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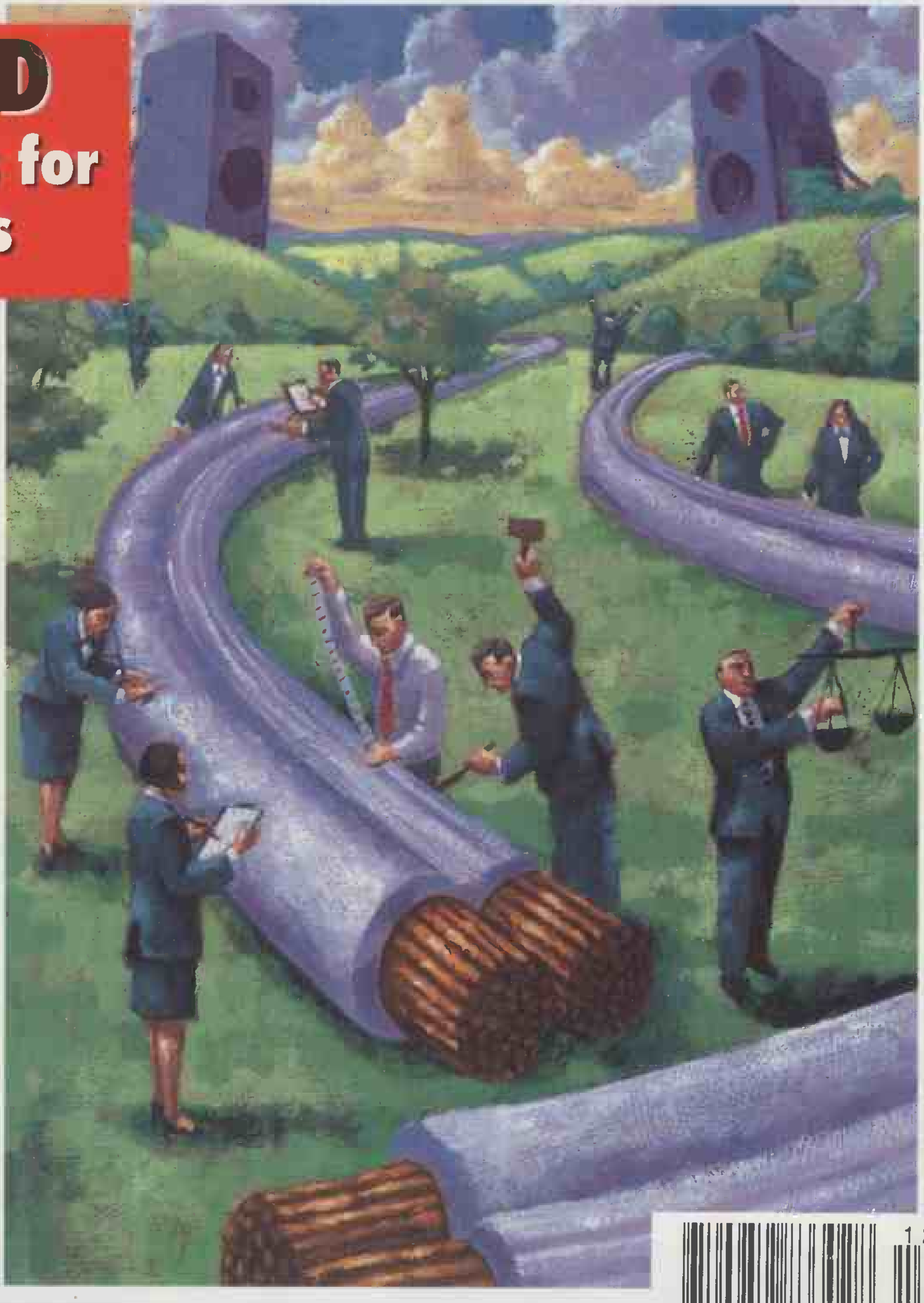

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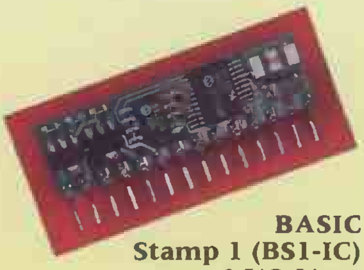

