors up by the same factor.

Reference 5 also gives the noise bandwidth of each filter type. The noise bandwidth of a given filter is the bandwidth of a fictional ideal brick wall sided filter which, fed with wideband white noise, passes as much noise power as the given filter. Ref. 5 also gives, for the Chebychev types, the 3dB bandwidth. Note that for a Chebychev filter, this is not the same as the specified bandwidth (unless the ripple depth is itself 3dB). For a Chebychev filter the bandwidth quoted is the ripple bandwidth; e.g. for a 0.5dB ripple lowpass filter, the bandwidth is the highest frequency at which the attenuation is 0.5dB, beyond which it descends into the stopband, passing through –3dB at a somewhat higher frequency.

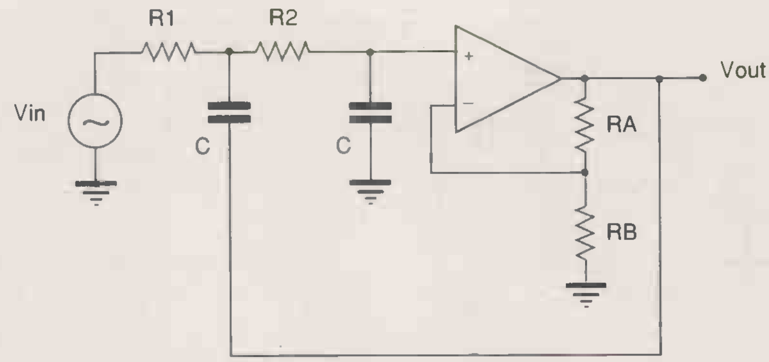


Fig. 5. The equal C version of the Sallen and Key circuit.

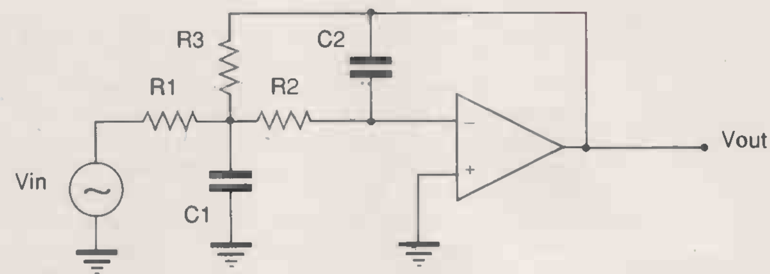


Fig. 6a). The mixed feedback or 'Rausch' filter – lowpass version.

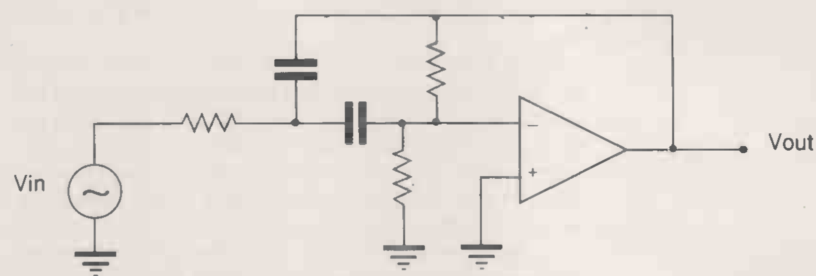


Fig. 6b). The mixed feedback or 'Rausch' filter – bandpass version.

Other variants

In the Sallen and Key filter, the signal appears at both inputs of the opamp. There is thus a common mode component at the input, and this can lead to distortion, due to 'common mode failure', which, though small, may be unacceptable in critical applications. Also, as already mentioned, the ultimate attenuation in the stopband will often be limited by another non-ideal aspect of practical opamps - rising output impedance at high frequencies, due to the reduced gain within the local NFB loop back to the opamp's inverting terminal. Both of these possibilities are avoided by a different circuit configuration, shown in its lowpass form, in **Figure 6a)**.

This is variously known as the infinite gain multiple feedback filter, or the Rausch filter, and it has the opamp's NI terminal firmly anchored to ground – good for avoiding common mode failure distortion. Another plus point is that at very high frequencies, C_1 short circuits the signal to ground, while C_2 shorts the opamp's output to its inverting input – good for maintaining high attenuation at the very highest frequencies. The design equations and tabulated component values are available in published sources; the filter is well known and is shown here just as a stepping stone to a less well known filter section, the SAB (single active biquad) with finite zero.

In some filtering applications, the main requirement is for a very fast rate of cutoff, the resultant wild variations in group delay not being important. The Chebychev design provides a faster cut off than the Butterworth, the more so, the greater ripple depth that can be tolerated in the passband. But the attenuation curve is monotonic, it just keeps on going down at (6n)dB/octave, where n is the order of the filter (the number of poles), not reaching infinite attenuation until infinite frequency.

A faster cutoff still can be achieved by a filter incorporating one or more 'finite zeros', frequencies in the stop band at which the response exhibits a notch. In a design with several such notches, they can be strategically placed so that the attenuation curve bulges back up in between them to the same height each time. Such a filter, with equal depth ripples in the passband (like a Chebychev) but additionally with equal returns between notches in the stop band is known as an 'elliptic' or 'Caur' filter.

In a multipole elliptic filter, each second order section is designed to provide a notch, but beyond the notch the attenuation returns to a steady finite value, maintained up to infinite frequency. The nearer the notch to the cutoff frequency, the higher the level to which the attenuation will eventually return above the notch frequency.

So for the highest cutoff rates, while still maintaining a large attenuation beyond the first notch, a large number of poles is necessary. It is common practice to include a single pole (eg an opamp buffered passive CR lag) to ensue that, beyond the highest frequency notch, the response dies away to infinite attenuation at infinite frequency, albeit at a leisurely –6dB/octave.

The elliptic filter

The building blocks for an elliptic lowpass filter consist of second order lowpass sections of varying Q, each exhibiting a notch at an appropriate frequency above the cutoff frequency.

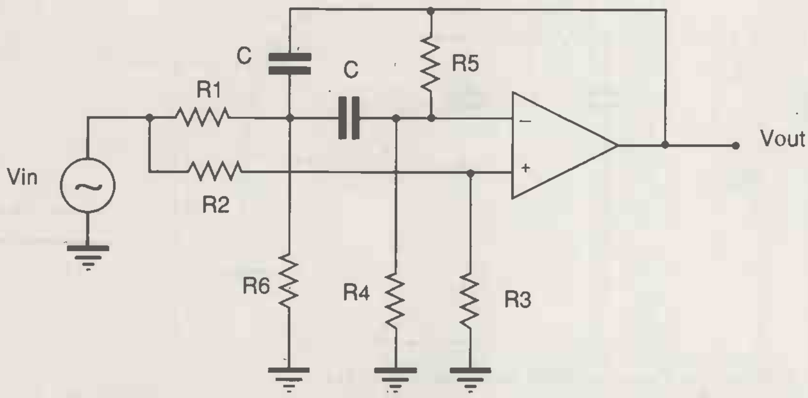


Fig. 7. The SAB circuit, with finite zero (or notch, above the passband).

A number of designs for such a section have appeared, based on the twin-tee circuit, but they are complex, using many components, and hence difficult to adjust. An alternative is provided by the SAB section mentioned earlier. This can be approached via the Rausch bandpass filter, which can be seen in **Figure 6b**) to be a variant on the Rausch lowpass design of Figure 6a). Clearly, due to the capacitive coupling, the circuit has infinite attenuation at 0Hz, and at infinite frequency, the capacitors effectively short the opamp's inverting input to its output, setting the gain to zero. Either side of the peak response, the gain falls off at 6dB per octave, the centre frequency Q being set by the component values. If the Q is high, the centre frequency gain will be well in excess of unity.

Figure 7 shows the same circuit with three extra resistors (R_2, R_3 and R_6) added. Note that an attenuated version of the input signal is now fed to the NI input of the opamp via R_2, R_3. Consequently, the circuit will now provide finite gain down to 0Hz; it has been converted into a lowpass section, although if the Q is high there will still be a gain peak. If the ratio of R_5 to R_4 is made the same as R_2 to R_3, then the gain of the opamp is set to the same as the attenuation suffered by the signal at its NI terminal, so the overall 0Hz gain is unity.

If the other components are correctly chosen, the peak will still be there, but at some higher frequency, the signal at the opamp's inverting input will be identical in phase and amplitude to that at the NI input. The components thus form a bridge which is balanced at that frequency, resulting in zero output from the opamp, ie a notch.

Figure 8 shows a five pole elliptic filter using SAB sections, with a 0.28dB passband ripple, a –3dB point at about 3kHz and an attenuation of 54dB at 4.5kHz and above. The design equations for elliptic filters using SAB sections are given in Ref. 6. The design equations make use of the tabulated values of normalised pole and zero values given in Ref. 7.

Some other filter types

Simple notch filters – where the gain is unity everywhere either side of the notch – can be very useful, eg for suppressing 50Hz or 60Hz hum in measurement systems. The passive TWIN TEE notch is well known, and can be sharpened up in an active circuit so that the gain is constant, say, below 45Hz and above 55Hz. However, it is inconvenient for tuning, due to the use of no less than six components. An ingenious alternative[8] provides a design with limited notch depth, but compensating advantages. A notch depth of 20dB is easily achieved, and the filter can be fine tuned by means of a single pot. The frequency adjustment is independent of attenuation and bandwidth.

Finally, a word on linear phase (constant group delay) filters. These are easily implemented in digital form, FIR filters being inherently linear phase. But most analog filter types, including Butterworth, Chebychev and elliptic are anything but linear phase. Consequently, when passing pulse waveforms, considerable ringing is experienced on the edges, especially with high order filters, even of the Butterworth variety. The linear phase Bessel design can be used, but this gives only a very gradual transition from pass- to stop-band, even for quite high orders. However, a fact that is not widely known is that it is possible to design true linear phase filters in analog technology, both bandpass[9] and lowpass[10]. These can use passive components, or – as in Reference 10 – active circuitry. ■

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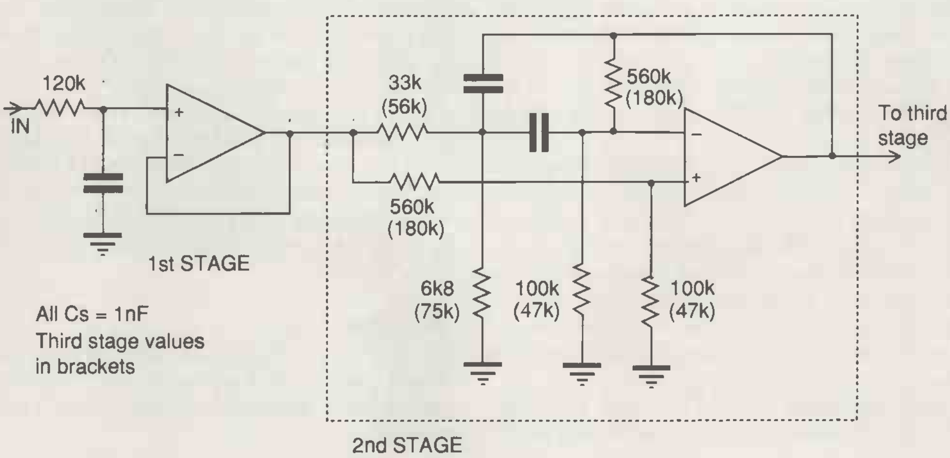

Fig. 8. A five-pole elliptic filter with 0.28dB passband ripple and an attenuation of 54dB at 1.65 times the cutoff frequency and upwards. The –3dB point is 3kHz, approx. All capacitors C=1nF, simply scale C for other cutoff frequencies.

Video inserter

Ian Polczynski outlines the software needed for overlaying text on standard video picture using hardware described last month.

The program for controlliong the video insertion hardware described last month begins at address 0000_{16}. The microprocessor begins execution at this location after a hardware reset.

Address 0000_{16} contains a jump instruction to the routine which initializes the cpu and clears the software flags. Next the program sets up the real time clock by writing two state words to Reg. A and Reg. B of the *6818*'s ram. **Table 1** shows the address map of the real-time clock while **Tables 2** and **3** describe functions of registers A and B. Register details for the 6818 are shown in the **Inset 1**. For further information on other features of the *6818*, refer to the manufactures manual. As the real-time clock IC resides in the external ram area, the MOVX instructions are used to communicate with it.

Within the real-time clock, the 24/12 control bit establishes the format of the hours bytes as either the 24-hour mode (logic one) or the 12-hour mode (logic zero). This bit is affected only by the software.

Table 1. Locations within the 6818 real-time clock. Registers A and B are used for control.

Address Locn	Function	Range
0	Seconds	0-59
1	Seconds alarm	0-59
2	Minutes	0-59
3	Minutes alarm	0-59
4	Hours – 12 hour mode	1-12
	Hours – 24 hour mode	0-23
5	Hours alarm – 12 mode	1-12
	Hours alarm – 24 mode	0-23
6	Day of week (1=Sun)	1-7
7	Day of month	1-31
8	Month	1-12
9	Year	0-99
0A	Register A	x
0B	Register B	x

Table 2. Functions of RTC register A.

MSB LSB

b7	b6	b5	b4	b3	b2	b1	b0
UIP	DV2	DV1	DV0	RS3	RS2	RS1	RS0

Table 3. Functions of RTC register B.

MSB LSB

b7	b6	b5	b4	b3	b2	b1	b0
SET	PIE	AIE	UIE	SQWE	DM	24/12	–

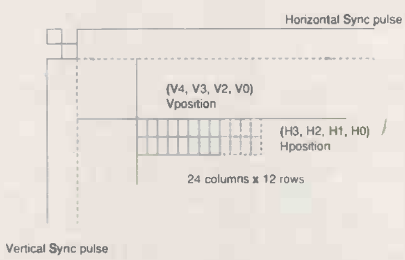

Fig. 1. The Hposition and Vposition define the top left hand corner of the displayed area.

For example, if number $A6_{16}$ ($1010\ 0110_2$) is written to register A, the time-base frequency will be 32768kHz and the SQW output frequency is 1024kHz.

If $0A_{16}$ ($0000\ 1010_2$) is written to register B, it disables all interrupts, activates SQW pin, indicates bcd format and 24-hour mode.

The following is the machine code starting from $\#081D_{16}$:

```
B8, 0A MOV    R0, #0Ah
23, A6 MOV    A, #0A6h
90     MOVX   @R0, A  ; Reg. A=A6h
B8, 0B MOV    R0, #0Bh
23, 0A MOV    A, #0Ah
90     MOVX   @R0, A  ; Reg. B=0Ah
```

The same instructions are used for a read time or calendar operation. For example,

```
B8, 00 MOV    R0, #00h
; Set the R0 register to the RTC RAM
location 00.
80     MOVX   A, @R0
; Read SECONDS from the RTC.
```

The second and last circuit requiring setting up is the *µPD6145* on-screen display chip. As stated in the hardware article in the September issue, the *µPD6145* commands consist of nine bits, but the shift register for the serial interfacing operates with eight bits. As a result,

List 1. Serial communication routine for sending a byte from the cpu to the on-screen display chip – in 8039 assembly language.

```
OSD_Ser:   9A, 7F   ANL    P2,
#7Fh
; OSD CS line (OSD 1) goes Low.
  BF, 08    MOV      R7, #08h
; Bit Counter R7 loaded with 8.
  FE        MOV      A, R6
; Read Character/Command
OSD_Rotate:F7       RLC     A
; Shift MS Bit to Carry.
  F6, AC    JC       Was_H
; Is it 1 or 0?
  9A, EF    ANL      P2, #0EFh
; If 0, Data (OSD 4) goes Low.
  04, AE    AJMP     Time_Call
; Skip next instruction.
Was_H:     8A, 10   ORL    P2,
#10h
; If 1, Data (OSD 4) goes High.
Time_Call: 14, F9   ACALL
OSD_Time
; Call time delay routine.
  9A, DF    ANL      P2, #0DFh
; Now OSD Clock line goes Low.
  14, F9    ACALL    OSD_Time
; Wait a while again.
  8A, 20    ORL      P2, #20h
; Clock line goes High.
  EF, A5    DJNZ     R7, OSD_Rotate
; Go to OSD_Rotate if not last
bit
  8A, 40    ORL      P2, #40h
; Byte completed, Strobe High.
  9A, AF    ANL      P2, #0AFh
; Now Strobe goes Low.
  00        NOP
; 3 cycles of time delay.
  00        NOP
  00        NOP
  8A, A0    ORL      P2, #0A0h
; Strobe and Data are kept low.
  83        RET
; Byte transferred, return.
```

The time delay routine is located at address $08F9_{16}$. It corrupts only cpu register R5:

```
OSD_Time:  BD, 10   MOV    R5,
#10h
; Load the loop counter.
OSD_Time_St:        00     NOP
; Do nothing inside the loop.
  00        NOP
  FD, FB    DJNZ     R5,
OSD_Time_St
; Is the loop counter zeroed?
  83        RET
; Return to the OSD subroutine.
```

To set up the µPD6145 OSD IC, first input the Format Reset Command at 0830_{16},

```
  MOV       R6, #0FE
; Load R6 with "FE"
; (Format Command for Bank1)
  CALL      OSD_Ser
; And CALL OSD serial subroutine.
```

Table 4. Command list for the 6145 on-screen display chip.

Content	Fo	D7	D6	D5	D4	D3	D2	D1	D0
Bank-0 commands Fo=0									
Display character data	0	0	C6	C5	C4	C3	C2	C1	C0
Colour blink data for each character	0	1	0	0	0	Bk	R	G	B
Character display line address	0	1	0	0	1	R3	R2	R1	R0
Character display column address	0	1	0	1	C4	C3	C2	C1	C0
Background specification	0	1	1	0	S4	S3	Rb	Gb	Bb
Display on/off, smoothing etc.	0	1	1	1	0	0	Sy	Sm	Do
Blinking/oscillator control	0	1	1	1	0	1	B1	B2	Os
Format Selection	x	1	1	1	1	1	1	Fo	Fr
Bank-1 commands Fo=1									
CRAM write address	1	0	0	A5	A4	A3	A2	A1	A0
CRAM word address	1	0	1	0	0	W3	W2	W1	W0
CRAM line address	1	0	1	0	1	L3	L2	L1	L0
Display position vertical address	1	0	1	1	V4	V3	V2	V1	V0
Display position horizontal address	1	1	1	0	H4	H3	H2	H1	H0
Character size specification	1	1	0	S5	S4	R3	R2	R1	R0
Test mode setting	1	1	1	1	0	T3	T2	T1	T0

Control suggestions

These button functions were implemented on the prototype for programming the on-screen display via software.

+(up arrow): To position the overlayed screen upwards
Change DATE and TIME
Select character

–(down arrow): Position overlayed screen downwards
Change DATE and TIME
Select character

(left arrow): Position the overlayed screen to the left
Step blinking text character backward

(right arrow): Position the overlayed screen to the right

DATE/TIME: Selects date and time adjustment mode (4s)

TEXT: To select text adjustment mode (4s)

TEXT OFF: To switch text line on and off

SET: To complete setting and move blinking character forward.

instructions are divided into two banks. **Table 4** shows the *μPD6145* command list.

Initially, the format reset command must be input to the *μPD6145* (Fr at logic one). To do this, first consider the serial communication routine. It transmits a hexadecimal byte from the cpu to the *μPD6145*. The byte to be transmitted must be stored in cpu register R6 before entering this routine. The CALL to OSD_Ser routine, located at the $08A0_{16}$, starts transmission, **List 1**:

Next the horizontal and vertical display positions must be specified. As shown in Table 4, these functions belong to the Bank-1 Command Set. That is why R_6 was loaded with FE_{16} in the previous transfer. **Figure 1** shows how to calculate a position of the 24-column-by-12-row screen.

As shown in Fig. 1, Hposition and Vposition define the top left hand corner of the displayed area. Formulas are as follows:

Hposition(μs)=
$[12/F_{osc}(\text{MHz})]\times[2^4\times H4+2^3\times H3+2^2H2+2^1\times H1+2^0\times H0]$

and,

Vposition=
$9\text{Hdot}\times[2^4\times V4+2^3\times V3+2^2V2+2^1\times V1+2^0\times V0]$

Note that (H4... H0)=(0... 0) is not a valid combination, and Hdot represents a single tv line. The CCIR standard has 625 lines per screen. If, for example, the on-screen display chip's oscillator generates 6MHz. This frequency is determined by L_1, C_{17} and variable capacitor C_{18}.

If (H4, H3, H2, H1, H0)=(0, 0, 1, 0, 0) then calculated Hposition is 8μs. This is about 12.5% of the duration of a single tv line ie. the position of the first displayed column will be shifted by 12.5% from the left screen edge, and so on. These sets of bits (H4... H0 and V4. ... V0) combined with value of capacitor C_{18} determine the position and width of the overlayed screen.

Now back to the assembler language, located at 0834_{16}:

```
MOV     R6, #60h
; Display position Vpos=0.
CALL    OSD_Ser
MOV     R6, #C1h
; Display position Hpos=0
CALL    OSD_Ser
```

Next, the size of the displayed character has to be set. This size is defined by bits S4 and S5 from the character size command. Four size options are available: size 1 occupies 9 tv lines, size 2 18 lines, etc. The following code specifies displayed character size:

```
MOV  R6, #80h          ; Size-1.
CALL OSD_Ser
```

To complete the OSD set up the cpu has to send some additional properties. All belong to the Bank-0 command set. The first byte to be sent is the format reset command for Bank-0 and then the other outstanding parameters. This code is located at 0840_{16} of the program memory eprom:

```
MOV   R6, #0FCh
; "FC" specifies Bank-0.
CALL  OSD_Ser
MOV   R6, #88h
; "88" defines Blinking on and colour Blk.
CALL  OSD_Ser
MOV   R6, #0C0h
; "C0" means No Background.
CALL  OSD_Ser
MOV   R6, #0E7h
; Turns the entire display ON.
CALL  OSD_Ser
MOV   R6, #0E9
; Turns On oscillation and Blinking Off.
```

So, that is it. Now you can try to display something on the screen. To display '8' in row three and column five for example.

```
MOV   R6, #92h
; "90" would indicate Row 1
CALL  OSD_Ser
MOV   R6, #A4
; "A0" would indicate Column 1
CALL  OSD_Ser
MOV   R6, #08h
; "08" is the number we want to display.
CALL  OSD_Ser
```

and the desired number '8' will be displayed where we wanted.

After the initialization, most of the time the program will rotates around a loop, waiting for a key to be pressed or seconds from the time counter to be elapsed.

Publishing the whole firmware's source code – about 4kbyte – with assembler and explanations is not feasible, but I think that ther should be enough here to give you some idea of what is involved in writing/modifying the software for the on-screen display unit. ■

Technical support

Readers interested in a designer's kit incorporating the *6145* on-screen display IC, osd and keypad pcbs and a pre-programmed e-prom can obtain one from Polvision at 77 Glanton Way, Dianella, Western Australia 6062 for AU$99. The NEC μPD6145 is difficult to obtain in small quantities in the UK, but it is freely available in Australia. NEC's head office there can be reached on 0061 392 621111. The μPD6151 appears to be a drop-in replacement, but this device will not allow you to define your own characters. The μPD6156 could also be used, with minor circuti alterations. Thuis device's command set is also slightly different.

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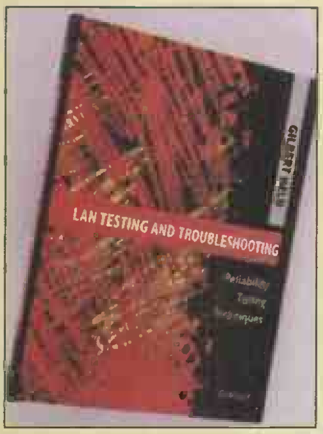

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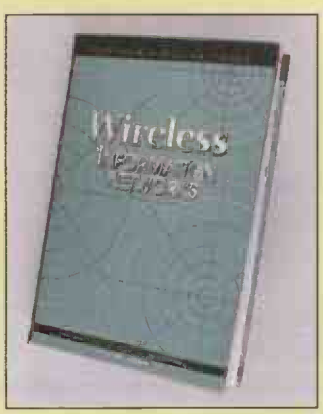

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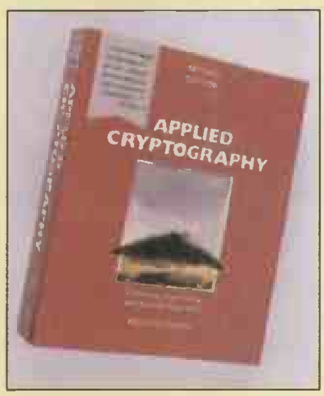

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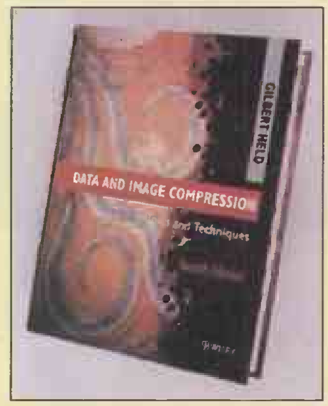

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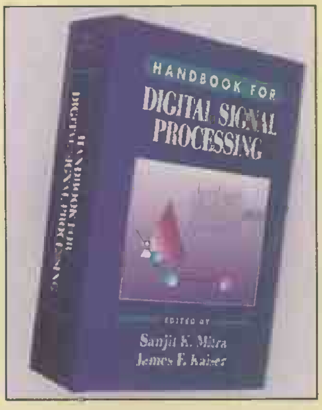

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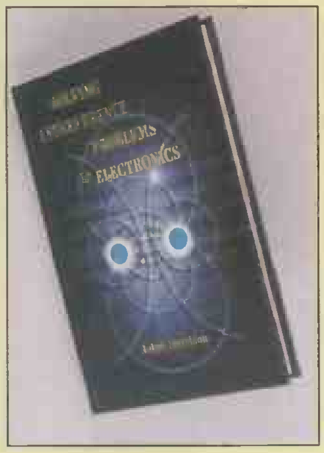

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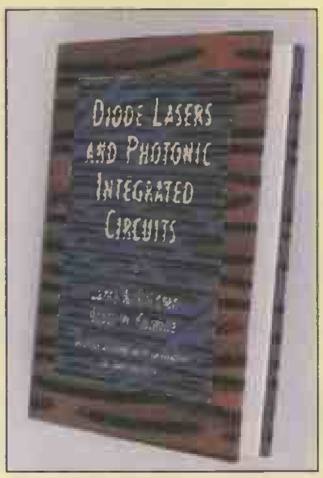

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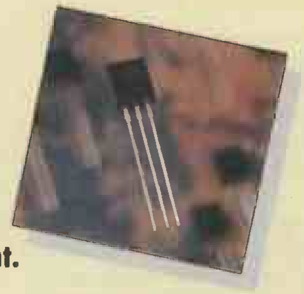

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Hesitant pricing of the radio spectrum

DTI's proposals for spectrum pricing offer the prospect of very large benefits to the UK economy – provided some remaining traditional assumptions can be relinquished, reasons David Rudd.

David Rudd, Ph.D., F.I.E.E., C.Eng., is an engineering and economics consultant. He can be contacted at 14 Colcokes Road, Banstead, Surrey, SM7 2EW, telephone number 01737 356427.

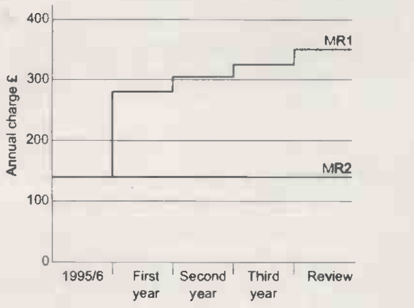


Fig. 1. Private business radio – PBR – shared local 2×12.5kHz channel, 10 mobiles, 25W in two regions. The first region covers London, Manchester and Birmingham, the other the remainder of the country.

The DTI white paper, 'Spectrum Management: into the 21st Century'[1], proposes to introduce a radically new method of charging for radio transmission licences – known as 'spectrum pricing'. It follows a two-year consultation, to which more than 400 spectrum users, industry bodies and others responded. The method of charging will come into operation when Parliament can find time for the legislation.

The purpose of spectrum pricing is to alleviate the present congestion in some parts of the spectrum. Spectrum pricing will also make future allocations and assignments (see **Inset 1**) depend on the scarcity value of the spectrum in those parts. In this way, users can make better informed choices and potential users who are currently denied licences may be able to obtain them. This will allow them to improve their services to their customers. The principle was discussed in last month's issue[2].

The proposals are largely a revival and further development of a proposal that I wrote for the Department of Transport's contribution to the Merriman Report in 1983[3] and published again in 1986[4] but which was then pigeon-holed. The main objectives are the same, as are the parameters of the charges, see **Inset 2**. Even the options by which the spectrum users who face increased charges will be able to avoid or reduce them, so releasing spectrum for other potential users, are the same **Inset 3**. But there are some serious differences.

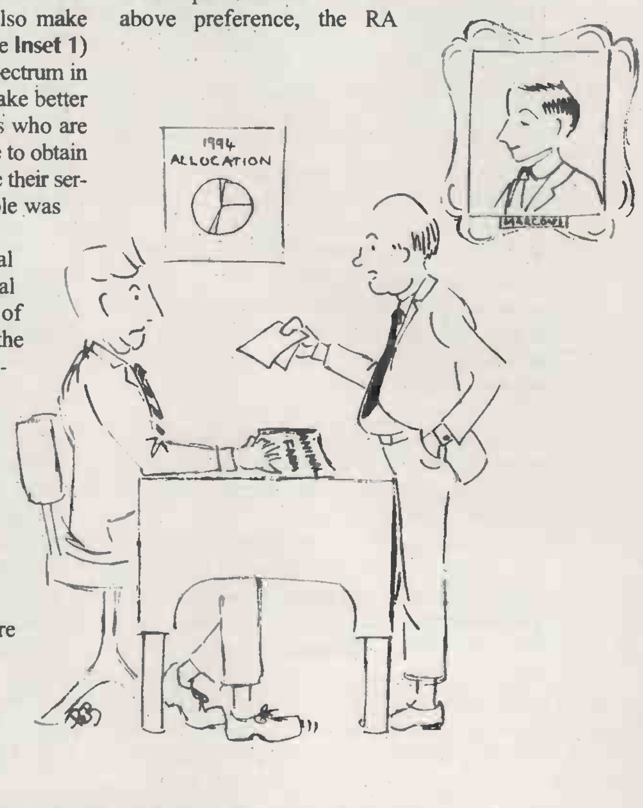
Setting the prices

The white paper recognises that the prices should be set to reflect the value of the spectrum – not to maximise revenue. DTI's Radiocommunications Agency (RA) is considering two methods of setting the prices in the parts of the spectrum which come under its management, namely:

- Auctions – the Government's preferred method for users in the private sector, on the supposed grounds of economic efficiency, transparency and speed. Also because auctions are thought to enable the market rather than the spectrum manager to set the prices;

- Administrative pricing – so called – under which the RA will have to set the initial prices without knowing the true value of the spectrum but which the responders to the consultation markedly prefer.

Perhaps because of the above preference, the RA



"How should we develop this new policy on spectrum pricing, Sir Humphrey ?"
"Well, Bernard, the principle is that all spectrum users are equal. It means they must all pay for their spectrum on a comparable basis."
"Will that include the broadcasters and the MOD, sir ?"
"Certainly, but we know of course that some users are more equal than others."
"Yes Min- er, Sir Humphrey!"

Inset 1 – Allocation and assignment
Allocation is the identification of frequency ranges for specific applications, e.g. broadcasting.
Assignment is the authorisation for a transmitter to use a specific frequency or channel.
These two are roughly analogous to wholesaling and retailing respectively in commerce.
Source – glossary of the white paper.

Inset 2 – Parameters of the charges
Administratively determined charges will depend on:
- bandwidth – pro rata,
- effective power – pro rata for private business radio,
- position in the spectrum – specific frequency or channel,
- geographical location.

All are as proposed in the IEE paper of 1986.

Inset 3 – Options for users
Users who face higher charges will have the following options or some of them:
- more spectrum-efficient technology, such as trunking,
- greater sharing with other users,
- migration to less congested bands,
- modifying operating procedures,
- using different means of communication, such as cable or optical fibre

Again, all are as previously proposed.

intends to price the spectrum for the first affected services administratively. They are:

- private business radio (PBR, previously known as private mobile radio),
- public access mobile radio (PAMR),
- personal communication networks (PCN)
- cellular telephony (CT),
- point-to-point fixed links.

The figures show the present charges and some illustrative future charges. The RA intends to phase in the new charges over three years and then review them.

For PBR, **Fig. 1**, there will be two regions. First is MR1, covering the major cities London, Manchester and Birmingham. Here, the charges will more than double over the three years. Second is MR2, covering the rest of the UK, in which the charges will not rise and may fall.

For PAMR, **Fig. 2**, the charges will rise by more than five times over the three years and for PCN and CT, **Fig. 3**, by more than three and six times respectively.

For point-to-point fixed links, **Fig. 4**, there will also be two regions. FR1 will cover links with one or both ends in major population centres – Greater London, West Midlands, Greater Manchester, Tyneside, Liverpool, Glasgow or Leeds. Charges in FR1 will rise by up to nearly twelve times, depending on spectrum band and availability. Secondly, FR2 will cover the rest of the UK. Charges will also not rise and may fall.

Those are large increases. Some implications for the users are given in **Inset 4**. Unfortunately the way in which the prices have been estimated reveals some vagueness – or perhaps misunderstanding – about the objectives of spectrum management. The white paper acknowledges that the prices should reflect the scarcity value of the spectrum – as proposed in 1983 and 1986. However, the initial prices have been calculated by consultants from estimates of the marginal value of the spectrum to the user. Marginal value in that sense is not the same as scarcity value and so may lead to the spectrum being substantially over-priced or under-priced, **Inset 5**.

Balancing supply and demand

When the charges for spectrum begin to reflect its scarcity value, some users will begin to exercise their options for reducing their charges. This will reduce the demand for spectrum and in turn reduce its scarcity value in those bands. That is the intended effect of spectrum pricing, but that elasticity of demand cannot be measured in advance.

So the initial prices will have to be reassessed as soon as they begin to affect the demand for spectrum. This means it is probably unavailing to try and improve the estimates in advance. However the over-riding, long-term objective – which the white paper fails to emphasise – must be to try and balance the availability of spectrum in any band and the demand for it in that band.

Ideally, as the earlier proposal stated,

> *"any applicant should be able to obtain a licence at the going rate in any geographical location and any region of the spectrum, but there should be no unoccupied band where the rate is greater than zero. Inevitably, in practice, the rate will often be higher or lower than that, resulting in some queuing for spectrum and some bands being unoccupied, if only temporarily, where the rate is not zero."*

Such imperfections have to be accepted in the interest of making the best use of the spectrum in the long term. They are not adequate grounds for changing or weakening the objective.

Those difficulties, coupled with fear of uninformed public criticism if there are unused bands and/or queues, are probably the underlying reasons for the Government's preference for auctions in the private sector. Here, high prices, unused spectrum and queues can all be blamed on market forces, which are widely acclaimed though poorly understood. The users, on the other hand, probably associate auctions with the much publicised sales by auction of works of art, where speculation and hoarding are rife and prices fluctuate wildly from year to year.

Fluctuating prices are anathema to engineers who are trying to plan long-term projects. Some references to the RA's regulatory powers to prevent major users from hoarding spectrum to exclude competition are too vague to be reassuring. It is significant that the Government does not intend to make the public-sector users bid for spectrum in auctions. Perhaps it will reconsider its preference for auctions in the private sector when the RA has some practical experience of administrative pricing.

The principle of equality

The white paper mentions some well-known technical and international constraints on the extent to which the price mechanism can be applied to the spectrum. They are on a par with the way in which planning legislation effectively constrains the prices at which land is sold or leased. Within those constraints, the earlier proposal emphasised the importance of equality in the treatment of spectrum users. Any discrimination between commercial and non-commercial, public and private, civil and military or major and minor users will inevitably weaken the benefits of pricing on the economically efficient use of spectrum.

Inset 6 shows the percentage allocations to the major and minor user categories over four frequency ranges in 1994. The three major categories – broadcasting (BBC & ITV), defence and telecommunications (BT & Mercury) – together predominate. They occupy roughly two thirds of the total spectrum below 30GHz and one third of the spectrum so far allocated above 30GHz. Minor users – in some nineteen categories – are interspersed between them.

It follows that a small percentage improvement in the spectrum efficiency of a major user, who then relinquishes spectrum, would be worth as much in congestion relief as a large improvement in that of any minor user. So DTI's plans for the future allocations in those three major categories will be particularly important to the success of spectrum pricing.

BT and Mercury are in the private sector and the RA will presumably charge them at the new rates for their point-to-point fixed links. They can have no legitimate complaint. This is because BT's privatisation prospectus warned that the Government intended to commission a feasibility study into "some form of pricing for the radio spectrum in place of or in addition to the present licence fee basis." In the event, the study report[5] turned out to be mainly about deregulating and privatising the congested parts

Inset 4 – Implications of new charges
The implications of charges for a user will depend on their amount relative to the user's turnover. The white paper estimates that the charges are unlikely to be prohibitive, even for small firms, but of course there may be a few individual exceptions. The crucial question is whether the increases will be large enough to induce some businesses to relinquish spectrum in the congested bands (see Inset 3), thus enabling other businesses, which value that spectrum more highly, to move in. If they are not, they will have to be increased until they begin to have that effect.

of the spectrum. It was critically reviewed in *EW&WW* – **Inset 7** – after which no action was taken on it, but the warning had been given.

Special pleading

However, as regards defence, the white paper states that: "the public sector [including the armed services and the emergency services, one of the minor categories] should have the same incentives for spectrum efficiency as the private sector. Accordingly public sector users will pay administrative charges on a comparable basis to the private sector." That looks like a move towards equality, but 'comparable' is not the same as 'equal' and there is no mention of applying the price mechanism to determine the size of those public-sector allocations.

On the contrary, the statement is followed by: "the Government's control of spectrum allocation will ensure that the bodies concerned continue to have access to fulfil their operational needs", without stating how such needs will be measured. Those allocations are managed by the Ministry of Defence, the Home Office and so on, not by the RA.

The white paper also applies what it calls 'particular considerations' to the broadcasting allocations, which are managed by the Radio Authority and the Independent Television Commission – again not by the RA. It claims that the competition for Broadcasting Act licences "imputes a market-determined scarcity value for spectrum". But again there is no mention of allowing market forces to determine the overall broadcasting allocations. This alone would ensure genuine equality of treatment between the broadcasters and other users and applicants.

The prospect which unfortunately emerges is of several government departments putting forward competing assessments of operational needs on behalf of their sponsored users to justify their retention of their privileged allocations – at much lower rates per kilohertz of bandwidth than private-sector users in immediately adjacent bands. Now an abrupt change in the price of land at, say, the edge of a marsh or a precipice may be justifiable, but the radio spectrum does not have such natural edges. It is continuous from zero to 100GHz and beyond.

Any abrupt change in its price per kilohertz will be a sure indication that it is not being used economically on the lower-price side. By pushing up the prices in the congested parts of the spectrum without inducing the privileged users to relinquish spectrum, such discrimination might bring the whole concept of spectrum pricing into disrepute.

In spite of that argument, many people will probably assume instinctively, as does the white paper, that at least the emergency services – police, fire and ambulance – ought to have special treatment. The counter-arguments have been set out more than once but so far have not been much heeded. They are there fore repeated in **Inset 8**.

Inset 5 – Value definitions

The scarcity value is the amount which those who do not use the spectrum would be able and willing to pay for it and derive a net benefit from it.

The marginal value, on the other hand, is – according to the white paper – "a measure of the worth of the assignment to the user. It reflects the amount the user would have to pay [for an equivalent service] if deprived of it." But that amount may be much greater or less than what a different user, with different problems and priorities, would be able and willing to pay.

Inset 6 – Percentage allocations

Allocation to:	BBC & ITV	Defence	BT & Mercury	Other	Unallocated
<1GHz	39.9	28.8	–	31.3	–
1–3GHz	11.7	30.4	20.0	37.9	–
3–30GHz	–	37.8	32.0	26.5	3.7
>30GHz	–	14.3	3.6	28.8	53.3

Source: 'The Future Management of the Radio Spectrum – A Consultative Document', Radiocommunications Agency, March 1994.

Inset 7 – 'Privatisation of the radio spectrum' *EW+WW*, September 1987

The study reviewed in a my earlier article *Privatisation of the radio spectrum*[6] had been commissioned by DTI to consider the practicality of spectrum pricing, as had been mooted in 1983 in the Merriman Report. The article criticised the study report for its change of emphasis from pricing to deregulation and in particular for two major departures from the 1983 proposals plus a remarkable privatisation proposal.

The first departure was to exclude both defence and broadcasting from the pricing system, thus leaving only a rump of mainly small users in the system. That would have undermined the operation of the price mechanism so seriously as to invalidate it.

The second departure was to allow revenue maximisation to become the guiding principle in pricing the spectrum instead of the principle of balancing supply and demand. That would have distorted the decisions of the paying users to the detriment of the whole UK economy.

The report went on to assert that there was no prospect of a general spectrum shortage for the next ten or twenty years – which was completely belied by events – and to propose that spectrum management licences should be granted to a limited number of 'Frequency Planning Organisations', or FPOs, in the private sector.