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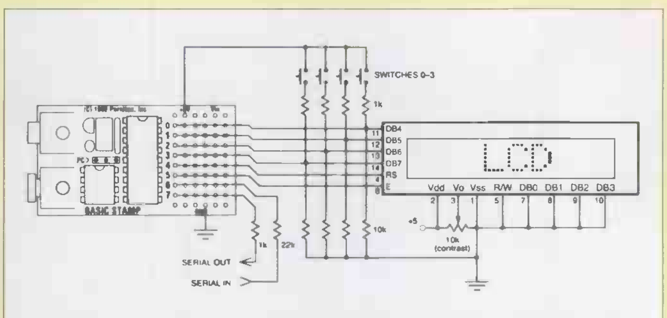

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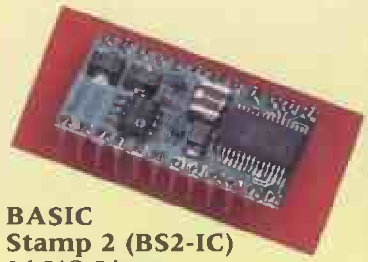

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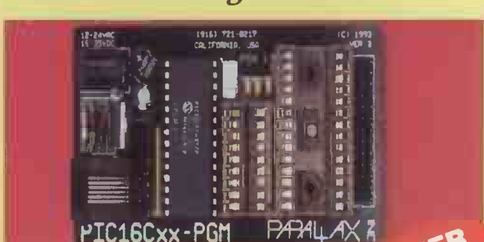

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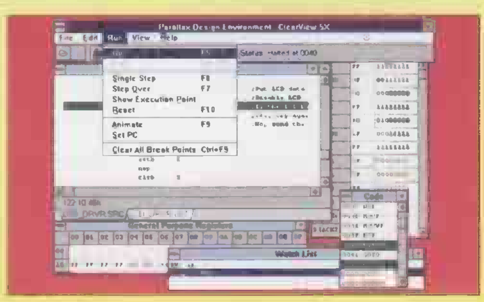

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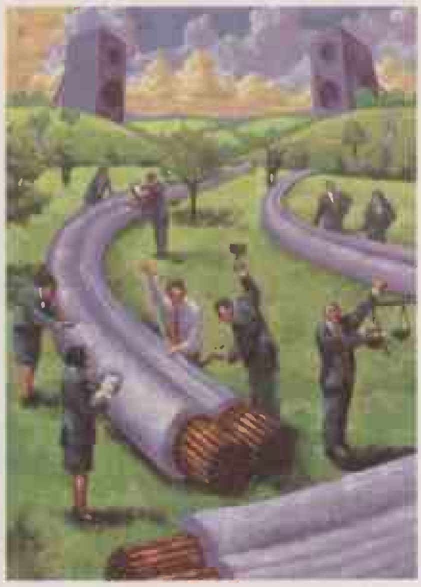

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This 10Hz to 1MHz audio signal generator is available for a second month to *Electronics World* readers at 20% discount – page 935.

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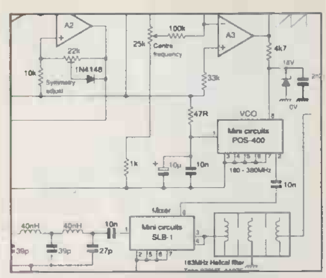

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EDITOR
Martin Eccles
0181 652 3128

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
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REED BUSINESS PUBLISHING

Market forces rule?

Market forces are supreme. They always ensure the best price and the widest choice of goods and services. Or do they?

Look at the state of the consumer electronics industry. Desperately low margins and retail bankruptcies. High customer expectations of the products themselves, but an equal expectancy of low prices. Unfortunately, you get what you pay for, so generally the quality is questionable and customer satisfaction is low. Given this climate, what encourages manufacturers to invest in new ideas? Isn't it all too risky?

No, there are still great prizes to be won. Many homes do not have computers, mobile phones or satellite television. There is no need for any 'quantum-leap' products, like the change from mono to stereo radio or the move from black and white to colour television. Just bigger, faster and more features will do. The direction the market is taking seems to be quite predictable.

For example, the market driver in personal computers is speed and size of storage, but it is almost self sustaining in that software developers guzzle up extra features without much return in performance. Why does Windows 95 need over 50 megabytes of hard disk space? So pcs have to get bigger.