By defining the band(s) within which each FPO would operate exclusively, the proposal would have effectively negated their inducements to compete with one another. Moreover they would not have had to pay for the scarcity value of their spectrum but would have been allowed to charge their users as much as they could get. The article dubbed that as a remarkable example of privatisation by gift.

The white paper recognises that revenue maximisation should not be the objective in setting the prices and it does not exclude defence or the broadcasters from the pricing system, but it still instinctively tries to protect both of those categories. It does not propose any FPOs but it talks about the possibilities of 'Spectrum Management Organisations', which would undertake some administrative and technical management functions of parts of the spectrum.

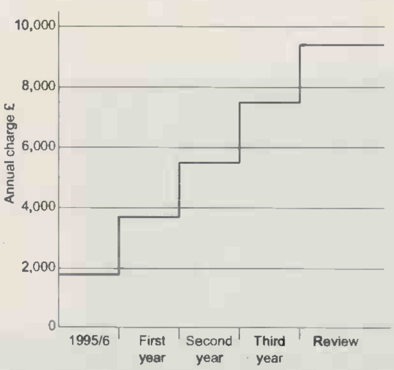


Fig. 2. Public-access mobile radio – PAMR – national 2×12.5kHz channel. Charges will rise by more than five times over three years.

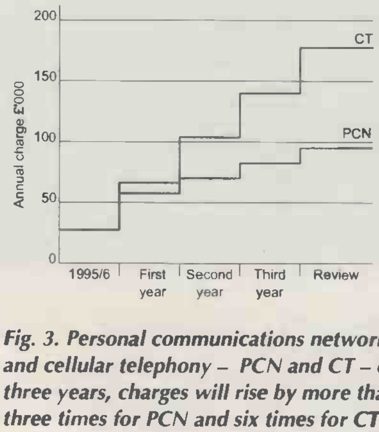


Fig. 3. Personal communications networks and cellular telephony – PCN and CT – over three years, charges will rise by more than three times for PCN and six times for CT.

Second-hand opinions

The white paper asserts that: "broadcasters have little scope to increase spectrum efficiency using existing technology" but that "digital broadcasting offers the prospect of considerable spectrum efficiency gains." So the Government "wishes actively to promote the switch to digital" in the hope of generating "exciting wealth creation opportunities."

continued on page 812...

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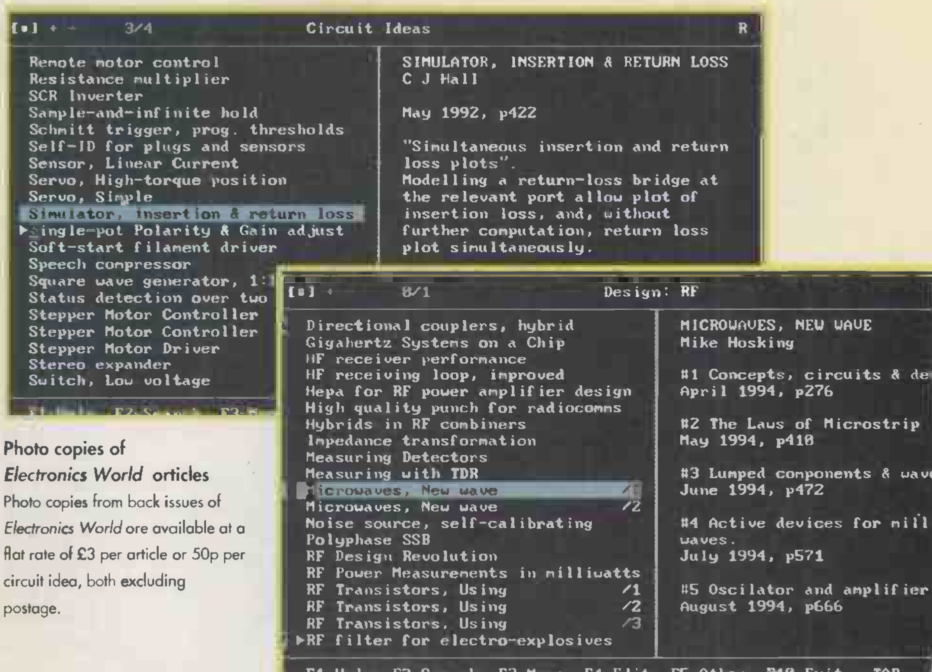

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Applying speech storage chips

Colin Attenborough **shows how easy it is to apply speech storage and playback chips, using talking weighing scale to illustrate his discussion.**

I have designed several sets of speaking weighing scales during the past decade, chip counts dropping as technology advances. The availability of the *ISD1016* speech storage/playback chip, together with Microchip Technology's *PIC16C5x* microprocessors, set my fingers itching to see if I could do the job with just two integrated circuits.

Weight-to-electrical-signal conversion? I cheated by buying a set of low-cost kitchen scales with a digital readout from a well-known chemist. I was rewarded by finding a signal of 10kHz in addition to a 2kHz/lb signal accessible inside, which formed an excellent starting point.

This article summarises what I had to learn about the *ISD1016* speech storage/playback chips before I could complete the scales. Complete details about the scales are not given, but you will learn how to generate speech output for you own application.

Speech storage and playback chips

The *ISD1016* is one of a family of speech/sound storage chips manufactured by Information Storage Devices*, **Fig. 1**. It stores up to 16 seconds of sound.

All members of the family run from single 5V supplies, draw 20mA when quiescent, and a fraction of a microamp when powered down. Up to 50mW of audio power can be driven into a 16Ω speaker. Sound input is supplied as a simple analogue signal and a microphone preamplifier with agc is built in.

Different members of the family, which comprises the *ISD1012, ISD1016* and *ISD1020*, store differing lengths of sound, of 12 seconds, 16 seconds and 20 seconds respectively. Upper frequency limits differ too, at 4.5kHz, 3.4kHz, 2.7kHz respectively.

Sound data are stored in an analogue electrically erasable and programmable rom with 128K elements, so messages are retained when the chip is unpowered or unplugged.

Analogue inputs and outputs

The main analogue input accepts signals at a maximum level of $50mV_{p-p}$. A microphone preamplifier with an associated agc circuit provides a maximum gain of 24dB at low levels. As a result, microphone inputs of a little over a millivolt will drive the device fully.

During playback of a stored message, the amplifier takes its input from the analogue eeprom; however, when /CE is high, the amplifier is fed from an auxiliary input.

Digital inputs and outputs

Eight address lines, A_{0-7}, allow the definition of 160 starting points for record or playback – yes, 160 not 256. When the two most significant address lines are both taken to logic one, the device enters one of several different operational modes, depending on which of the other address lines is taken to logic one. I'll describe these modes later.

Three inputs, PD, /CE and P//R, control the state of the device. Their functions are explained in the sections on simple record and playback. One active-low output, /EOM, is provided which goes to logic zero at the end of a message.

*In the UK, the ISD parts are distributed by Sequoia, 01734 258000.

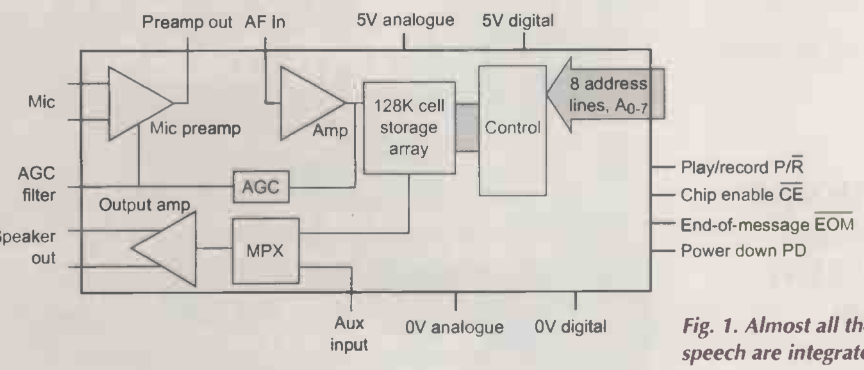


Fig. 1. Almost all the elements needed for recording and playing back speech are integrated into the ISD1016.

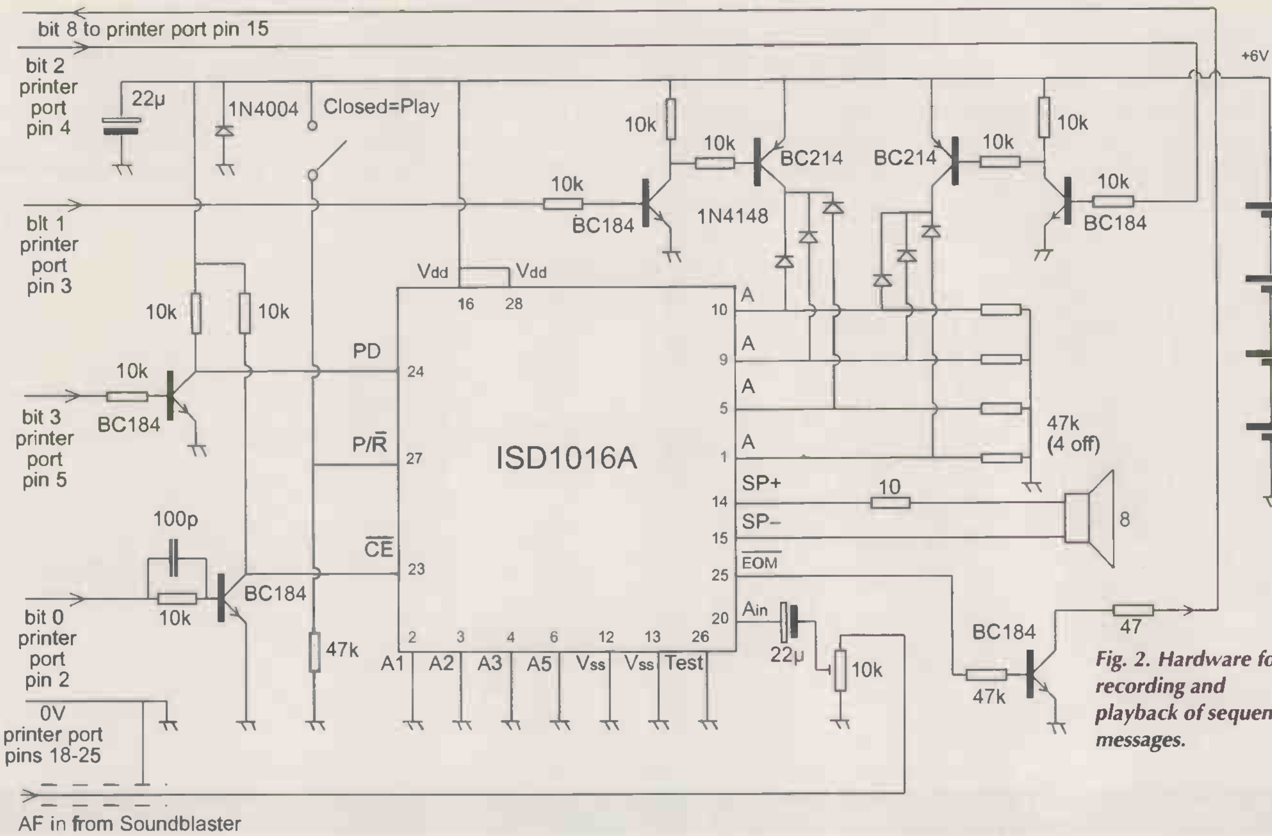


Fig. 2. Hardware for recording and playback of sequential messages.

Not surprisingly, the play/record input, P//R, selects play when logic zero or record when logic one. Active-low chip-enable /CE starts and stops recording , and starts playback. The power down pin, PD, reduces current consumption to a fraction of a microamp when taken to logic one.

Recording speech

Let's deal with recording first. Lines PD and P//R are taken low; recording starts at the address defined by the address lines when /CE is taken low, and ends when /CE is taken high. If this process is repeated, a second message is recorded. It overwrites the first message, unless the address lines are changed.

There's the problem for applications which, like the talking kitchen scales, make a large number of phrases by selecting and concatenating chosen words. You need to know the length of a word so that the address can be appropriately set before the next one is recorded. If this is not done, the second word may overwrite some of the first one.

This problem is solved by using a mode where messages are recorded one after the other, without needing to know the address. One of the modes which have address lines A_6 and A_7 high simultaneously provides this function; it requires that A_4, A_6 and A_7 are all taken high. As before, P//R must be low, and recording is started and stopped by lowering and raising the chip-enable line. However, the messages are recorded sequentially with an end-of-message marker at the end of each message; the address is not reset unless the state of P//R or PD is changed.

There is a corresponding method of selecting a word for playback without knowing the address at which it is recorded. The address pointer must be reset by raising PD for at least 12.5ms. Of course, P//R must be high; take A_0, A_4, A_6 and A_7 high, and apply (n–1) brief (between 100ns and 10μs) low-going pulses to /CE. This skips over the first (n–1) messages at 800 times the normal playing speed with the output muted. If A_0 returns to logic zero and /CE pulsed low briefly once more, the nth word will be played.

Optimising multi-message recording

With only 16 seconds of recording time available, it is obviously desirable to record only the words that are absolutely necessary, and to trim off leading and trailing silences. This is an obvious job for a pc with a *Soundblaster* system.

As for logic signals to control the recording process, the ubiquitous printer port will give us more than sufficient outputs. However, the obvious approach of, in C terms,

```
outp(PRINTER_PORT, 1);
system("PLAY <filename>");
outp(PRINTER_PORT, 0);
```

is unsatisfactory. There are delays between the issuing of the PLAY command and the beginning of playback, and between the end of playback and the second change of printer port state. These delays are more predictable, but not eliminated, if the file to be played is stored in ram disc rather than on the hard disc; the delays re-introduce the waste of recording

Software on disk

A disk to accompany this article is available and contains the following files:

ISD_FILL.EXE recording control software.

PORTDEF printer port definition file, which allows the printer port address used by the software to be set to the correct value for the computer used. By default, an address of 378_{16} is assumed.

SOUNDS directory containin g example .VOC files.

FILELIST file, allowing chosen files to be loaded into an *ISD1016* in a chosen order. As supplied, it looks for files in the SOUNDS directory, which should be installed as C:\SOUNDS.

PLAY.EXE file which takes a parameter which selects the message to be played PLAY 2 plays the third message, as messages are numbered from 0.

Object and C code files for ISD–FILL.EXE and PLAY.EXE are also included. Simply send £14 with a request – including your address – to Electronics World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS or fax your request with credit card type, number, expiry date and cardholder address on 0181 652 8956.

time removed by editing with the *Soundblaster* system.

I am indebted to Ifor Powell of Creative Labs UK for providing a solution. He was able to send me the source code of a program, written in Borland Turbo C++, which takes a *Soundblaster* *.VOC format file and plays it without the delays associated with more direct methods. The program only works with 8-bit mono, or 16-bit mono or stereo files. I have augmented the program to read a list of *.VOC files representing sounds to be stored on the *ISD1016*, and to provide logic signals via the printer port to control the recording process.

Figure 2 shows the hardware needed to record and play a selected message. A_0, A_4, A_6, A_7, /CE and PD are controlled by software

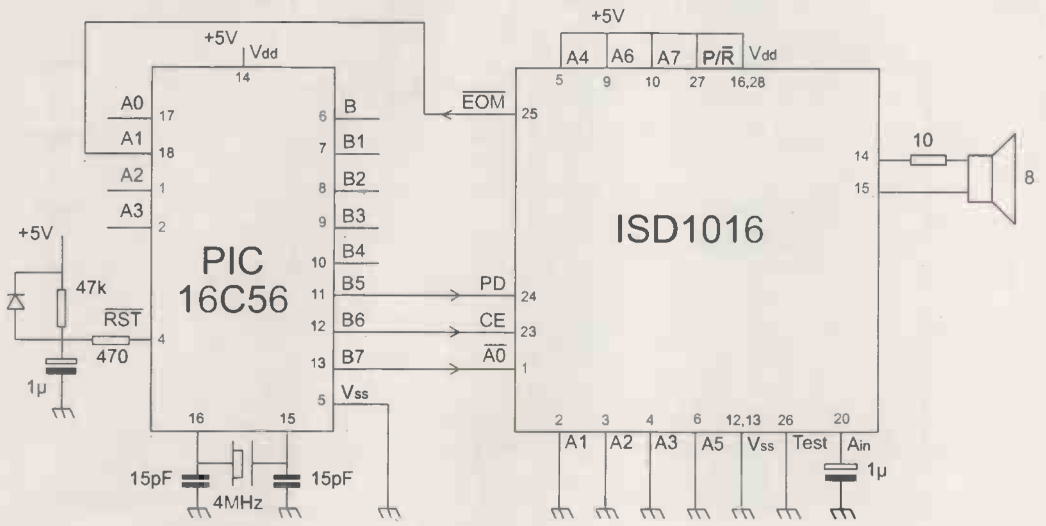


Fig. 3. Interface between PIC processor and speech chip.

List 1. Partial PIC code for speaking weighing scales

```
sub-routine for PIC processor (see fig. 3) to say a word stored in ISD1016
;########## register allocations ###########
;############ and their bits #############
        RTCC            equ 1
        status          equ 3
        C               equ 0
        Z               equ 2
;ins connect to port A- define port direction In main section of program
        in              equ 5
        not_eom         equ 1
;outputs are port B- define port direction in main section of program
        output          equ 6
        A0              equ 7
        not_enable equ 6
        power_down      equ 5
;######## to say word N, load register word_ptr with N ##########
        word_ptr        equ 7
;#########################################
;######### SUBROUTINE SAY ##############
;#########################################
;START OF SEEKING & SAYING A WORD
;set A0, enable high
say
        movlw   192
        movwf   output
;#########################################
;power down for >12.5ms to reset
;set max prescaler=256
;internal clock 000111
;256us output rate ASSUMING 4MHz clock
;so go round 50 times
        movlw   7
        option
;actual power down
        bsf output,power_down
        movlw (255-50)
        movwf RTCC
delay1
        movf RTCC,0
        btfss status,Z
        goto delay1
;counter is zero
;power up again
        bcf output,power_down
; apply appropriate number of /CE pulses
; is word_ptr at zero?
cue_again
        movf word_ptr,0
        btfsc status,Z
        goto cued
send_enable
;apply not_enable pulse
        bcf output,not_enable
        bsf output,not_enable
;wait for not_eom
wait_eom
        btfsc in,not_eom
        goto wait_eom
;and wait for it to disappear
wait_end_eom
        btfss in,not_eom
        goto wait_end_eom
        decf word_ptr
;if bit 7 of word_ptr is set, must have been 0 before
; and thus have spoken, so end
        btfsc word_ptr,7
        goto endit
        goto cue_again
cued
;drop A0
        bcf output,A0
        goto send_enable
;############ end of subroutine ###################
endit
        retlw 0
```

via the printer port; P//R is switched manually. End of message is fed back to the computer via pin 15, an input, of the printer port.

Playback hardware and software

Figure 3 is the circuit of processor/speech chip interface as used in the talking scales. The *ISD1016* needs only four connections to the microcontroller. These are A0, /CE, PD outputs from controller and the /EOM input..

List 1 is a subroutine for a *PIC16C56* processor; it forms part of the code for the talking kitchen scales. To speak the *N*th word, load the register 'wordptr' with *N*, counting from zero.

It should be possible to add limited speech output to a computer with no Soundblaster card by making a unit to connect to the printer port. Such a unit would contain an ISD device and a *PIC* processor to wait for a printer enable pulse, produce an appropriate word, and reply with an acknowledge pulse at the end of the speech output.

Recording messages

It is convenient to record the words onto a tape recorder, rather than directly into the *SoundBlaster* card. When asked to make a recording of text, many people remember whatever they were told about public speaking, and speak at a low rate, ie words per minute. This is to be avoided as the time available for recording is limited, and the user of the talking scales wants to know weights, not listen to a poetry recital.

One rather morbid thought – the user of the complete equipment may want messages recorded by an anonymous person. I've encountered the "I couldn't keep using it if you fell under a bus" phenomenon.

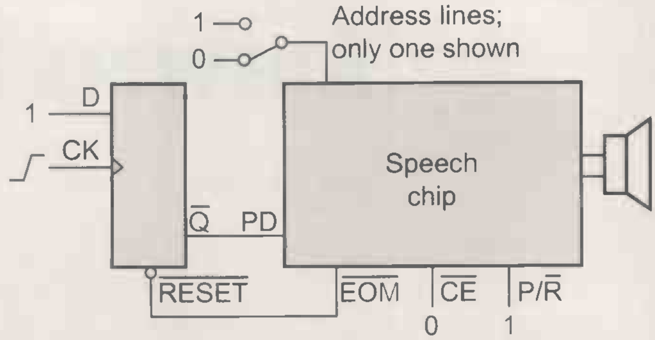


Fig. 4. Low power player; circuit outline. Playback starts when PD is sent low by a rising edge on the D type clock. The message appropriate to the state of the address lines is played. At the end of the message, the /EOM output goes low, resetting the D type and sending PD high. In this state, the ISD1016 draws a fraction of a microamp.

By the way...

Has anybody noticed how the old imperial weights, with 16 ounces to the pound, sit very nicely with a binary word where the bit zero represents half an ounce, bits one to five represent ounces, and bits six to eight represent pounds? The downside comes in the logic needed to give the correct grammar; for example 'one pound and half an ounce', 'one pound three and a half ounces'. On the other hand, the 'grammar logic' is simpler for metric. Probably the simplest route between metric and imperial is to use 1oz=(255/9) gram – a relationship with an error of much less than 1%.

A simpler system

For a small number of short messages, it is possible to calculate the start address of each message so that messages don't overwrite each other during recording. A simpler playback circuit can then be used. To record, PD and P//R are taken low; recording starts (at the address defined by the address lines) when /CE is taken low, and ends when /CE is taken high. The circuit of **Fig. 4** can then be used for playback. /CE is permanently low. A zero-to-one transition on the clock of the D type sends PD low to start playback; PD is reset to logic 1 when the /EOM output goes low at the end of the message. Where several messages are recorded, the address lines define the message to be played. An advantage of this method of playback is that, as the chip is powered down except during actual playback, the standby current can be very low.

I'm grateful to Cambridge Consultants for permission to publish this article. ■

Shifting phases?

I am looking for a circuit to phase shift by 90° the components of a signal with frequencies in the range 10Hz to about 350Hz. Although simple integration or differentiation can achieve this, they do so at the expense of a frequency dependent change in the signal amplitude which I cannot use.

In *Electronics World* of April 1993, Terrence Finegan mentions that such 'a useful analogue function' may be realised differentially with 'all-pass' filters, but this hint has proven insufficient. Text books even mentioning all-pass filters seem to be the exception, at my level of mathematical sophistication anyway.

Are there any readers with a solution to this problem? It would help me and being an unusual function may inspire other interesting designs.

Alan Scrimgeour
London

Looking for diode amplifiers

I am interested in diode amplifiers and their circuit design with regard to: a) detector or power diodes and b) variable capacity varicap diodes. Perhaps several stages would be required to obtain good amplification.I would appreciate any information about their operation and simple circuit to demonstrate the diode amplifier for low frequency rf and also af stages.

Ray Stead
Hampton, Middlesex

Looking for a small uhf tx/rx unit

To me, rf design is still a bit of a black art. Although an experienced analogue engineer, I am woefully short of rf knowledge.

I am working on a direction-finding project that requires a very small uhf transmitter, of about 1mW output and run from a 3V battery. Are there any rf engineers out there who can supply such a circuit or help with the design of such a device?

Mike Bull
Balsham, Cambs

Problem with computer read caches

Standard usage of hard disk integral caches assumes a high percentage of hits. My special requirements normally give zero hits and a greatly increased run time. Logically, with suitable hardware/software, 100% cache hits should easily be possible but so far no one has been able to suggest how. Writing to a cached disk is OK. The problem is reading delays where single runs may last hours, days – even months.

Each run uses four or more files. At any one time programs write to one file and read from two different files. Files are all the same size and may be up to 512Mbytes each. With a fast processor reads can occur tens or hundreds of times per second continuously – with each block, of any size up to a maximum of 32Kbytes, usually in 'random' sequence from anywhere in the relevant file.

The important point is that all read locations are always known before that read file is opened.

My problem is how to advise the disk cache – well in advance of each memory need – to preload the required read blocks. Surely someone has the answer to this problem? Is my type of use really unique?

R.G. Silson
Herts.

Answers to questions

In the July/August issue, P W Fry asked:

"If a short pulse is generated at one end of an open circuit transmission line then that same pulse can be observed to return at a time proportional to the line length and the line velocity factor. Conducting the same test but with the line terminated in a short circuit returns an inverted pulse. Why does this pulse inversion take place?

If you take a snap-shot of the voltage and current when the pulse was half way down the line, eg at a quarter of total elapsed time, what would we see that would indicate if the pulse was going away from or towards the generator? That is, how does the pulse, when it is half way down the cable, know in which direction it is supposed to be travelling?

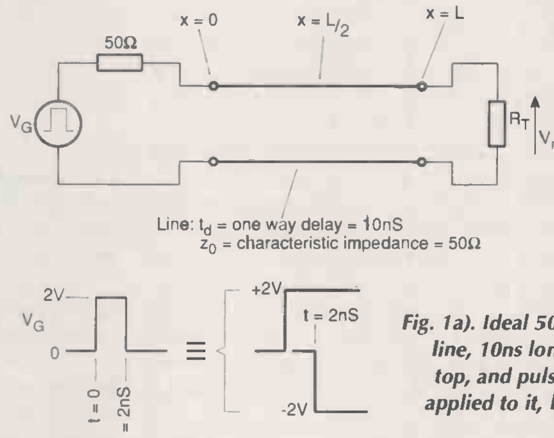


Fig. 1a). Ideal 50Ω line, 10ns long, top, and pulses applied to it, b).

Bryan Hart, of Leigh-on-Sea, Essex was one of a large number of readers who replied. Space permitting, we will show you more replies next month. Thank you to all who replied.

Physically, reflections occur on a line because all the energy in an incident waveform cannot be accepted at a termination. Consider the setup of Fig. 1: a) shows an ideal 50Ω line 10ns 'long'; b) shows a 2V, 2ns pulse applied at x=0, t=0, through a 50Ω source-matching resistance and its composition from step edges. The progress of the pulse down the line and back again can be visualised using a 'reflection chart' (see, eg, 'Digital signal transmission: line circuit technology' by B. L. Hart, published by Van Nostrand Reinhold, 1987).

Fig. 2a) shows a chart for RT=∞. In this case there can be no current in the termination and this condition can only be met by having a positive going reflected pulse equal in amplitude to the incident pulse.

Fig. 2b) shows a chart for RT=0. In this case the boundary condition VT=0 can only be met by having a negative going reflected pulse.

Figs. 2c) and d) show the conditions at x=L/2 for RT=∞ and RT=0 respectively. In the case discussed, the negative-going pulse in Fig. 2d) is indicative of motion towards the generator. ■

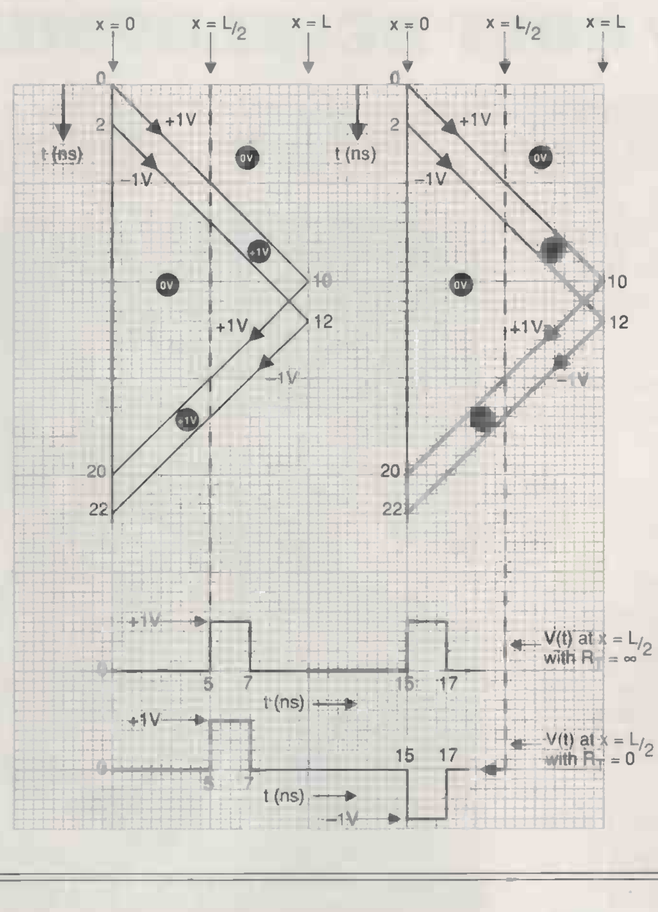


Fig. 2. a) Chart for Rt=∞, b) for Rt=0 and c/d) for the same, with x=L/2.

LETTERS

Letters to "Electronics World"
Quadrant House, The Quadrant,
Sutton, Surrey, SM2 5AS

Great balls of fire

In July/August 1996's Research Notes, you had an item entitled 'Ball Lightning Comes Down to Earth'. I experienced ball lightning as a young farm boy in southern Minnesota back in the late forties. I also have acquaintances who have had such experiences, including a couple of physicists, of which I am now one.

Mr. Lowke's description may explain some of the movement, but, it falls short of explaining how it is formed. I have studied this quirk extensively. Unfortunately, it never lasts long enough to be properly measured, nor does it seem to occur when one is ready to study it. However, experience and observations do allow this tenative conclusion; the soap bubble model seems to at least first order describe its general characteristics.

Generally, when ball lightning does occur, there have been 'sheet lightning discharges' in the vicinity. A strong breeze, turbulent wind or other that can form a distortion in the plasma sheet that makes up sheet lightning will under certain circumstances allow a closed plasma bubble to form. It can be anywhere from a few centimeters to tens of centimeters in diameter. It is generally blue-white in color and has the distinct sound of bacon frying along with the smell of ozone and NxOx products.

The one I encountered as a youngster was about 10 to 15cm in diameter. It appeared shortly after an extremely loud and bright lightning discharge near the house and drifted through an open window of the upper floor bedroom that I was occupying.

As I remember, it moved about the foot board of my brass-pole bed and illuminated the room with blue-white light. It lasted only about 5 to 10s at the most. The ball quickly drifted up and over to a wall, dissipating itself with an enormous flash similiar to a photo flash bulb going off.

The next morning my father inspected the wall for damage but found none – no sign whatsoever that it had touched the wall. There is no doubt in my mind that this was a spherical shell of ionized air molecules that was comprised of a great deal of charge. One could feel the electric effect it produced, similiar to having a hand on a high-voltage generator.

Another story by a physics professor that I had at the university was about one that came down from an elaborate transformer platform at a linear accelerator facility during a lightning storm. This ball was similiar in size, color, noise, etc., and followed a 440V, three phase conduit to where a large polarized receptical was located. When the ball went in front of the receptical, it was reported that eye witnesses saw a brilliant flash and the entire receptical exploded outward with bits of insulator and other over the area. The breaker was opened at the event.

Now that I am ready and know what to look for in clues on the subject, I have yet to experience another.

D. D. Schendel
Arizona
USA

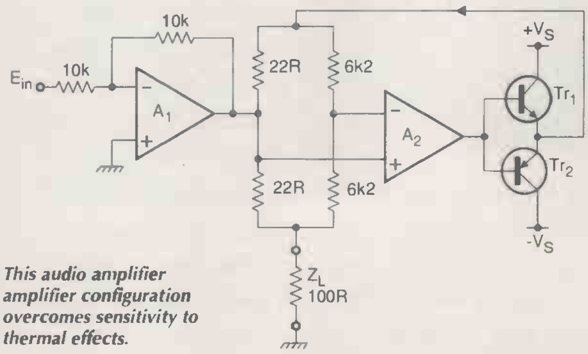
Forget thermal effects

Douglas Self's article on 'Thermal dynamics in audio power' was well done, but was it necessary?

As J. Linsley Hood has explained in 'The art of linear electronics, Butterworth, 1993', there is another way to approach Class B amplifier design. It is to use my 'Class S' design shown on p. 165. fig. 9.34.

My original 1982 article in this magazine (Class 'S', *Wireless World*, p.38. Sep. 1982) explained the operation of the circuit. It clearly implied that Class 'S' is immune to thermal variations and can be built without setting up. The cross over distortion performance is excellent, even if a normal tolerance variation exists on the bridge resistors. Only the large signal performance is affected by such resistor tolerances.

Dr Aubrey Sandman
London



This audio amplifier amplifier configuration overcomes sensitivity to thermal effects.

Ether or not?

No physical theory can unify electricity and gravity. Or can it?

In response to Ivor Catt's call for new ideas in electromagnetic theory (Letters May 1995), a paper which seems to mechanistically and numerically unify electricity and gravity – apparently proving the ether hypothesis correct – has been written by Nigel Cook.

Interested readers may obtain eight-page copies of the complete theory for a copying, postage and administration charge of £4.50 by writing to the editorial offices.

Setting the record straight

Regarding the abusive letter from Mr M.Jones on crossover networks, I spent a substantial amount of time in the Keele University library, so the comment about homework I shall ignore.

Taking some of his points in order:

a) If correctly designed networks are specifically designed for a predetermined unit, then why do companies like Maplin sell crossovers at up to £99 each to put in your own enclosure?

c) Is Mr Jones seriously suggesting that the average hifi enthusiast who wants to build up a loudspeaker unit, get hold of an Audio Precision test set (at huge cost) and measure the performance of the unit, before they actually build their crossover network. Come on, be realistic.

d) The purpose of the article was to provide a cheaper alternative to buying the expensive crossover units.

e) The article specifically mentioned the use of emi power toroids. Toroids as anyone knows don't interact magnetically with each other, due to the closed magnetic circuit. So orientation is irrelevant. 10 years of working in the video filter industry verify this. For example using *T20-2* toroids actually touching each other for the filter and group delay equaliser sections does not cause any major problems. The unit that was built up was tested at 100Wrms without problems, apart from the neighbours. At 50p each, the toroids aren't expensive.

g) Cascading high and low pass sections to achieve a band pass response is quite a commen technique actually. See the relevant sections in Williams. This also elliminates the problem of requiring more inductors at ridiculously high Q values as generated by the low pass to band pass transform. Again see Williams. If Mr Jones had bothered to look at the plots, he would have seen (in Fig 4a) that it is entirely possible to cascade sections as long as an adequate bandwidth is maintained. The reason for using C (not C++) was that it was available. Any language could have been used, or even a spreadsheet as Mr Jones suggests, however the output from the program is a bit neater as to documentation purposes. If I had only used 1 decimal digit precision, someone would have complained. You can't please everyone. If you don't want the 6 digit precision, then its a trivial matter to change the output formatting, that is unless Mr Jones cannot understand a simple language like C.

Finally, it is obvious that Mr Jones works for a crossover manufacture, by what he says at the end of point d, so he obviously doesn't want to lose business, well, thats the way the cookie crumbles, I'm afraid.

Bill Teleki
Newcastle-Under-Lyme
Staffordshire

Raked over the coals

In his letter in the July/August issue, G.E. Miller writes: "I have long ago learned that if one side in a debate or discussion resorts to personal abuse then it is clear that that person cannot make a case for his views."

The next paragraph of Mr. Miller's letter is devoted to personal abuse. Therefore...

J.S. Linfoot
Oxford

Self Preamplifier '96

On Fig. 11 of Doug Self's preamplifier article in the September issue, R_{55} should have been 100Ω. One potentiometer is unmarked. As mentioned in the text, all potentiometers are 10kΩ.

Also, R_{207} should be reduced to 10Ω to accommodate a *BC184L* whose gain specification is on its minimum. Finally, C_{32} should be polyester, not ceramic as indicated. Apologies for these misprints.

Sell Out at Europe's Biggest Cable Show!

ECC'96, Europe's cable communication showcase, has completely sold out of stand space, over four months before it is due to take place.

A 30% increase in the size of the event has required a move to a larger venue, the National Hall Olympia, and now even this extra space has been taken.

ECC'96 takes place in London between 15 & 17 October 1996. Asked to explain the event's success Sharon Chapman comments: "ECC'96 is the only forum where there is significant representation from cable, telecoms and programming companies. I know many exhibitors are using the event to launch new products, making ECC'96 one of the few truly international exhibitions held in the UK".

200 Companies

With over 200 companies on display, the exhibition is an event in itself. By far the largest show outside the US, ECC'96 will be welcoming visitors literally from around the world.

Top Names in Cable, Telecoms & Programming

ECC'96 is the forum to launch new to market products. Among its 200 plus exhibitors, the show sees existing favourites such as Motorola, GI, Ericsson, United Artists, Sky and Nortel, joined by newcomers IBM, GEC Marconi, Nordex, Pace, Paramount and Fujikura,

Arena

Free to all exhibition visitors and one of the most dynamic parts of the convention is the ECC Arena. A show within a show, the Arena allows visitors to see launches, demonstrations, product applications as well as put top industry personnel through their paces.

Comprehensive Conference

Many visitors take advantage of the modular conference programme. Ian Lang, President of the Board of Trade and Martin Bangemann, Director DGXIII of the European Commission lead the plenary session on day one, **Tuesday** 15 October. This focuses upon the future and new challenges facing the industry and covers topics from digitalisation to finance and strategy.

Day two, **Wednesday** 16th, has top names from the BBC, Sky and BT discussing cable's competition. The European dimension has a complete session in the afternoon.

Thursday 17th deals in marketing with highlights on new programming, customer services, market penetration and customer retention.

10th Anniversary

Social Programme

"The emphasis we place on networking has contributed to the success of the event" says Sharon Chapman. ECC'96 provides a unique setting for making contact with the industry's movers in an informal and relaxed atmosphere. This year is no exception with the World Cable Dinner for 800 on the evening of Tuesday 15th, and the ECC Gala Party the following evening for 1000.

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CIRCLE NO. 133 ON REPLY CARD

794

STEPPING OUT

Ian Hegglun's new voltage multiplier promises higher efficiency and simpler implementations.

Cockroft-Walton voltage multipliers or charge-pumps can eliminate inductors in some power converters such as negative rail generators and voltage doublers. Higher conversion steps are possible by cascading doubler stages. But losses increase rapidly with higher ratios making high ratio multipliers less practical than inductor based converters.

A recent multiplier arrangement improves efficiency[1]. To demonstrate this a 12V to ±50V dual rail 300W converter is presented. The Mosmarx multiplier[2] is another technique that achieves high efficiencies, but it is limited in voltage by mosfet voltage ratings. The new arrangement is not limited and can produce hundreds of kilovolts.

Recent improvements in low-impedance electrolytics, mosfet drivers, mosfets and lower cost schottky diodes make voltage multipliers attractive for a wider range of power converter applications. Adding the improved multiplier gives higher efficiency, power density, i.e. W/kg, and specific power, W/cm^3, with values similar to inductor based dc-to-dc converters at similar frequencies. Also, the problem of efficient voltage regulation with multipliers appears to be overcome in the demonstration circuit.

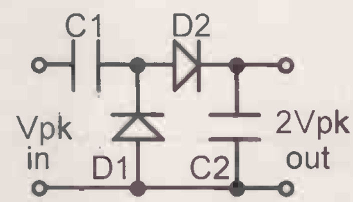


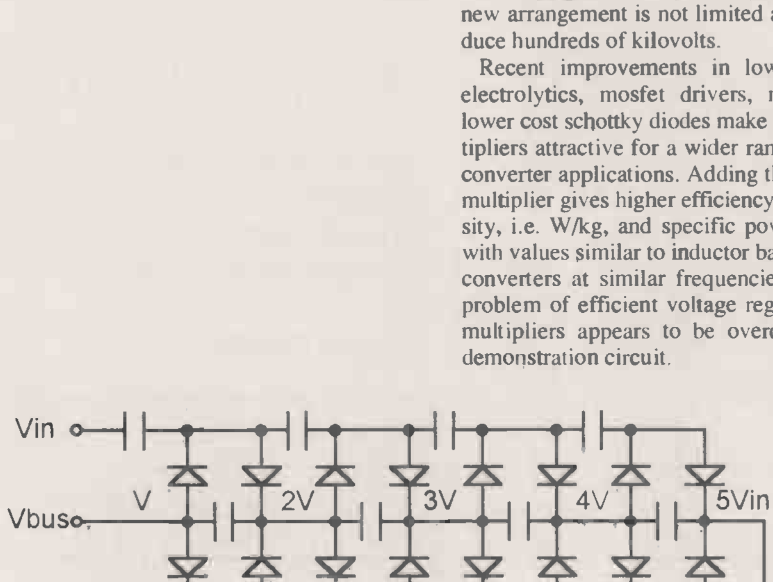
Fig. 1. The Cockroft-Walton doubler is the simplest voltage multiplier.

Conventional half-wave multipliers

The simplest multiplier, the Cockroft-Walton voltage doubler, is shown in Fig. 1. Output voltage reaches twice the peak input voltage, but when loaded the output voltage falls by two diode volt drops plus an ac ripple component. This is because of current flow in the capacitors.