There are some interesting developments and huge investment in mobile communication with the advent of GSM and, shortly, hand portable satellite telephones linked to Iridium, Inmarsat or a Bill Gates variant. Maybe wrist-watch telephones are just around the corner; the pagers are already here. But no videophone yet. With its slow changing images, the worthy Amstrad attempt a couple of years ago wasn't quite what the market wanted.

The world of radio and television is less fast moving. Digital broadcasting is almost here together with wide screen tv and surround sound. The technology may be brilliant but will there be anything worth watching with the mushrooming number of mediocre tv channels?

Occasionally life is not always so predictable. Look at the Internet. No one designed it, and yet it is here. What use is it I hear you say? A massive library, a low cost communication medium, a place for pastimes? Its applications will develop in time – did not the mobile phone develop from amateur radio?

Generally speaking market forces have delivered progress, using an incremental approach with minimal risk. However, the stage is set for another quantum leap, but one which market forces cannot deliver. It's not new but it needs saying again.

It is the provision of a terrestrial high bandwidth communications infrastructure – a proper fibre connection to businesses and homes – provided that they want it. It has been talked about for a long time but the time is right to do it.

BT has offered install the infrastructure but is prevented by its license. Cost-conscious cable-tv companies are installing coaxial cable with separate lines for telephones, but no fibre optics. Surely, if you are going to dig up the road and disrupt the traffic why not do the job properly? The trouble is that the provision of this infrastructure benefits lots of different applications, but one application on its own cannot afford to do it. Hence there is a vacuum.

What can this connection give us? A real videophone service – hopefully compatible with the rest of the world – and fully developed on-line services including banking and reference services. Or interactive learning which could boost further education perhaps, and video-on-demand, which could turn broadcasting upside down. It could also offer telecommuting, giving a flexibility to working that companies will not countenance at the moment. And interactive television.

I think the latter is the most revolutionary application of all. It goes further than tv talent shows or phone-ins. Imagine watching a parliamentary debate on tv – presented with proper visual aids – and then having a chance to vote. To have your say on devolution, European integration, a single currency – or even the proposed local bypass scheme.

"Let us harness these ideas ....look forward and don't be afraid of the future."

Of course there would be the same arguments against it as referendums; these are that the questions can be loaded, computer security, people voting against an unpopular government rather than addressing the question, people unqualified to vote, or just plain old apathy. But isn't it worth trying?

We have to cable up. The benefits are enormous and the opportunities for industry are massive. But then the investment will be massive and it won't happen unless the Government takes the lead and defines the playing field to enable and encourage things to happen, and perhaps throw in a little vision. We must think of it in terms of supplying water, electricity and gas to people's houses – is there any argument about this?

The moral of the tale is that we cannot rely on market forces to completely shape the future that we want. We could easily get stuck in a rut. The Government must take an active role.

It should facilitate change, cajole and encourage, and above all think long term. But first, let's all get connected. ■

Peter Marlow

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New mixed signal FPGA technology developed in UK

Mixed signal Asic design house, WML, is developing a field programmable system-on-a-chip (Fipsoc) that mixes analogue and digital blocks on the same device.

The analogue sections can be configured to implement filters, amplifiers, drivers and d-to-a/a-to-d converters. The logic section comprises some 10,000 gates configured with look-up tables and registers.

Device programming is controlled by an on-chip 8051 microprocessor. Two different configurations can be stored and swapped with a command to the processor.

The actual programs themselves are held within a separate e^{2}prom – much like a ram-based fpga.

A CAD system has been developed by WML to design circuits and program the devices. The design flow includes mixed signal design specification, simulation, place and route, programming and emulation.

The company claims the Fipsoc can be used for analogue systems in the same way that gpgas can be used in the digital world. Designs could be prototyped on a Fipsoc and migrated to a mixed-signal Asic for volume production.

First silicon of the Fipsoc is expected next month.

Rooms for rent... A full range of EMC test equipment including screened rooms is available on lease purchase terms from Seaward Electronic. Both emissions and immunity testing kits can be hired for around £100 and £150 respectively. Equipment includes spectrum analysers, a harmonics meter, a mains interference simulator and a surge generator.