Figure 2a is a simple voltage doubler based on a popular mosfet half-bridge driver. Negative rail generator **Fig. 2b** is similar to the doubler circuit but it sits on the 0V rail with diodes and capacitors reversed. These circuits can be very efficient with low on resistance mosfets, schottky diodes and low impedance electrolytics. Mosfet driver ics greatly simplify the circuitry.

Higher multiples are made from cascading



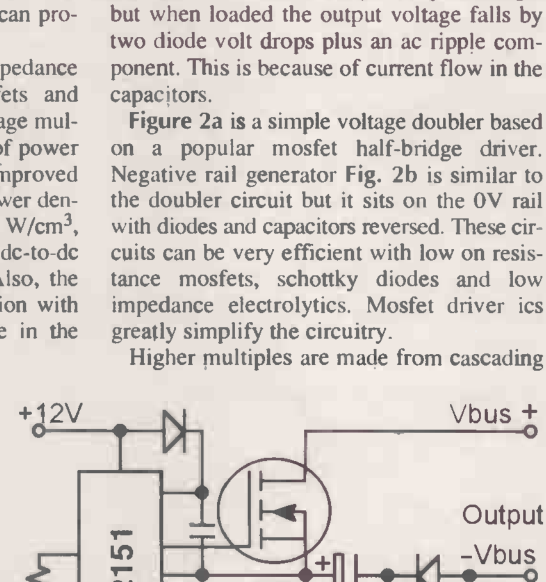


Fig. 2. a) Simple voltage doubler based on a popular mosfet half-bridge driver. Negative rail generator b) is similar to the doubler circuit but it sits on the 0V rail with diodes and capacitors reversed. b) is a negative rail generator

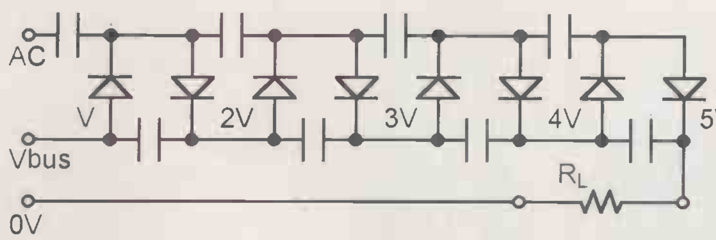


Fig. 3. Higher multiples of the input voltage are obtained by cascading several doubler sections.

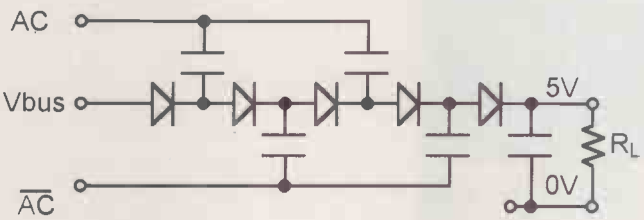


Fig. 4. Improved half-wave pentupler. Compared to Fig. 3, this multiplier needs three fewer diodes and two fewer capacitors.

several doubler sections as shown in **Fig. 3**. Voltages indicated are those for a multiplier that sits on the dc bus. This enables a dc-to-dc pentupler to be made with only four stages instead of five, increasing efficiency and reducing cost.

Note the difference in output when a multiplier is fed from an ac source such as from a transformer as in Fig. 1, rather than a pulsed dc waveform as in Fig. 2. With an ac source, input capacitor C_1 charges to the peak input voltage on the negative half cycle. When the input reverses, $2V_{pk}$ is presented to C_2 ultimately charging it to $2V_{pk}$. But in Fig. 2b, a pulsed dc waveform is fed to C_1. When the low-side mosfet Tr_2 conducts the input capacitor C_1 is charged to V_{bus} via D_1 and when the high side mosfet Tr_1 conducts C_2 is charged ultimately to V_{bus}, not $2V_{bus}$ as might be expected from Fig. 1.

This can be explained by looking at the Fourier series for a pulsed dc waveform. A dc component of $0.5V_{bus}$ is present which is blocked by C_1. The remaining ac component, a square-wave with a peak value of $0.5V_{bus}$, is doubled giving V_{bus} across C_2 and $2V_{bus}$ at the output to 0V.

As a rule, the peak-to-peak input voltage determines the output voltage of each stage and each additional stage adds another component of peak-peak input voltage.

Improved half-wave multiplier

Fig. 4 shows Ian Hickman's improved half-wave multiplier[1]. Compared to Fig. 3, only five diodes are needed rather than eight for a pentupler that sits on the dc bus, and only five capacitors are required rather than seven. However, two drivers are required to generate the complementary squarewave drive but this can be done relatively simply these days with ics.

Full-wave multipliers

A full-wave pentupler is shown in **Fig. 5**. This circuit is effectively two half-wave multipliers in parallel. Hence the output current can be doubled for the same output ripple and efficiency.

Apart from the complications of the extra diodes, capacitors and a differential drive either from a full-bridge converter or a transformer, these complications are partly offset by the double pulse frequency in the dc capacitors. As in conventional full wave rectifiers, the value of the filter capacitor can be half that of half-wave for a given ripple content. Also, as I discovered, the dc capacitors can be eliminated when the input is fed with a square wave.

Improved full-wave multiplier

When Fig. 5 is fed with a squarewave such as from a full H bridge, the dc capacitors can be removed without upsetting operation since the output duty cycle is close to 100%.

With the capacitors removed there is a current path through the junction of the four diodes in **Fig. 6a**. These current paths are independent so the junctions can be broken. Since there are now two diodes in series in each path, the circuit can be simplified to **Fig. 6b**. Although I have not done an exhaustive literature search, this full-wave circuit appears to be new.

Fewer diodes means lower cost – especially in low voltage converters when using schottky diodes. Reducing diode numbers also improves efficiency; in low voltage converters diode losses tend to predominate. Eliminating the dc capacitors also reduces cost and improves efficiency because there are fewer charge transfers. In Fig. 6 for example, there are four charge transfers. This includes one from the supply reservoir capacitor, compared to eight charge transfers for a conventional full-wave pentupler. Comparing diodes, there are five diode volt drops compared to eight.

In general, there are $2n$ diodes where n is the multiplication factor and where V_{bus} is used to reduce the number of stages by one. Note that there are two diodes more than the number of capacitors; the last two diodes can be seen as termination diodes. Adding an extra two diodes at any point can tap-off different voltage steps if required.

All these improvements are achieved with the same voltage and current ratings of both diodes and capacitors and without compromising output power. Compared to the simpler half-wave multiplier the only extra components, apart from the two extra diodes, is the extra half bridge, which is relatively simple these days.

Safety hazard

The high voltage multiplier described here is potentially lethal. Do not attempt to build or use it unless you fully understand the dangers of extremely high-voltages and follow the safety warnings given in this text.

Capacitor losses

The law of charge conservation can be used to show that capacitor losses are independent of how much or little resistance is in the circuit when two capacitors are connected together. Energy loss when transferring charge from C_1 initially at V_1 to C_2 initially at V_2 is,

$$\Delta E = \frac{1}{2}\left[\frac{C_1 \times C_2}{C_1 + C_2}\right]\left[V_1 - V_2\right]^2$$

Even if diode losses could be eliminated, the efficiency of a charge pump multiplier is limited by the sum of the squares of the individual capacitor ripple voltages. Capacitors for power converters are costly so it is important to choose capacitors carefully.

Choosing capacitor values

To minimise the cost of capacitors you need to know how much output ripple is acceptable

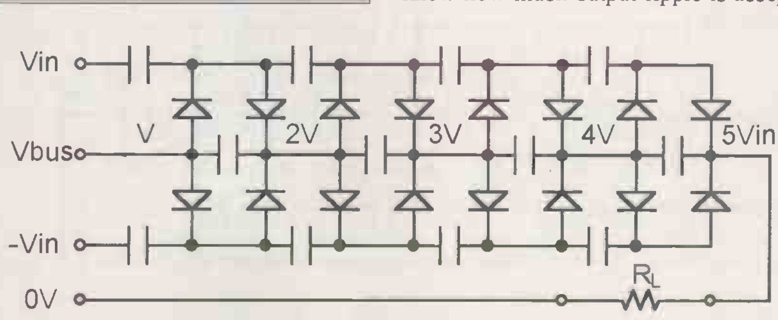


Fig. 5. Conventional full-wave pentupler. This circuit is effectively two half-wave multipliers in parallel.

and the output current. Electrolytic capacitors are useful up to several hundred volts and work best in the 3-30kHz range. Electrolytics are usually chosen for their ripple rating rather than for minimum capacitance because they have high losses. Typical *D* figures are 0.1 to 0.2 compared to non-electrolytics with 0.001 to 0.01, where *D*, and tan δ, is the dissipation factor.

I have used various types of electrolytics in multipliers. Standard electrolytics can be used but they are more bulky and require a lower frequency for minimum impedance and hence maximum efficiency. The XYB series miniature low impedance 105°C electrolytics from Rubycon are used in my recent designs. The RS catalogue provides useful ripple current data.

I have found the continuous ripple current rating of 105°C capacitors can be more than doubled for an ambient temperature not exceeding 50°C. The Philips electrolytic capacitor data book gives useful information on temperature over-rating.

In the absence of suitable data, run a test to measure the temperature rise at maximum current. From this the highest safe ambient temperature can be found. For example, a temperature rise of 45°C means 105°C capacitors can operate up to an ambient temperature of 60°C, so a 50°C ambient temperature will be safe.

Bipolar types that are non-electrolytic are chosen on the basis of output ripple voltage; for 5% peak-peak output ripple the final capacitors reactance should be a hundredth of the load resistance[3]. Given an operating frequency and reactance, the value of the final capacitor in the multiplier chain can be calculated.

Grading capacitor values in proportion to current helps to minimise charge transfer losses. For Figs 3 and 5, capacitors closer to the input carry more current than the final stages, increasing linearly along the chain starting from the load. For example, if I_L is the average current flowing through the load in Fig. 3 then the input capacitor carries $4I_L$.

12V-to-100V 300W converter

Fig. 7 shows a 13.8V to ±50V 300W dc–dc converter. It demonstrates that output power of several hundred watts are relatively easy to achieve. An efficiency of over 90% can be maintained from a few watts up 300W – even with a multiplication ratio of eight times If load current must be returned to 0V, this reduces to 150W and ±4 times. Peak efficiency was 95–96% for loads from 0.2A to 1A.

Comparing this multiplier to that in Fig. 6b, shows that the capacitors are arranged slightly differently; they are common to the input rather than in a string. This improves efficiency of electrolytic based multipliers, where higher voltage electrolytics generally have lower losses (*D*) per microfarad. Note that the capacitor voltages increase toward the output in this arrangement. Also, capacitor currents are similar so each capacitor needs to be rated for the output current. For the values shown the highest capacitor case temperature rise was 30°C with 2.2A load.

The W/kg power density and W/cm^3 specific power compare favourably to inductor based converters. For example, an *ETD34* ferrite core measures about 50cm^3 and weighs 50gm. At 200W the power density and specific power are 400W/100gm and 4W/cm^3 respectively. For this multiplier (capacitors, diodes and pcb) the values are similar at 300W/100gm and 6W/cm^3. If schottky diodes are not used to maximise efficiency, the cost per watt for this converter is better than inductive converters. These comparisons are valid for non-isolated step-up converters with ratios of up to ±5 or so – ten or so for a floating load.

Although Fig. 7 includes voltage regulation, it is easily removed if not required. By adding C_1 and R_1, IC_1 can run in self-oscillating mode. If you only require a single output, then simply remove one of the multipliers. Also, given higher voltage mosfets, diodes (not forgetting D_1 and D_2) and capacitors, the bus voltage can be as high as 500V.

With no regulator circuitry, the operating frequency is preset with R_1 for maximum efficiency. This can be found by making R_1 variable. Best efficiency is seen as a peak in the output voltage (or input current) as the frequency is raised and for the values shown it is 12kHz.

There is little change in efficiency until 35kHz, but at 100kHz and full load the output power falls by 15% and efficiency falls from 91% to 88% . The reduction in efficiency and power can be attributed mainly to the *IR2151*'s 1μs dead time. Setting the operating frequency too high reduces efficiency at light loads because of the increased gate drive losses. Too low a frequency requires larger and more expensive capacitors.

The unregulated version gives 90% efficiency down to 2W. This is possible because the frequency is only 12kHz, resulting in only 4mA supply current for the ics plus 10mA from the supply bus. The regulated version is less efficient at light loads because it operates up 100kHz when lightly loaded.

This converter was intended to feed a standard 100W amplifier for operation from a nominal 12V supply. For this application it is desirable to keep the frequency above 20kHz to prevent audible interference and preferably above 40kHz to prevent intermodulation products being heard at low audio levels.

To drive a 100W amplifier, the peak current required into 8W is 5A and the minimum voltage to the amplifier should be 45V. The converter in Fig. 7 is rated for 2.5A average and can deliver 5A peak without large reservoir capacitors ($C_{6,7}$).

By delivering the peak current directly rather than from say two 10,000μF reservoir capacitors, for 30Hz low frequency roll-off, the converter is more compact. If reservoir capacitors are added it is possible to run two 100W amplifiers on music signals, but amplifier clipping needs to be avoided.

The right-hand *IR2151* is slaved from the oscillator of IC_1 via R_1 to the comparators of the *555* type internal oscillator. Propagation delay through the comparators is insignificant compared to the 1μs dead time delay for the mosfets. Using two *IR2151* drivers was a lower cost option than full H-bridge drivers advertised at the time. This circuit does not require a separate oscillator for the unregulated option. Resistor R_2 is added as a precaution in the event of IC_2's under-voltage shutdown being enabled before IC_1.

Regulating the output

It is difficult to regulate the output voltage of a multiplier by the usual means, such as pulse width modulation. Attempting to reduce the frequency to increase capacitive reactance also increases losses in proportion to voltage

continued on page 805...

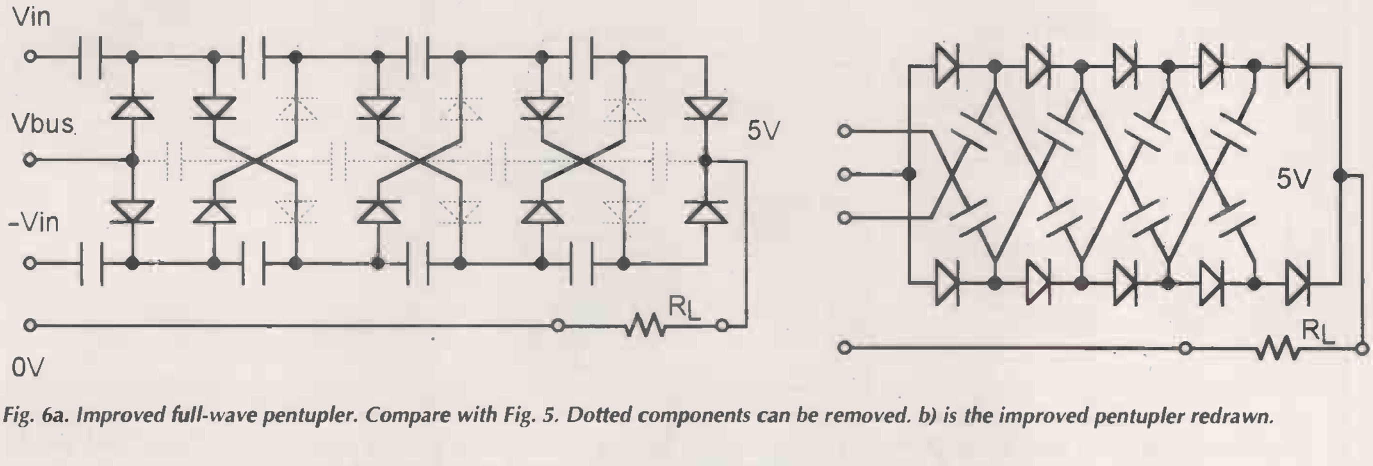


Fig. 6a. Improved full-wave pentupler. Compare with Fig. 5. Dotted components can be removed. b) is the improved pentupler redrawn.

NEW PRODUCTS CLASSIFIED

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ACTIVE

Arrays

'Fastest' pld. *GAL16LV8D* is the first member of the Lattice Semiconductor UltraMOS VI 3.3V low and high density plds. Its e^{2}cmos process enables a T_{pd} of 3.5ns and typical supply current is 45mA, which provides a power consumption up to 70% lower than 5V 16V8 devices. The pld operates with 200MHz system clocks and interfaces with 100MHz buses where both clock edges are used. Compiler software is the same as that for standard 16V8 devices. Future Electronics Ltd. Tel., 01753 763000; fax, 01753 689100.

Bipolar asics at cmos prices. NEC has introduced the *QB-8* asic technique to provide the power, price and short development time of cmos with the high speed of bipolar devices, using a new architecture named *Puzzle*. A special 622MHz version of *QB-8* is intended for embedding in high-speed telecomms applications. Puzzle uses mos input and Bicmos output to provide low input capacitance and drivability. These devices contain up to 223,000 used gates. NEC Electronics (UK) Ltd. Tel., 01908 691133; fax, 01908 670290.

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

14-bit, 100MHz d-to-a. Harris announces the first digital-to-analogue converter to give 14-bit resolution at 100MHz. The *HI5741* simultaneously converts 20 voice channels at a 70dB thd – better than the requirement for single-channel cellular base stations; single-tone spurious-free dynamic range is 86dBc at Nyquist frequency. A significant feature is its capability of handling eight channels in one package, rather than the eight separate signal-processing chains that have until now been needed. Harris Semiconductor UK. Tel., 01276 686886; fax, 01276 682323.

Low-noise a-to-ds. Two new cmos 12-bit converters by Crystal Semiconductor are of the successive-approximation type, offer a 100kHz processing rate, 75mW power dissipation and 73dB s:r ratio. *CS7870* (±3V) and *CS7875* (5V) are pin-compatible with existing 12-bit types and give a performance improvement without circuit modification. A self-calibrating capacitor eliminates time and temperature drifts. Crystal Semiconductor Corporation. Tel., (USA) 001 512 442 7555; fax, 001 512 445 7581.

Multimedia data converter. Said to be meant for use in multimedia and audio, the AKM *AK4510* is a 16-bit stereo a-to-d and d-to-a converter, using fourth-order delta-sigma modulation for accuracy and low cost. The a-to-d section has an on-chip anti-aliasing filter and the d-to-a a post filter to afford tolerance of system clock jitter to 100ns. Switched-capacitor and continuous time filters give out-of-band noise down to –83dB at 44.1kHz sampling. DIP International Ltd. Tel., 01223 462244; fax, 01223 467316.

Linear integrated circuits

General-purpose op-amps. Burr-Brown's *OPA234* series of gp op-amps feature low power and good dc performance and come in single (*234*), dual (*2234*) and quad (*4234*) versions. They work on single or dual supplies; in single-supply working, input common-mode range extends below ground, output swinging to within 50mV of ground. Capacitive loads up to 10,000pF are acceptable in unity gain and the multiple versions are independent for lowest crosstalk. Specifications include a supply range of 2.7 to 36V (±1.35 to ±18V), 250μA/amplifier quiescent current, 25nA input bias and 100μV input offset. Burr-Brown International. Tel., 01923 233837; fax, 01923 233979.

Microprocessors and controllers

8-pin microcontroller. Microchip has 8-pin, one-time programmable microcontroller, the *PIC12CXXX* family, which uses the risc-based *PIC16/17* architecture in a SOIC package to make, it is claimed, the world's smallest 8-bit controller. It provides maths and Boolean operation which, with its small size, makes it competitive with asics and types with greater pin numbers. Two are available: *PIC12C508* with 512word of program memory and 25byte of user ram; and the the *PIC12C509* with 1024word and 41byte. Both have six i/o and an on-chip oscillator, 33 single-word instructions, 1μs instruction cycle at 4MHz, seven special-function hardware registers and direct led drive. Operating power is 2.5-5.5V at 2mA. Arizona Microchip Technology Ltd. Tel., 01628 851077; fax, 01628 850259.

Dsp, risc microcontroller. Hitachi's *SuperH* family of 32-bit microcontrollers is joined by the *SH-DSP*, which is claimed to be the first single, integrated core to include full dsp and risc functions. It gives 60Dhrystone mips as a controller or 120mops as a dsp, or any point in between. The device is based on the *SH-2* with dsp extension and operates at 60MHz, 3V, accepting SuperH code with no need for modification. There is a good base of software tools available. Hitachi Europe Ltd. Tel., 01628 585163; fax, 01628 585160.

Supervisors. *MAX6301/2/3/4* from Maxim are microprocessor supervisor chips, issuing resets on power-up/down, brownout or failure in software execution, model difference being concerned with the nature of the reset outputs. Two external resistors set trip thresholds, resets being emitted when the supply drops below the threshold and maintained until an adjustable time after it rises again. Resets are guaranteed for supplies down to 1V. There is an internal watchdog timer to issue a reset when the the adjustable timeout ends after an absence of transitions indicates a software failure. Maxim Integrated Products UK Ltd. Tel., 01734 303388; fax, 01734 305511.

Optical devices

'Smallest' ir transceiver. A new optical transceiver pair by Sharp is compatible with the IrDA 1.0 standard for infrared communication. Normally external components are integrated to reduce the board area needed to about 20% of that required by earlier designs. Wait time is reduced by using the half-duplex mode and the delay between transmit and receive modes is down to 30μs. Since the two devices are separate, the receiver cannot 'see' the light from the transmitter and a sunlight saturation prevention circuit is automatically matched to the receiver. Data transmission rate is in the 2.4 to 115kb/s range. Microelectronics Technology Ltd. Tel., 01844 278781; fax, 01844 278746.

Power semiconductors

Rf power. New from Motorola, the *MRF927T1* rf power n-p-n silicon transistor for low-voltage, low-current use, particularly in pagers and hand-held telephones. It operates in the 2GHz region and exhibits an 8GHz gain./bandwidth product at 3V, 5mA. Unilateral gain is 15dB and noise figure 1.7dB. The company also offers the *MRF6401* rf power device, specified with a gain of 10dB minimum at 1.66GHz, output power 0.5W. Motorola Semiconducteurs SA. Tel., 001 33 61 199981; fax, 001 33 61 199565.

PASSIVE

Passive components

Transformers for valves. Variable Voltage Technology offers the *VTM* range of transformers intended for use with valves. They are designed for valve-age but using modern methods and materials such as annealed copper wire and grain-oriented laminations. All meet emc and low-voltage directives and are CE marked where appropriate. The transformers are either frame or vertically mounted and are for use as mains transformers for ht, with or

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without heater windings; as heater transformers; as mains smoothing chokes; or as output transformers for triodes, pentodes or in ultralinear mode using EL34 and EL84. Variable Voltage Technology Ltd. Tel., 01983 280592; fax, 01983 280593.

Thin inductors. TDK's *NLU* series of thin-film, surface-mounted inductors are for 1-3GHz application and are only 0.58mm thick. The copper spiral inductors are available in values from 1.2nH to 100nH and come in the 0805 and 0603 sizes for flow and reflow soldering. Flint Distribution. Tel., 01530 510333; fax, 01530 510275.

Resistor networks. *BCN 16 4A* resistor networks in the 1206 size are eight-terminal units containing four isolated resistors, with either internal or external termination. Resistance range is 10Ω to 1MΩ at a tolerance of ±5%, with ±2% also available. BI Technologies Ltd. Tel., 01384 442393; fax, 01384 440252.

Emc chokes. Wearnes Hollingsworth offers a range of common-mode chokes, which are designed to prevent noise entering or leaving equipment by way of power or signal lines, all to do with the current preoccupation with electromagnetic compatibility. Both standard and custom-made chokes are available, mainly using toroidal cores of iron powder, ferrite or amorphous alloy, in sizes from 3mm to 30mm diameter. Inductance values are in the 1-100µH range and they operate at frequencies to 30MHz. Wearnes Hollingsworth Ltd. Tel., 01433 621555; fax, 01433 621290.

Audio connectors. Cliff Electronics has a range of audio connectors and terminations, including the *Plastic XLR* range of light, three-pole plugs and sockets for audio connection, in cable, panel and pcb mounting forms. All are mateable with the metal-bodied XLR connectors and all have cable strain-relief and silver-over-nickel-plate brass contacts rated at 16A, 250Vac. there is also the *Clifcon* series of four-pole locking connectors for use in professional audio systems and instrumentation. In addition, the *Quick Connect* terminals are for loudspeakers, having spring-loaded levers to trap the wire in the terminal. Electrospeed. Tel., 01703 644555; fax, 01703 610282.

Vari-C diodes. Variable-capacitance diodes from Zetex in the SOT-23 *ZC930* range give octave tuning from a 1-4V voltage change. At 1V, the seven devices in the range have a minimum capacitance range of 8.7pF to 95pF; as an example, the *ZC932* gives 17pF at 1V and 5.5pF at 4V, with a 'hyperabrupt' *C/V* characteristic. Stray capacitance is 0.08pF and lead inductance 2.8nH. Zetex plc. Tel., 0161 627 5105; fax, 0161 627 5467.

Small trimmer capacitors. *TZVX2* series capacitors by Murata measure 2.3 by 3.2 by 1.2mm, which makes them, says Murata, the world's smallest trimmers. The capacitance range is 2.5-20pF in five values, with temperature stability 0±300ppm/°C for 2.5-10pF and -750±500ppm/°C for 20pF. Settling drift is said to be extremely low. Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

Connectors and cabling

Two-in-one optical fibre connector. Molex *SC* optical-fibre connectors use two NTT-SC standard connectors in one housing. Insertion loss is typically under 0.15dB for single-mode and below 0.34dB for multi-mode. The connectors are available in flange or snap-mounting versions. Molex Electronics Ltd. Tel., 01420 477070; fax, 01420 478185.

Solderless coax. connectors. Transradio offers the *Coaxipress* range of coaxial connectors fitted with solderless, press-fit terminations, for use in existing plated-through holes in diameters from 0.94mm to 1.09mm on 1.6-7mm board material. Designs are available for MCX, SMB and DIN series of miniature connectors with right angles or straight receptacles. Detailed procedures for insertion and removal, and information on tooling are available. Transradio Ltd. Tel., 0181–997 8880; fax, 0181–997 0116.

Displays

Better tft lcds. Major features of Sharp's *Super-V* lcd 13.8in XGA module are a 140° horizontal viewing angle, 250cd/m^2 brightness, 300:1 contrast and 10W power consumption. The module is only a quarter the weight, a third the thickness and uses a fifth the power of a crt of the same size. Sharp Electronics (Europe) GmbH. Tel., 0049 040 2376 2215; fax, 0049 040 2376 2991.

Test and measurement

Dso with 'analogue' display. Aside from its other claims to fame, Gould's *Classic 6000* 4-channel, 200MHz digital storage oscilloscope has TruTrace, which is a technique to make the dso traces look like those on an analogue instrument, with variable intensity. This allows fine details, normally invisible on the usual dso display, to be seen; particularly useful for complicated signals in noise. The instrument has a range of options, from a low-end monochrome model up to a colour type with mass storage, auto sequencing and maths functions. Up to eight traces can be viewed simultaneously, to allow live traces on four channels to be compared with four reference traces or zoomed versions. Sampling rate is 100Msample/s and basic, segmentable memory 10k/channel with options of 50k or 200k. Gould Instrument Systems Ltd. Tel., 0181 500 1000; fax, 0181 501 0116.

Line-impedance stabiliser. Thurlby Thandar offers the *LISN1600*, a line-impedance stabilisation network, to measure the level of conducted emissions at the supply of electrical equipment operating from a single-phase ac supply. It works with a spectrum analyser or measuring receiver to allow these measurements to be done without the need for test-house facilities. Its current rating is 16A continuous and various output connectors are available. The instrument meets CISPR16 for Band A measurement of 10-150kHz and Band B in the range 150kHz-30MHz. A switchable 150kHz filter limits lf signals in Band B to reduce the dynamic range requirements. Connection is to either supply line, or the unit can be disconnected to check noise floor. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

Differential oscilloscopes. *OX802* and *OX8022* differential oscilloscopes by Metrix are believed to be the only differential types available. Both are 20MHz instruments; *OX802* is an analogue model, while the *8022* will also work in digital mode at a 40Msample/s rate. Both operate in normal or differential mode, the diff. inputs giving true floating measurement and channel-to-channel isolation. A maximum input voltage of 500Vrms and the diff. inputs enable direct examination of single and three-phase mains voltage. Conversely, a sensitivity of 10mV.div is available for small signal work. The *8022*'s digital facilities include roll, refresh and single shot, a pre-trigger in steps of 1Kword from 0 to 4Kword, a 2 by 4Kword memory and an RS232 port. Metrix Electronics plc. Tel., 01384 402731; fax, 01384 402732.

20MHz and 50MHz rsos. Two low-cost real-time and storage oscilloscopes from Hitachi Denshi, the *VC-6523* and *VC-6524* have hard copy by way of a plotter interface and waveform transfer via an RS232 interface. Bandwidths are 10MHz (6523) and 50MHz with sampling rates of 20Msample/s and 2kword/channel memory. Two waveforms may be captured and saved for 72 hours or longer if mains power has been used. Both offer roll mode, averaging, smoothing, interpolation and pre-trigger. Hitachi Denshi (UK) Ltd. Tel., 0181 202 4311; fax, 0181 202 2451.

Paperless chart recorder. Yokogawa's *VR100* chart recorder is a paperless type using 3.5in floppy disks and samples at 125ms with 14-bit resolution. Display is a 320-by-240 pixel, 5.5in colour tft lcd, showing the data in a variety of forms with split-screen, magnification and reduction. Data is saved continuously in the built-in memory and is saved to disk at any time, each disk holding up to a month's recording of four channels with samples at 60s intervals. Software enables interaction with Windows and Lotus 1-2-3, Excel or Ascii files are supported. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002.

Low-cost, 20MHz oscilloscope. Leader offers the *LS1020* 20MHz, dual-trace oscilloscope, which has a maximum Y sensitivity of 0.5mV/div and sweeps at 50ns/div. Trigger modes include alt. trigger, which allows a stable display of non-synchronous signals on both channels at the same time; hold-off time is variable from the start to the end of a sweep. One channel can be used as an amplifier to provide 50mV/div output and the two channels can be used to give an XY display. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

Emc tester. Newly announced by Schaffner is *BEST 96*, which is a complete electromagnetic compatibility test set in one box, providing all the functions needed to for full EU compliance of electronic products; CE mark pre-compliance and compliance testing can be carried out in-house. The set comprises a generator to give burst, electrostatic discharge, surge and power quality pulses for single-phase powerline and dataline compliance test to EN-50082-1, plus ground plane, cables, ground strap and resistor and coupling clamp for dataline test. All functions are controllable from the front panel or remotely using Windows software. Schaffner EMC Ltd. Tel., 0118 9770070; fax, 0118 9792969

Literature

Suppression filters. Murata's 108-page catalogue on suppression filters and ferrites has much data on other emi products, including applications a list of emi kits and a guide to noise suppression. Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

Emc filters. Arcotronics, specialising in emc filters, has a new catalogue, which contains an informative introduction to the filters and their characteristics and complete electrical and mechanical data on the range on offer. The catalogue is available free. Arcotronics Ltd. Tel., 01327 351515; fax, 01327 353761.

Relays, switches, etc. A new edition of the Hhv short catalogue of thermal overload and circuit protection devices is available. New this time are extensions to the thermal circuit breaker range and new ranges of power relays and rocker switches. One of the relays is the miniature (1in cube) normally open type 691, which switches 30A at 240V, equivalent to a 2hp motor. Hhv Components Ltd. Tel., 01543 416667; fax, 01543 416140.

Fpga data book. Actel offers, free, the *FPGA Data Book and Design Guide* for anyone considering using Actel programmable logic arrays. Apart from technical details of fpgas and development tools, there is information on the Designer Series development system, which allows the specification of delay through logic blocks. Application notes on design and software tools are also included. It can be obtained through the company's web site on http:/www.actel.com. Actel Europe Ltd. Tel., 01256 29209; fax, 01256 55420.

Production equipment

Soldering system. From Production Equipment Sales, the *AS 2000* industrial five-axis automated soldering system for post-process work. It is an in-line conveyorised station, using a high-speed positioning system and multi-tasking computer control to cope with all automated soldering applications including thermally sensitive components, flexible circuitry, connectors and others that cannot be mass reflowed or wave soldered. Temperature control is ±3°C with a programmable dwell time in milliseconds. An RS232 port allows communication to a computer, soldering routines being taught or derived from cad data. Production Equipment Sales Ltd. Tel., 01825 766644; fax, 01825 766464

Power supplies

Switching regulators. Semtech's *LM2575/2576* 1A and 3A miniconverter switchers are pin-compatible with National's devices. They are buck or buck/boost converters needing only four external components to provide fixed or adjustable outputs in the 3.3–35V range. Input is 40V and efficiency 82% at 5V. Semtech Ltd. Tel., 01592 773520; fax, 01592 774781.

Wide-range dc converters. The *Mascot* dc-to-dc converter range accepts all common input voltages from 6V up to 140V. Sixteen models, both linear and switched-mode types, provide all the usual voltage outputs, some being adjustable, at powers from 27W to 158W. For demanding application, there are four models with inputs and outputs isolated from each other and ground. Inputs and outputs are all fully protected against acts of God and absentmindedness. Relec Electronics Ltd. Tel., 01962 863141; fax, 01962 855987.

Low-noise dc converters. Interpoint claims that its *MHV* series of single and dual output dc-to-dc converters have the lowest output noise in the military/aerospace industry, at 10mV. Input range is 16-50V and the choice of outputs is 3.3, 5, 12, 15, ±5, ±12 and ±15V and the units will cope with transients of up to 80V for 120ms. Interpoint UK Ltd. Tel., 01252 815511; fax, 01252 815577.

Cv/ci battery charger. The Linear Technology *LT1511* current-mode pwm battery charger ic will charge a battery pack while the equipment it is powering continues to work, a control loop in the charger regulating current drawn to allow rapid charging without overwhelming to power-management chip. The ic is 90% efficient and gives 3A out for all popular battery types, operating from an input of 8-28Vdc. Micro Call Ltd. Tel., 01844 261939; fax, 01844 261678.

Temperature-stable zener regulator. Zetex has augmented its wide range of adjustable shunt regulators with an extended temperature version of the *ZR431*, claiming the widest temperature range available for this type of device. The *ZHT431* copes with temperatures from –55°C to 125°C, a 44% increase on the typical range. It is temp. compensated over its whole working range and has a temperature coefficient of 50ppm/°C. Tolerance is 1% or 2% and quiescent current 35μA. The device is simply programmed between 2.5V and 20V by two resistors. Package is the ultra small SOT23, but the SOT223 and SO8 surface mounts are also available. There is also a through-hole TO92 type. Zetex plc. Tel., 0161–627 5105; fax, 0161–627 5467.

Radio communications

Synthesised video Tx/Rx. Mainly for use in security applications, Wood & Douglas's *VFMT-2/VFMR-2* uhf transmitter and receiver modules offer comparable performance to that found in crystal-controlled equipment, with the advantage that frequencies are programmable. The units are in separate aluminium cases and provide a mid-range video link over a line-of-sight 20km range. Working in the 280-500MHz band, the units provide two sound channels for line or microphone level; frequencies, which are stored in eeprom for front-panel programming, are selected by internal switches, up to four video channels being available over a 50MHz operating range. Two versions of the transmitter have rf output of 2.5W or 8W. Wood and Douglas Ltd. Tel., 01734 811444; fax, 01734 811567.

Protection devices

SCSI circuit breaker. Designed particularly for 5V SCSI application or any system needing 1.5A hot plug protection, Unitrode's *UCC3916* fixed trip-current circuit breaker provide unidirectional current flow, to emulated a series diode, and limiting in an 8-pin SOIC package. It replaces fuse/diode protection, providing a more accurate threshold and more rapid response. Trip current is 1.65A and has a programmed maximum current of 2.1A. Unitrode (UK) Ltd. Tel., 0181 318 1431; fax, 0181 318 2549.

Surface-mounted inductors. Toko's new *D10F* range of s-m inductors is now obtainable from Cirkit. The inductors measure 9.7mm in diameter and 5mm in height and come in values from 10μH to 1.5mH in current ratings of 0.25-2.6A. A magnetically shielded version is also available. Mounting pads are separate from the coil terminations to eliminate strain on the windings. Cirkit Distribution Ltd. Tel., 01992 444111; fax, 01992 464457.

Switches and relays

10mm reed switch. *Mini-DYAD* reed switches by C P Clare resist damage when leads are formed for mounting and exhibit a switching speed of 0.5ms. They carry 2A and switch 0.5A at 200V. C P Clare International NV. Tel., 0032 12/39 04 00; fax, 0032 12/23 57 54.

Transducers and sensors

Inclinometer. *Model 1D* is a £74 digital tilt sensor by Control Transducers, used to show the angle of an object with respect to gravity. Output is ttl in two or three channels, suited to equipment designed to ensure, for example, the machinery is level or that off-road vehicles or cranes are not going to topple over. An optical encoder disc, resolving to 0.25°, 0.1° or 0.05° is supported by two micro ball bearings, a weight on the disc causing it to take up a constant position with respect to gravity. Internal magnetic damping provides fast response and minimises oscillations of the disc after a disturbance. Power needed is 5Vdc at 40mA maximum. Control Transducers. Tel., 01234 217704; fax, 01234 217083.

Crash accelerometer. The *7264B-2000* piezoresistive accelerometer from Endevco weighs 1gram and has integral mechanical stops to enable the unit to survive 10,000g shocks in all axes. It is designed for rough road testing, flight tests and tests where a perfectly good vehicle is driven full tilt into a concrete wall, in which the small size of the accelerometer allows it to be put into a dummy person without altering its mass too much. The unit is undamped and produces minimum phase shift over its useful frequency range of 0–5kHz. Endevco UK Ltd. Tel., 01763 261311; fax, 01763 261120.

S-m pressure sensors. *MPXS4100A* is the first in a new family of surface-mounted pressure sensors from Motorola, this one handling 20-105kPa absolute (manifold or barometric) pressure and incorporating bipolar amplifier circuitry and thin-film resistor networks for high output and temperature compensation. Motorola Semiconductors. Tel., 01355 565000; fax, 01355 234582.

Hall-effect latch. Allegro has the *A3197LU*, a protected open-collector Hall-effect latcg ic for operation in the temperature range –40°C to 150°C. It senses magnetic fields in applications such as vehicle transmission speed sensing and wheel bearing speed sensors, the latching assisting in pulse counting when used with a multi-pole ring magnet. Position and speed information are provided by a digital output when the field exceeds predefined switch points, which are stable against temperature and voltage variation. The transducer is followed by a temperature-compensated comparator, a regulator and 35mA output buffer. Allegro MicroSystems Inc. Tel., 01932 253355; fax, 01932 246622.

Position sensor. Monitran's sensing probes in the *MTN/EP* range measure distances up to 8.5mm without contact with the moving target. An eddy current technique is used in which hf is radiated into the target and currents set. After signal conditioning, the gap is represented as a dc level, or an ac signal if the gap varies, as in a gear wheel. All models have stainless steel threaded bodies with securing nuts and armoured cable and the range covers gap measurement from 0-2mm to 0-8.5mm. Monitran also offers an eddy current driver. Monitran Ltd. Tel., 01494 816569; fax, 01494 812256.

COMPUTER

Computer board-level products

486 cpu card. By IMS, the *PCA-6144V* is a full-function, half-sized 486DX/DX2/DX4 cpu card with VGA display and other enhanced i/o interfaces. There is a local-bus VGA controller with Windows accelerator and 1Mbyte of display memory and the card takes up to 64Mbyte of on-board dram and a secondary-level cache of 128Kbyte. Other interfaces are an enhanced IDE hd controller, floppy controller, PC/104 interface bus connector for expansion, RS232 and RS232/485 ports, a parallel port and a PS/2 mouse connector. This is an industrial grade card. Integrated Measurement Systems Ltd. Tel., 01703 771143; fax, 01703 704301.

Computer

Industrial workstation. Fairchild's *AWS-822* is a fully specified, rack-mounted pc for use on the factory floor, fully sealed against dust and water, shock mounted and pretty well human-proof. There is a 14in monitor and a membrane keypad on the front panel containing 37 keys, which may be combined with a conventional AT-type keyboard plugged into the panel. Fairchild Ltd. Tel., 01703 211789; fax, 01703 211678.

Software

Autorouter for EASY-PC. Designed for use with Number One Systems' EASY-PC Professional XM, *MultiRouter* offers a number of features that make it, in spite of its £295 price, equivalent to much more expensive packages. For example, it is not based on a grid, but on shapes, s that components whose pins do not lie on a grid can still be used. Tracks can be pushed aside to let more through, providing this can be physically done. Routing is usually 100%, and if not, further passes are very rapid. Track widths and corners are made suitable for production and vias and track lengths are minimised, vias being eliminated for one-off boards, if required. Number One Systems Ltd. Tel., 01480 461778; fax, 01480 494042.

Bootstrap for *C16x* microcontrollers. Hitex offers this utility to allow embedded communication, test and programming of a microcontroller with a pc via its serial port and is meant for the Slemens *C16x* Flash devices. It runs with Windows and uses the pc link to communicate with the device and allows reading of registers to confirm selected bus modes; reads and writes to external memory to test address and data bits; programs the application into the Flash; and programs external Flash. Extensive testing can then be carried out. Hitex (UK) Ltd. Tel., 01203 692066; fax, 01203 692131.