Design awareness initiative is extended

DTI gives Microelectronics in Business design centres 18 months to become self-financing operations The government has extended its fpga and Asic awareness campaign in the hope that its university design centres can become self-financing within the next year and a half.

The original three-year MIB programme – which remains the government's most direct support for the microelectronics design sector – was due to end this month when funding would have run out for the project's nine design and support centres.

The DTI will now spend £800,000 to keep the design centres running for a further 18 months, after which the DTI expects many of them to be self-financing design and technology transfer centres.

Last year, existing commercial Asic design houses criticised the MIB programme for using DTI money to set up university design houses rather than supporting the existing industry. At the time the DTI denied this.

Now it seems the intention is to enable the university-based support centres to become self-financing businesses. Professor Sa'ad Medhat, head of the school of electronics at Bournemouth University, where he runs an MIB support centre, believes it is likely that some MIB centres will be self-financing technology transfer and design businesses. "Eighteen months was the period we chose and I think it is possible, if we ramp up our technology transfer node activities," he said.

***Richard Wilson,** Electronics weekly*

Imaging sensor for under $20

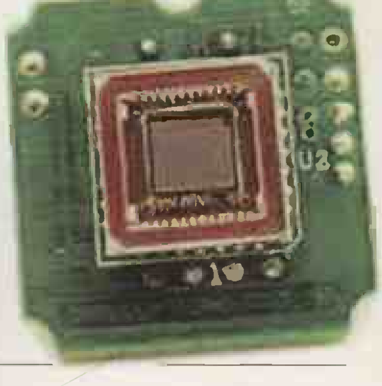
A CMOS imaging sensor, priced at under $20 in large quantities, has been introduced by US company Marshall Electronics.

Specifications of the monochrome camera-on-a-chip are near-identical to that of Vision's CMOS sensor. However, Roy Warrender, commercial director of the Edinburgh-based company, said: "This equates to an early generation of our product."

Leonard Rogers, vice-president of Marshall, responded:"Unlike Vision, we have something working, in production and being sold into products."

Marshall's camera, developed by Omnivision Technologies, features a 300 x 240 pixel array and EIA composite video output. The chip runs from a 9V battery, consuming less than 100mW.

A special feature allows for an unlimited number of cameras to be connected in series or parallel on a single coax cable. The multiple cameras can be mounted on buildings, for example, removing the need for expensive motors and lenses.



Video codec based on fractals

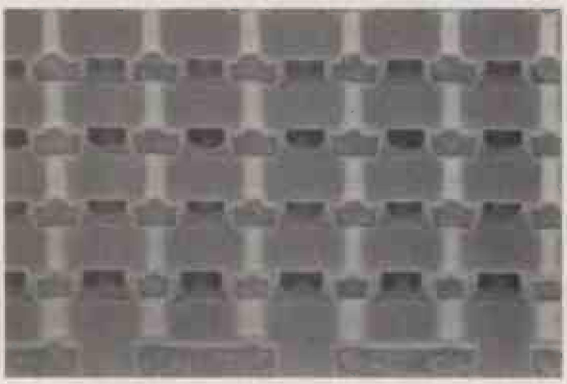
Iterated Systems, the Atlanta-based image compression company, has released a video codec based on fractal technology.

Called ClearVideo, the video decoder is available as shareware whereas the encoder is licensable and has already been taken up by Electric Switch, which offers a video compression service, and Pro-Sieben, for use on its Web site.

ClearVideo is claimed to be capable of compressing all classes of content, from talking heads to full action video. Resulting data rates are dependent on the image resolution and the amount of image movement, but rates as low as 28.8kbit/s are reported and QCIF 15frame/s full action video can be squeezed into 120kbit/s.

"Compression is non-real time, whereas decompression can be performed in real time on a 486 PC running Windows 95. WindowsNT and Macintosh versions are also available," said an Iterated spokeswoman.

New Asics carry 12 million gates



Heavy metal... Cross sectional view of TI's 0.18μm process showing the six layers of metal.

First samples of the new 0.18μm geometry Asic technology from Texas Instruments (TI) will be out in the middle of next year.

"We have test chips now, and we have designs being put through which are of about five million gates complexity," Mohan Maheswaran, TI's Asic manager in Dallas, told EW.

Currently the largest gate count gate arrays on offer in the market are the 3.5 million gate Asics offered by IBM Microelectronics.

"Our technology (called TImeline) gives us 12 million gate count gate arrays with 70 per cent utilisation and 30m gate count standard cells also with 70 per cent utilisation", said Maheswaran. Metal layers are currently up to five, with the capability to go to six.

"It allows people to start thinking in totally new ways", said Maheswaran, "you can actually implement a number of PC boards on one chip." Current applications are in high end telecommunications uses and in high end computing, says TI.

Gate delays on the TImeline technology are 19ps ('the time it takes light to travel 6mm') and power dissipation is 0.008mW/MHz/gate.

In smaller densities some very high speed/low power circuits can be fabricated. "At 100,000 gates and 200MHz frequency, circuits can be implemented which use 0.01mW/MHz/gate," said Maheswaran.

Cores include DSPs, ARM, ATM and MPEG. Memory cells are SRAM, ROM, flash and DRAM (up to 10Mbit).

Pace looks at cable tv

Pace Micro Technology, the Yorkshire-based volume set-top box manufacturer, is currently in discussions with four UK cable operators for a deal over digital set-top boxes. In its plans to capture the digital cable market, Pace has been in discussion with a number of cable operators worldwide.

"The opportunity for us in cable in the next few years is probably larger that when we started in Direct-to-Home," said Steve Barnes, sales and marketing director at Pace.

"Today Pace is talking to over 160 different broadcasters and operators. But not all of these will come out in a service and not every one will grant Pace their contract."

Meanwhile, BSkyB is still evaluating the bids for the next generation of digital set-top boxes for a digital satellite service expected to be launched in the autumn of 1997. One of the interested parties is Pace.

Faster fast Fouriers

Fast Fourier transforms, FFTs, can now be implemented on programmable logic from Altera as part of the company's *Megafunctions* library of cores.

It is claimed that the execution speed can be increased by a factor of ten to 15 over conventional dsp-based solutions.

The company quotes a 1024 point FFT running in 0.2ms when programmed into an *EPF10K100* – the company's flagship device.

The length and data width of the transform can be set by the designer. Suggested applications include rf communications systems in cable and wireless and spread spectrum modems.

Book-to-bill looks up

Chip demand jumped in September with a book-to-bill ratio of 0.99, its largest jump this year, according to the Semiconductor Industry Association.

"From any perspective, these are the most positive numbers we've seen all year," said Douglas Andrey, analyst at the SIA. "The modest increases in orders for August and September suggest that the 1996 slowdown in growth has bottomed out."

The book-to-bill ratio is still far below its most recent peak of 1.16 in September of 1995 but it is a welcome sign of better times ahead for numerous chip companies suffering from a downturn in the market largely because of over production.

IR advances igbt efficiency

International Rectifier has introduced a new range of igbts, called *Gen 4*, that are 20 to 40 per cent more efficient than their predecessors.

Tim Munday, a field application engineer for IR, said: "The gains in efficiency come from a combination of lower saturation voltage and reduced switching losses. Much of the advance has come because we are using our new fab which has reduced the manufacturing tolerances."

Insulated-gate bipolar transistors are power devices that are used predominantly in motor drives. Current *Gen 4* devices are rated at 600V with 1200V devices to follow soon. ■

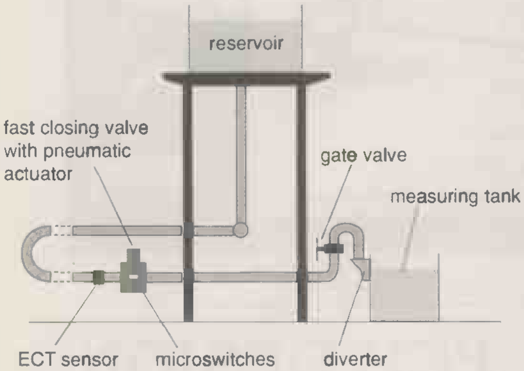
Jonathan Campbell

ECT used to nail hammer

Most of us know what water hammer sounds like and are aware that it can cause stress in a system: but what does it look like? Researchers at Mist in Manchester think they have the answer, by developing an electrical capacitance tomography (ect) technique that promises the first accurate method of characterising this common yet complex phenomenon.