MicroSim Schematics v. 6.3. Enhancements in this new version of MicroSim's Windows-based analogue and mixed-signal design and development software include a graphical parts browser, error traceback and 'wizards' to make symbols and goal functions, expanded libraries and improved Windows 95 and NT network licensing. The browser has a 40,000-part symbol library, accessible by name, number or description in seconds with a window to show its graphic before it is selected. Error traceback features a pop-up window to give warning of errors during netlisting, packaging, etc.; double-clicking on the message moves the cursor to the problem on the circuit diagram. If the penny has still not dropped, a more detailed message will appear. MicroSim Corporation. Tel., 001 714 770–3022; fax, 001 714 455–0554.

Programming hardware

Low-cost programmers. Two new programmers from ICE, the *Speedmaster 1000+*, which handles eproms and pals, and the *Micromaster 1000+*, taking eproms, pals, plds and micros, sell at £395 and £525 respectively, both being easily upgraded to cope with more devices and to support LV devices with a voltage down to 1.8V. No adaptors are needed for dil devices with up to 40 pins and adaptors are available for other packages. All are compatible with the company's built-in rom/ram emulator upgrade and also include chip test for ttl, cmos, dram ans sram. Ice's home page is on http:/www/icetech.com. ICE Technology Ltd. Tel., 01226 767404; fax, 01226 370434.

DASY*Lab* v.3. DASY*Lab*, the Windows-based data-acquisition package, is now in version 3, with many improvements. There are better trigger functions, to ease the definition of pre-trigger and post-trigger data to specify the area of interest; *VITool* allows a test rig or process to be visualised and documented, with icons combined with bitmap images, control buttons, switches and text to mimic the process; global strings allow sample or product batch data to be entered directly or via dde and stored in a single file with raw data and derived values. The package is in two versions: a basic edition and the extended form with *VITool*. Adept Scientific Micro Systems Ltd. Tel., 01462 480055; fax, 01462 480213. ■

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NEW HIGH POWER MINI BUG With a range of 800 metres or more and up to 100 hours use from a PP3 this will be popular! Bug measures less than 1" square! £28 Ref LOT102.

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WIRELESS VIDEO BUG KIT Transmits video and audio signals from a minature CCTV camera (included) to any standard television! All the components including a PP3 battery will fit into a cigarette packet with the lens requiring a hole about 3mm diameter. Supplied with telescopic aerial but a piece of wire about 4" long will still give a range of up to 100 metres. A single PP3 will probably give less than 1 hours use. £99 REF EP79. (probably not licensable!)

CCTV CAMERA MODULES 46X70X29mm, 30 grams, 12v 100mA. auto electronic shutter, 3.6mm F2 lens, CCIR, 512x492 pixels, video output is 1v p-p (75 ohm). Works directly into a scart or video input on a tv or video. IR sensitive. £79.95 ref EF137.

IR LAMP KIT Suitable for the above camera enables the camera to be used in total darkness! £5.99 ref EF138.

REMOTE CONTROLTANDATA TD1400 MODEM/ VIEWDATA Complete system comprising 1200/75 modem, auto dialler, infra red remote keyboard, (could be adapted for PC use?) psu. UHF and RGB output, phone lead, RS232 output, composite output. Absolute bargain for parts alone!! £9.95 ref BAR33.

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Double beam units designed to fit in the gun barrel of a tank, each unit has two semi conductor lasers and motor drive units for alignement. 7 mile range, full circuit diagrams, new price £50,000? us? £349. Each unit has two gallium Arsenide injection lasers, 1 x 9 watt, 1 x 3 watt, 900nm wavelength, 28vdc, 600hz pulse frequency. The units also contain an electronic receiver to detect reflected signals from targets. five or more units £299 ea. £349 for one. Ref LOT4.

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COIN OPERATED TIMER KIT Complete with coinslot mechanism, adjustable time delay, relay output, put a coinslot on anything you like! TV.s, videos, fridges, drinks cupboards, HIFI, takes 50p's and £1 coins. DC operated, price just £7.99 ref BAR27.

ZENITH 900 X MAGNIFICATION MICROSCOPE Zoom, metal construction, built in light, shrimp farm, group viewing screen, lots of accessories. £29 ref ANAYLT.

AA NICAD PACK Pack of 4 tagged AA nicads £2.99 ref BAR34

PLASMA SCREENS 222x310mm, no data hence £4.99 ref BAR67

NIGHTSIGHTS Model TZS4 with Infra red illuminator, views up to 75 metres in full darkness in infrared mode, 150m range, 45mm lens, 13 deg angle of view, focussing range 1.5m to infinity. 2 AA batteries required. 950g weight. £199 ref BAR61. 1 years warranty

LIQUID CRYSTAL DISPLAYS Bargain prices,
16 character 2 line, 99x24mm £2.99 ref SM1623A
20 character 2 line, 83x19mm £3.99 ref SM2020A
16 character 4 line, 62x25mm £5.99 ref SMC1640A

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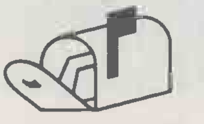

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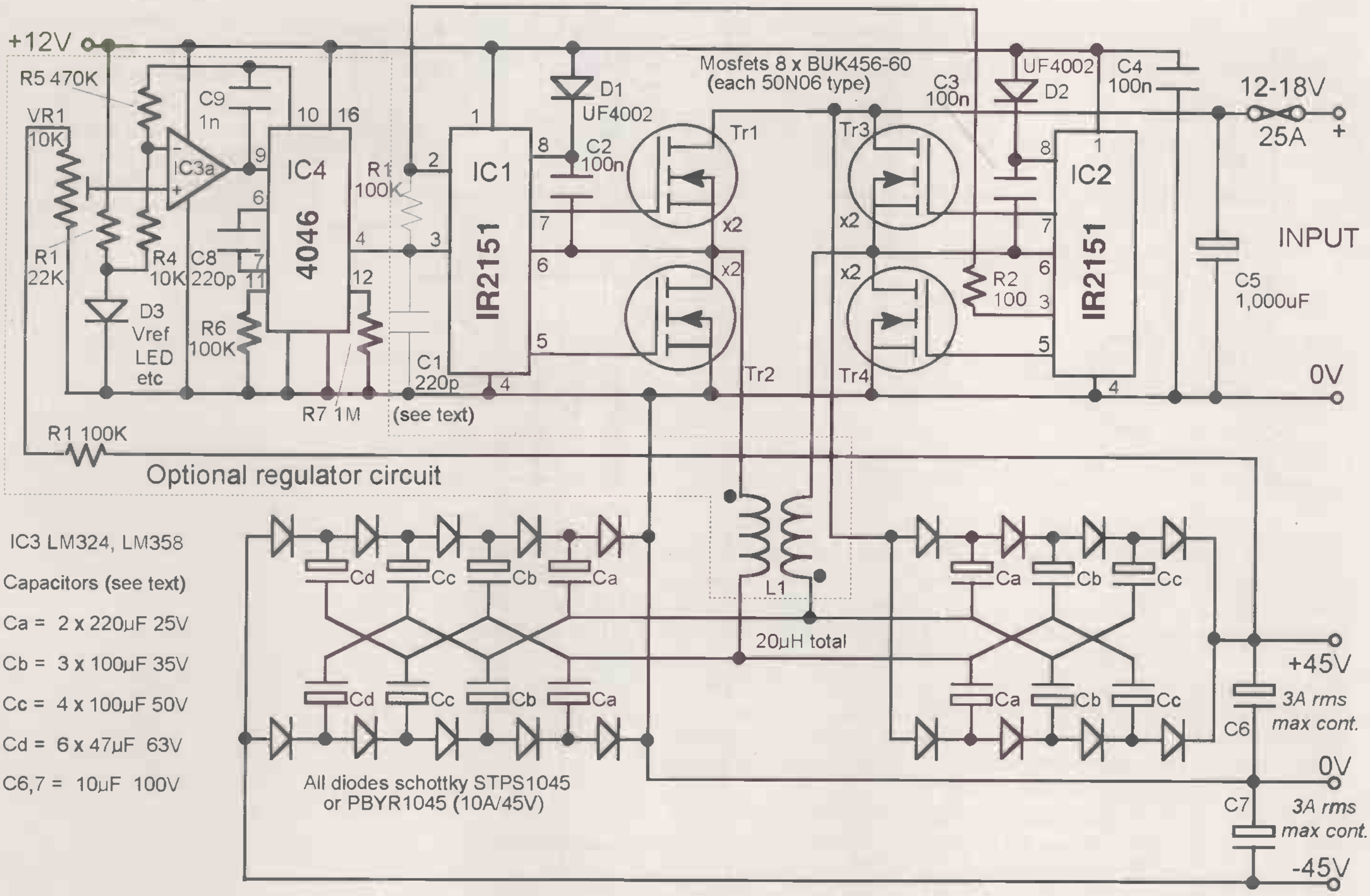

Fig. 7. 300W voltage multiplier featuring over 90% efficiency. It can be used to supply a standard 100W split rail amplifier using a 12V source.

...continued from page 797

dropped. Both methods give the same losses; the same as adding series resistance or a series regulator, which is inefficient with large voltage drops.

I concluded that the only way to efficiently vary the output voltage over a wide range is to use an a inductor, either a separate switching regulator, or as part of the multiplier. The latter method was chosen, where a series inductor is inserted between the dc-to-dc converter and the multiplier.

This method of efficient regulation is possible, but only over a limited current range down to about 10 or 20% of full load. This is because frequency is increased to reduce the output current. In turn, this increases gate drive losses at light loads which pulls efficiency down. This places a practical limit on the upper frequency of around 200kHz.

The inductor value is chosen so only a small fraction of the output voltage, around 1V or 2%, is lost at full load where frequency is at its lowest. A relatively small air-cored coil is sufficient, similar to two Zobel inductors but bifilar wound It should consist of dual seven-turn coils of 1.3mm wire on a 20mm former. Note the connection polarities.

Efficiency at half full voltage, i.e. a quarter of full power, is around 90%. The other methods mentioned above are 50% efficient. If independent regulation of the plus and minus rails is required then two single mosfet H bridges are needed. A separate regulator circuit including a level shifted feedback signal is needed, via an opto-coupler for example.

If regulation down to no load is required, a low drop-out linear pre-regulator can regulate from the point where the main regulator loses regulation. In this way dissipation in the series regulator will be at most $^1/_{25}$th of full output power. **In Fig. 8a**, both low-side mosfets $Tr_{2,4}$ can be used as regulators by controlling their on resistance at low loads. However, output capacitances C_6 and C_7 need to be 22µF or more to ensure linear regulation rather than burst or on-off regulation. Burst regulation can generate annoying interference in the audio range for some applications.

Figure 8b can be used where the fm regulator and inductor are omitted. A 2.2kΩ resistor is placed in the emitter of the feedback transistor to ensure linear operation. Output capacitors C_6 and C_7 should be at least 10µF.

These additions prevent the multipliers capacitors and/or diodes from being destroyed if the input voltage rises too high. The ratings of the diodes and capacitors can be rated closer to levels for normal output which reduces size and cost.

A *4046* voltage-controlled oscillator is used with an op-amp for closed loop voltage regulation. The full load (minimum) frequency is set with R_7 and the light load (maximum) frequency is set with R_6 to 100kHz in my circuit. With the improved full-wave multiplier, voltage regulation and response time is very good since only a minimal value of output capacitance is required to remove ripple due to dead-time in the H bridge – about 10% of the multipliers capacitance. Again, 10µF is sufficient. However, if the output capacitance is too large, the feedback loop may become unstable and require lag-lead compensation around IC_{3a}. Capacitor C_9 speeds up the oscillator's voltage follower and provides some overall loop phase advance.

Transient response time for a multiplier is related to the number of stages. Output increases from 0V at start up in an exponential way. The time constant was noted to be equal to *n* times the oscillators period. Here, *n* here is the number of multiplier stages. For example, four stages with an input frequency of 20kHz has a time constant of 200µs, which can be represented by a pole at 796Hz.

A multiplier for high voltage

The combination of a multiplier and transformer allows extremely high voltage dc to be generated – far higher than a transformer with a simple rectifier can achieve due to the limitation of secondary winding capacitance. The multiplier in **Fig. 9** has been used to generate 160kV from 12V using two pentuplers parallel fed similar to Fig. 7. Feeding two multipliers in this way reduces the number of charge transfers and the size of capacitors.

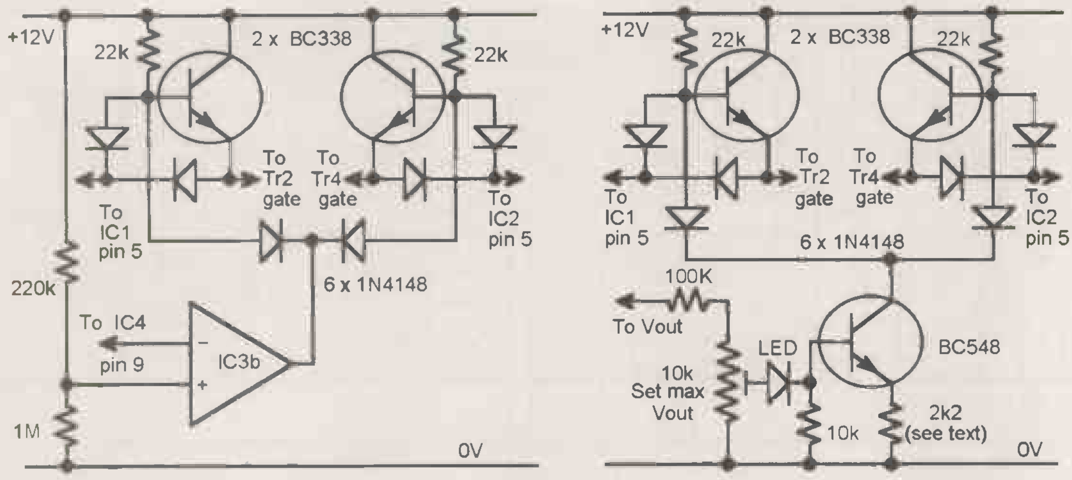

Fig. 8a) Add on circuit for Fig. 7 controls on resistance of the low side mosfets for over-voltage protection of capacitors and diodes. In b), also an add on for Fig. 7, the inductor regulator is not used.

Since the secondary is isolated, any one of the three output terminals can be earthed. This gives the option of either a positive supply, a minus supply, or a split supply. The secondary of a television line transformer provides 16kV peak with five turns on the primary using a an ht lead that can withstand 80kV. Alternatively 2mm thick SCL tubing from Raychem Corporation can be applied to normal wire.

Secondary resonance at around 30kHz is used to advantage to lift the secondary voltage from $3kV_{pk-pk}$ to 16kV. Varying the frequency from above, or below, resonance can be used for voltage control. A string of *BYV96E* 1.5A/1kV avalanche rated diodes – all 384 of them – were used to prevent over-voltage destroying diodes and capacitors by acting like zener diodes. Although the circuit in Fig. 4 can reduce the diode count to 192, the full-wave version provides a low ripple dc output without the very high voltage output capacitor in Fig. 4.

Note that the resistors in the output prevent high peak currents from damaging the diodes if the terminals flash over or are shorted. For those of you wanting to design a high voltage converter and experiment with the effects of high voltage dc, Reference 4 is a good starter. Take care with this converter – high peak currents can be delivered from the capacitors and discharge capacitors after use. When the centre rail is not earthed, the transformer core must be isolated to withstand 80kV to ground.

A provisional patent on the improved full-wave multiplier, regulator and high voltage generator has been filed[5]. Intellectual property enquiries should be directed through Intellpro, GPO Box 1339, Brisbane 4001, Australia, Fax +61 7 3221 4762. Experimenters are free to use these circuits for non-commercial purposes. ■

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3. Ralph E. Tarter, Solid State Power Conversion Handbook, Wiley 1993, pp 244-251.
4. Robert E. Iannini, Build your own working Fibre-optic, Infrared & Laser space-age projects, 1987 TAB Books, pp 229-255, ISBN 0 8306 2724 3 (pbk).
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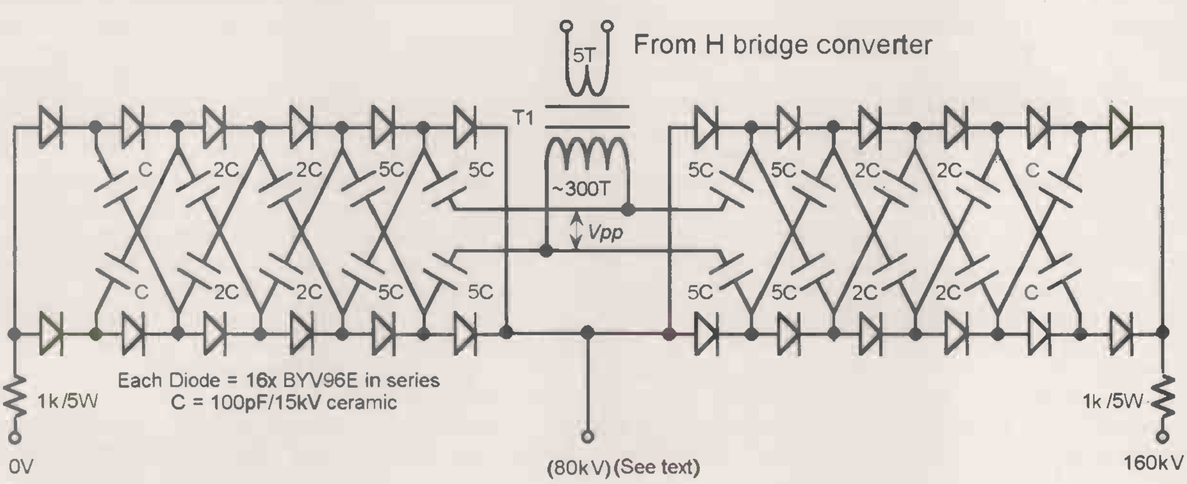

Fig. 9. This 160kV multiplier, made up from two pentuplers in parallel, outputs up to 100W. Compared with conventional designs, it is more efficient and uses fewer components

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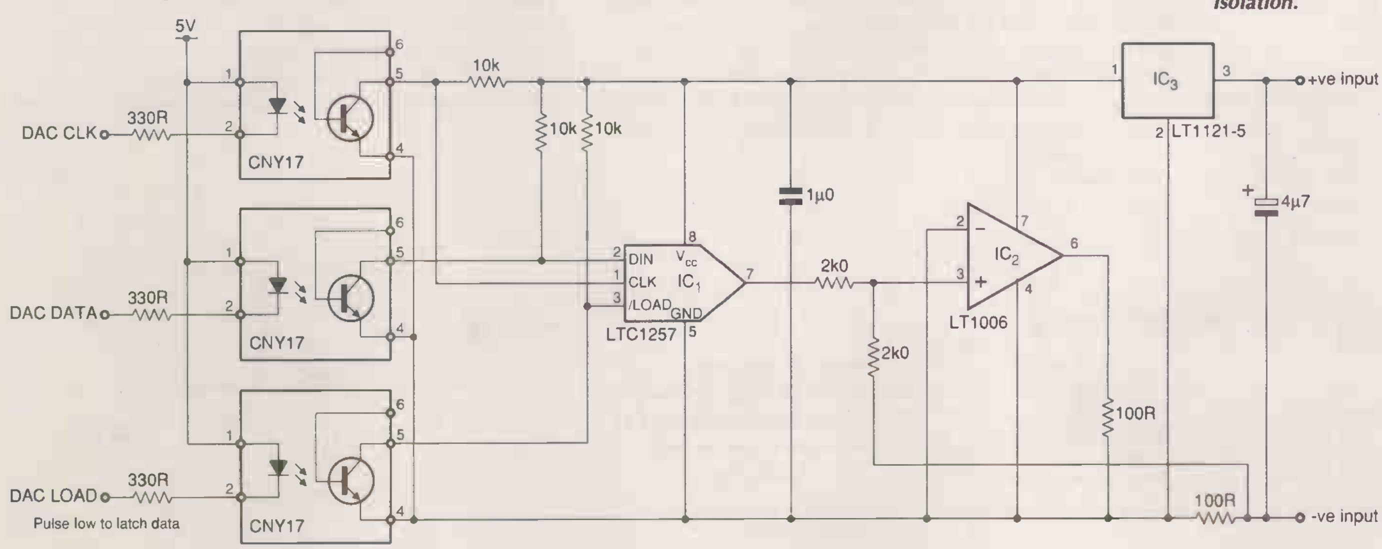
Simple, isolated, 12-bit current loop

A 4-20mA analogue current loop is the recognised method of transmitting signal between instruments in the presence of noise. This circuit provides a simple, isolated interface.