Typically, water hammer can occur when a valve is suddenly closed at the end of a long pipe. The water flow is abruptly stopped resulting in a pressure wave that travels back up the pipe. In turn this causes an expansion at the supply end which reverses the wave making it travel back to the valve, where the processes is repeated until it runs out of energy.

ECT is being used at Mist to unravel the mysteries of water hammer.



The problem has been that, up to now, recording techniques have not been fast enough to capture the very rapid transients that characterise hammer, while complexity of the effect has made modelling difficult and inaccurate.

But the Mist researchers have based their technique ("Monitoring water hammer by capacitance tomography", WQ Yang *et al*, *Electronics Letters*, Vol 32, No 19, pp. 1778-1779) on the fact that the expansion cause cavitation – pockets of air – within the pipe.

To make the measurements, a set of capacitance electrodes are mounted around the pipe, so that the inter-electrode capacitance-changes caused by variations of permittivity within the pipe can be used recorded. Cross sectional images can them be constructed from the data. The Mist system uses 12 measurement electrodes, 10cm long, mounted onto the outside of 41mm uPVC pipe, just upstream of the valve. When the valve is closed, a vapour bubble is formed then collapses, its life captured by the electrodes.

Though the transient process in the Mist experiment lasts only 0.27s, the system can collect measurements at 100frame/s allowing detailed behaviour of the water hammer to be observed.

Next step for the team is correlate data between an upstream and downstream sensor to find the transport speed of the water hammer waves and to find the velocity profile of the flow.

More information contact: WQ Yang, Process Tomography Group, Department of Electrical Engineering and Electronics, Mist, PO Box 88, Manchester M60 1QD.

Silicon fab goes flat out

A new technique that enables fabrication of atomically-flat silicon surfaces as opposed to the 'terraced' surfaces that exists in current devices could bring big improvements to performance and yield of silicon microelectronic and optical devices.

The technique, developed by materials scientists at Cornell University, uses high pressure and temperature to force atomic steps on the silicon surface to migrate to specially created boundaries. Though the slight irregularities, on the nanometre scale in current silicon layers, do not have much effect on the operation of the present generation of devices, future miniaturisation is going to make smoothness a critical factor.

Normal surfaces of silicon, though looking flat, consist of short, smooth terraces each ending in a step of atomic dimensions at about 1.5nm.

But using their new manufacturing procedure, the Cornell team has been able to create extensive regions on a silicon wafer that have no atomic steps at all. They have achieved this by creating a grid of ridges, 0.5µm high and 1µm wide on the surface of the wafer and clearing the intervening squares of their atomic steps by forcing them into the ridges.

Scanning tunnelling microscope image of a typical silicon wafer surface, taken at Cornell, shows steps each of a height corresponding to one atom spacing. Here, four atomic steps are separated by flat atomic planes, or terraces. Rows of silicon atoms are clearly visible on the terraces. Cornell materials scientists have developed a process to increase the areas of perfect atomic terraces by a factor of greater than 1000, producing a step-free surface.

The grid is created using electron beam lithography, and each square, about 10µm wide, has about a billion atoms on it, with several thousand atomic steps all across the square. The sample is then subjected to ultra-high vacuum and then high temperatures of 1020-1150°C.

At these temperatures, silicon atoms are detached from the atomic steps so that in effect the steps migrate to the ridges at the boundary of the square, leaving the surface of the square atomically flat.

"The benefit is that it should now be feasible to make smaller devices with better control of the dimensions, at the atomic level, and it should eliminate the harmful features of the surface that could get through the manufacturing process," says Jack Blakely, Cornell professor of materials science and engineering who has led the work

"Circuits built on step-free surfaces can be designed with smaller dimensions and utilise thinner semiconductor channels and insulating layers to increase performance and decrease power consumption. By having it flat, this could be an ideal surface on which to build an integrated circuit."

More information from Jack Blakely, Materials Science and Engineering, Cornell University Ithaca, NY, USA.