Digital data, by way of the *CNY17* low-cost opto-isolator, go to the *LTC1257* digital-to-analogue converter, which is controlled by an external processor through the other isolators and contains a 2.048V reference. Pull-up resistors of 10kΩ are needed to give less than 4mA total current consumption, which limits bit rate to around 1kHz. The d-to-a converter gives 500μV/count into the *LT1006*, which supplies 10μA/count to the loop. If a different op-amp is to be used, it must operate with both inputs near the negative rail and source nearly 20mA.

Mark McLean
Skelmersdale
Lancashire

This 4-20mA current loop for low-speed operation features optical isolation.



Message module

ICs in the *SD10XX* range, made by Information Storage Devices in San Jose, store analogue information in non-volatile eeprom cells with no data conversion. They include a microphone amplifier, agc, antialiasing and smoothing filters and a 50mW speaker amplifier. A general-purpose message module based on one of these chips will record and play back messages from 12s to 60s. A message can be re-recorded many thousands of times and the device retains the message for years.

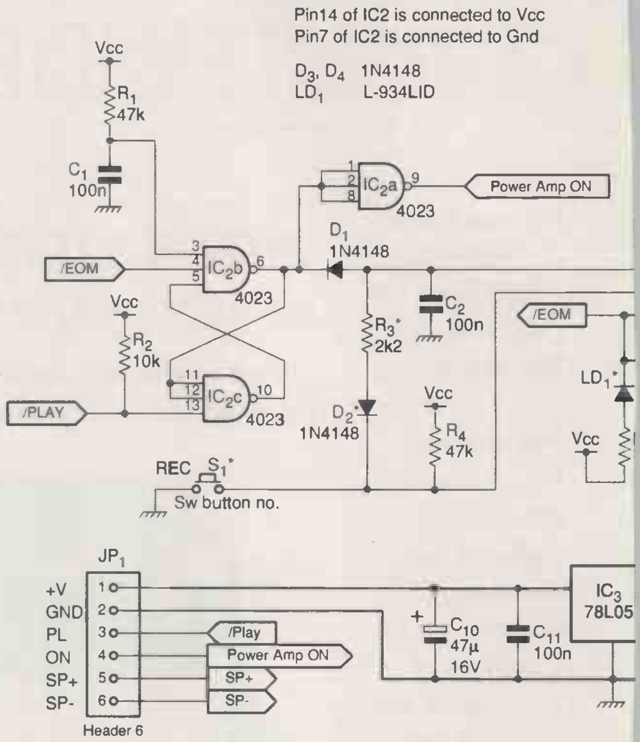
The analogue part of the circuit shown is based on the data sheet, while the rest consists of a 4023 Nand for chip control to simplify operation.

Input to the /CE pin is always held low; the s/r latch drives the power-down input, which is normally high to reset the chip, R_1C_1 ensuring correct initial conditions.

Pressing the record switch takes the play/record input low, power-down goes low and the device starts to record microphone input, the process stopping when the switch button is released; if the led comes on, the memory filled up, part of the message was lost and should be done again.

If the Play input on the header goes low, the message is played back and repeated once if the signal is still low. During this time, the power-on amp output is high and is usable to control an external amplifier.

Audio power of 50mW to a 16Ω speaker – or an 8Ω one with 10Ω in series – comes from the SP+/- outputs. To drive an external speaker, use SP+ and disconnect SP-. Do avoid shorting the two or grounding them, since disaster will inevitably ensue. Power consumption is 2.4mA when idling, 18mA recording and 21-60mA during playback.



Costas Toufexis
Athens
Greece

Diac lamp flasher

While the bimetallic switch is difficult to beat from the expense point of view, this diac flasher circuit offers some advantages in that the flash rate and number of lights are variable, it has a longer life expectancy and it accepts any mains voltage from 110V ac to 250V ac. With one or two limitations, it can be assembled inside a mains plug.

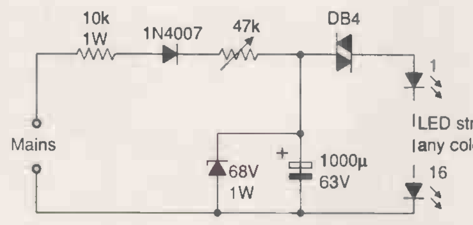
The zener diode prevents capacitor overcharging, should the chain be interrupted or fed from a different mains socket; zener and capacitor voltage are determined by the number of leds x in $1.5(V_{diac}+x)$.

Flashing frequency depends on the number of leds, the mains voltage and the *RC* combination. On 220V mains and with 16 leds, the circuit shown flashes with a period adjustable from 1.1s to 4.3s, giving a 0.5s flash.

If the circuit is to go in a mains plug, you might need to use a smaller capacitor, giving a lower light output, and a fixed resistor.

D Di Mario
Milan
Italy

Note – without proper mains isolation and insulation, this circuit is deadly – Ed.



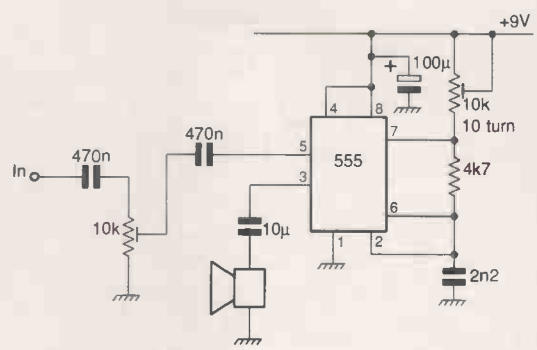
More flexible than a bimetallic strip, this lamp flasher for warning signs or decoration can be built into a mains plug.

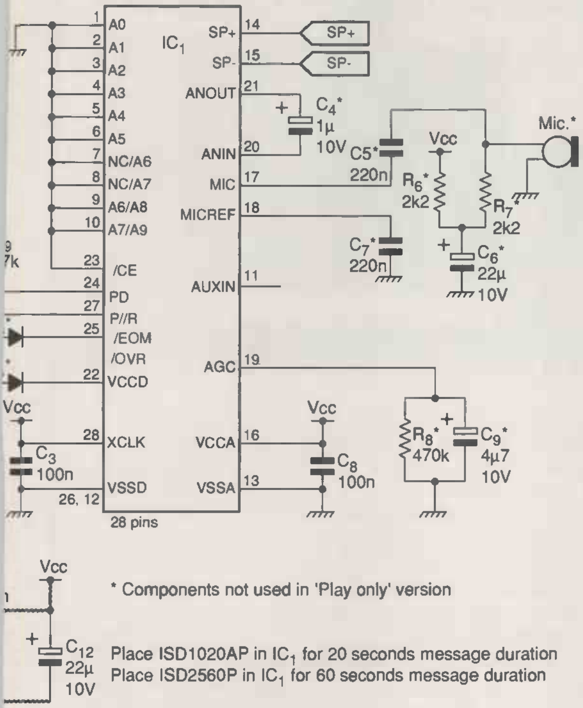
Fm communicator for under-water use

Intended for use in underwater communications, though not yet tried in that role, this transmitter and receiver operates on 32kHz. For reception, the if and detector section of a GEC Plessey SL6652 is used, together with the rssi output, which provides a stable 90dB-range log. signal.

The transmitter uses a 555 to produce a frequency-modulated output to the transducer under the control of the audio input to pin 5.

Input from the receiving transducer goes to the if amplifier of the SL6652, which drives the detector to provide output at pin 3. The audio stage is simple and power consumption is reduced by the application of the received signal strength indicator signal, by way of the op-





Message record/playback for such applications as shop displays, emergency instructions and exhibitions. If you only need to play back pre-recorded messages, omit the components marked with an asterisk.

amp on pin 11, to remove the supply to the output amplifier.

Since the rssi is a current output of the order of microamps, it may be advisable to use a fet-input op-amp, but the bipolar type used here works reasonably well.

S Mason
Stoke-on-Trent
Staffordshire

Meant for future use underwater, this communicator needs little power and operates at 32kHz. Transmitter is on the left.

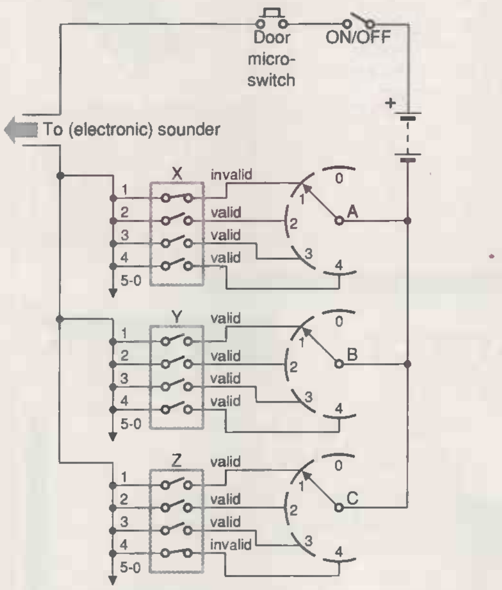
Fund raiser with odds switches

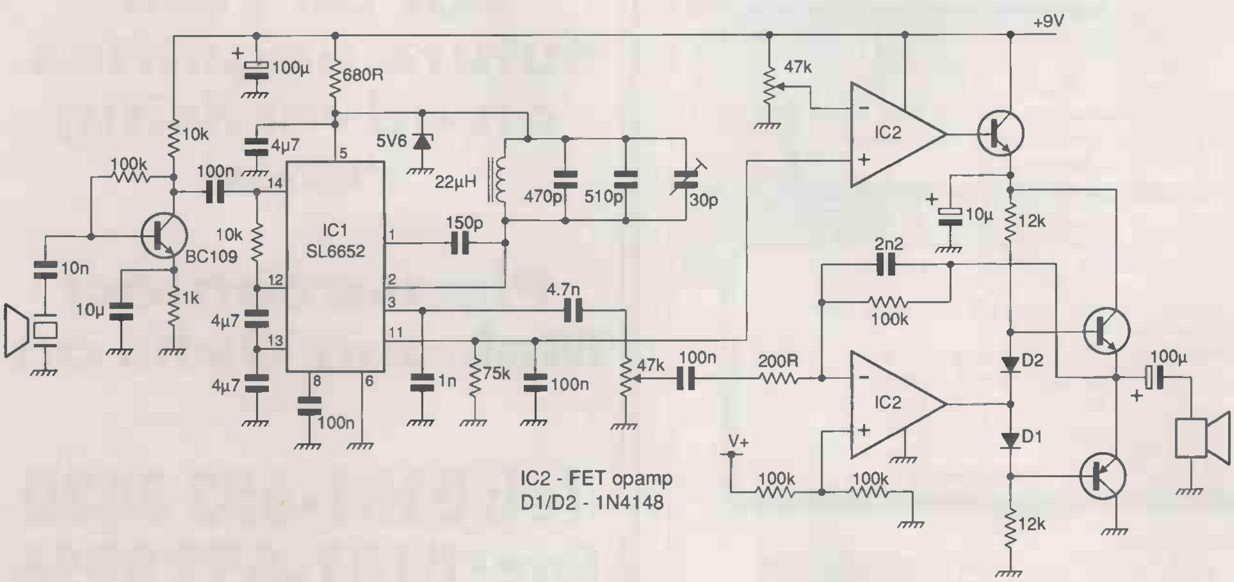
This electronic version of the "combination lock" seen at church fêtes, in which you have to guess the combination to open a door to win a prize, can be adjusted to vary the odds – high for when children try, since they always seem to do better than adults.

If the three ten-position rotary switches select an invalid combination, pressing the on/off switch activates the sounder; if it does not sound, you get a prize. It could clearly be made to operate a lock to prevent people grabbing a prize anyway, but the idea was cheapness and simplicity. Use the dil switches to vary the odds.

Keith Read
Fleet
Hampshire

Entertainment at the fête. Select the correct combination to win a prize.





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CIRCLE NO. 138 ON REPLY CARD

...continued from page 783

That opinion may be sound, but the DTI has obtained it at second hand. Only the broad-casters and their equipment suppliers can know at first hand how much scope they have for greater spectrum efficiency and the costs of their options. And even they can have only a vague idea until they study them in earnest, which they will not do until they are faced with a real prospect of having to pay for the true value of their spectrum. Meanwhile they have a vested interest in playing down the scope for better spectrum efficiency and exaggerating its cost.

Inset 8 – Allocations to emergency services

Police, fire and ambulance services require, and pay for, a large range of equipment and materials. They also pay salaries which are at least large enough to retain their work forces and they trade off the costs of equipment and materials against each other and against the cost of personnel like any other employer. The commercial environment is generally beneficial to those services and raises their standards, compared with countries where the price mechanism is suppressed.

Having to pay for spectrum would not undermine their ability to catch criminals, put out fires and treat injured people any more than having to pay for police cars, fire engines and ambulances, which nobody suggests should be provided free of charge.

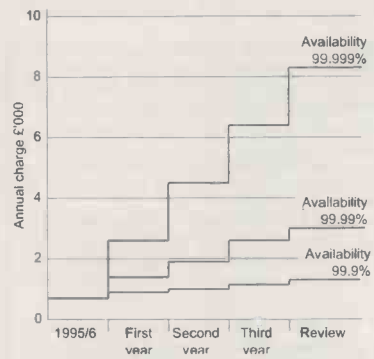

Fig. 4. Point-to-point fixed links between 4 and 15GHz. In the first of two regions involved, FR1, which includes Greater London and West Midlands, charges will rise by nearly 12 times.

Elsewhere the white paper speaks of using licensing powers to promote strategic objectives and develop innovative technical approaches. The white paper also speaks of giving financial assistance to accelerate desirable changes and using spectrum pricing to achieve specific management objectives. In other words the intention is for the spectrum managers to continue using their judgment of how radio communications should develop instead of relying on the price mechanism.

How much any government is wise to rely on second-hand information from financially interested parties to decide which industrial developments to promote is always controversial. Before spectrum pricing that was the only way in which the RA or its predecessors could prevent waste in the use of spectrum. In the future however, when spectrum pricing has bedded down, it will not have to be so pro-active. It could allow the users and manufacturers to take those decisions, in the knowledge that spectrum pricing will curb any tendency to extravagance. Perhaps in due course the penny will drop in ministerial circles. ■

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1. HMSO Cm 3252, £9.10. (DTI invites comments on or before 25 October.)
2. D. Rudd, 'Pricing versus rationing', *Electronics World*, September 1996.
3. Report of the Independent Review of the Radio Spectrum (30-960MHz), chairman Dr. J.H.H. Merriman C.B. O.B.E. F.Eng., July 1983, HMSO Cmnd 9000.
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5. CSP International, 'Deregulation of the radio spectrum in the UK', March 1987, HMSO.
6. D. Rudd, 'Privatisation of the radio spectrum' *EW+WW*, September 1987.

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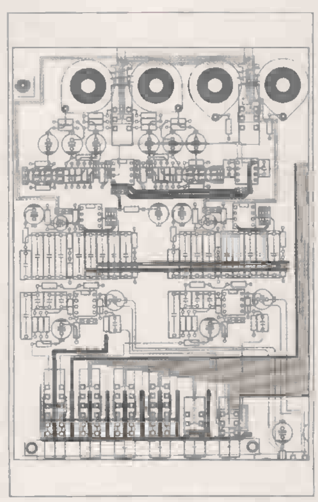

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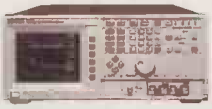

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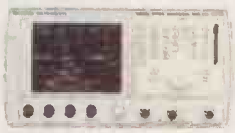

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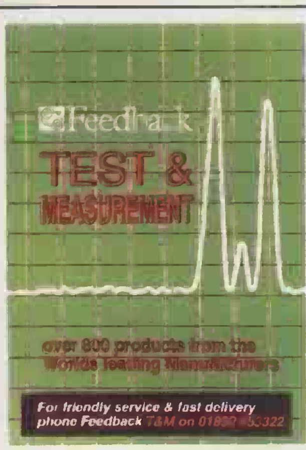

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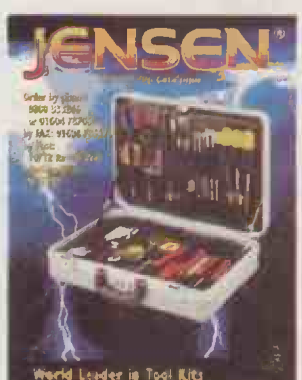

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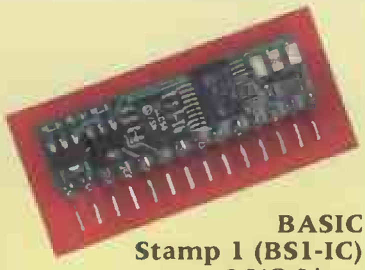

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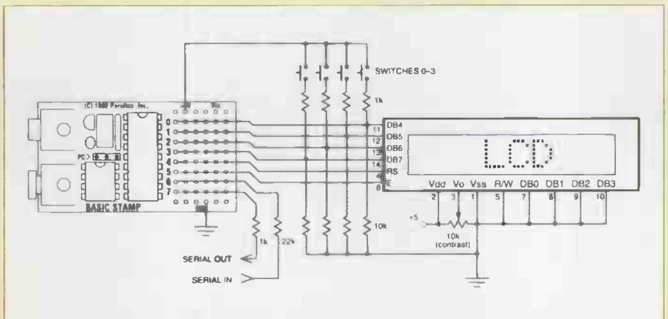

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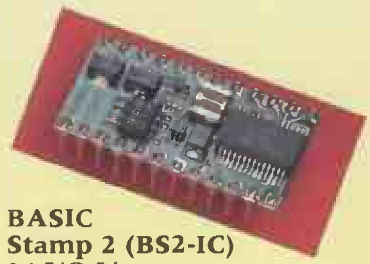

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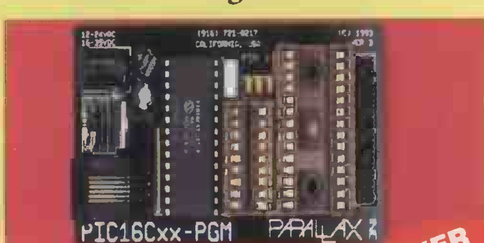

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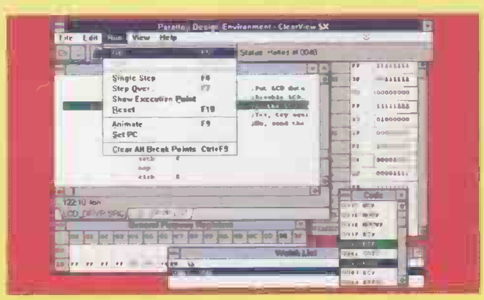

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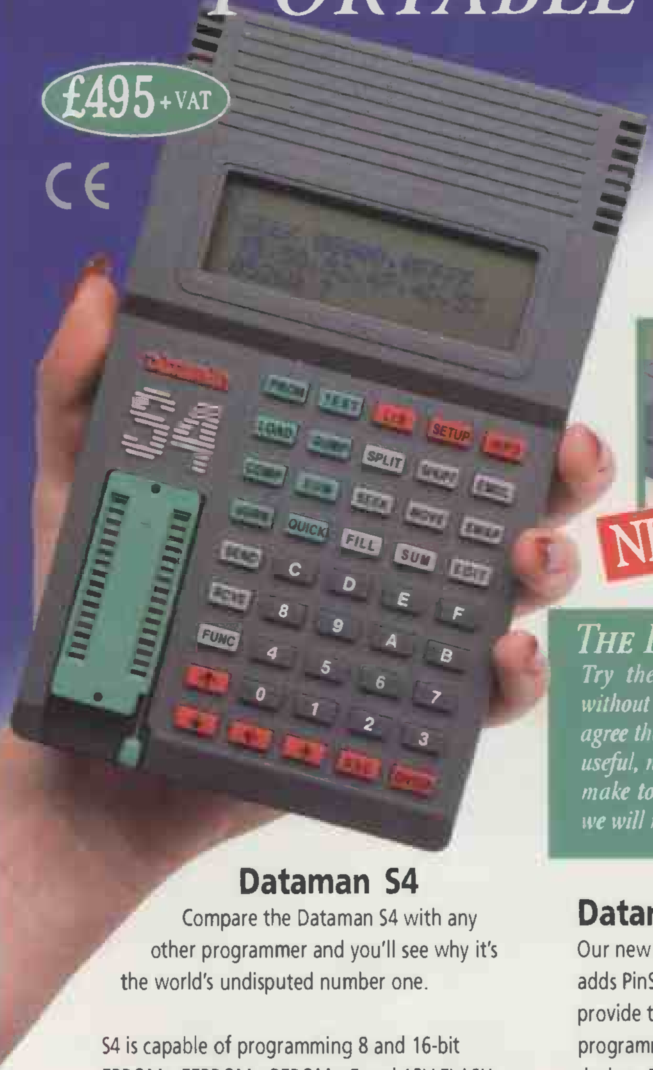

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