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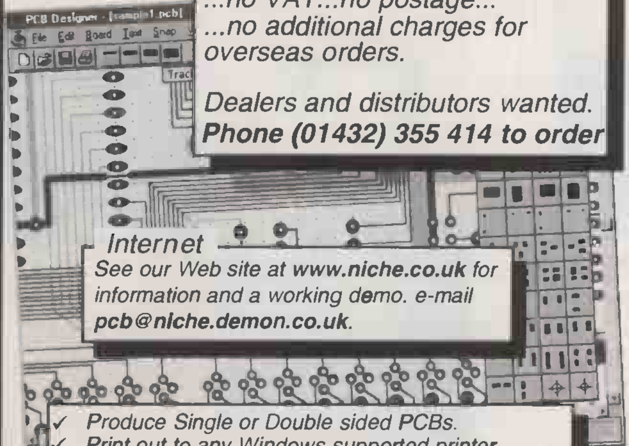

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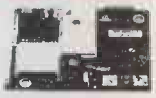

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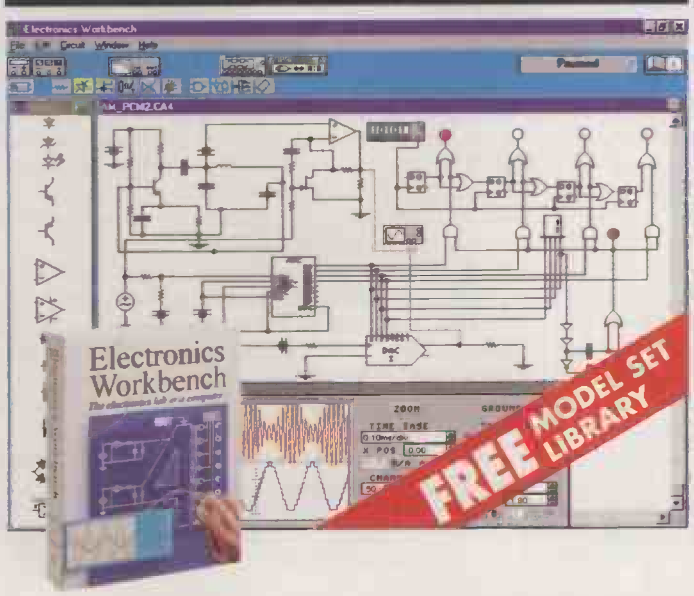

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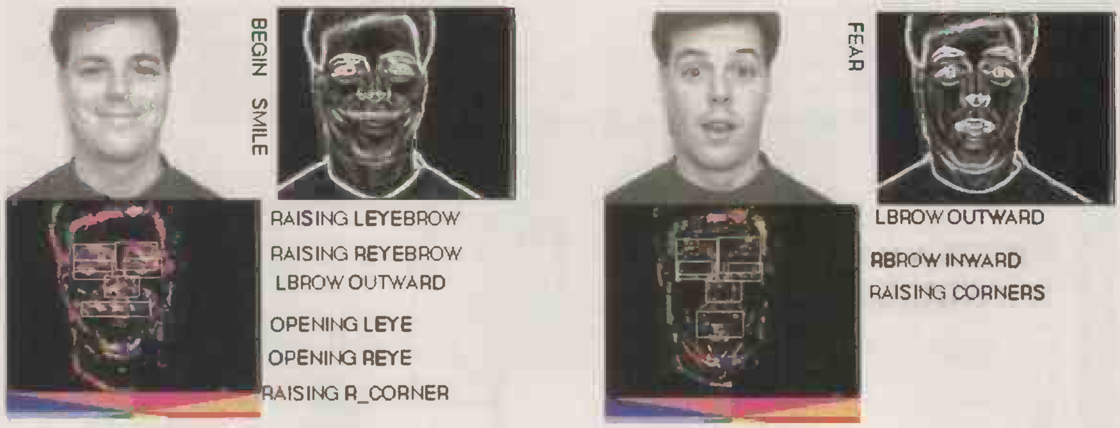


Analysing our expressions. The upper left quadrant shows the intensity image, the upper right shows the gradient image, the lower left shows the optical flow field with the rectangles enclosing the face regions of interest and the mapping of colours onto directions, and the lower right shows the mid-level descriptions that were computed.

Sometimes your computer does something so stupid – like trashing a vital file it really should have know you wanted – that words just stick in the throat. But work being carried out at the University of Maryland could mean that your computer will one day be able to recognise those looks of open-mouthed disbelief and face-twisting fury, and react accordingly. (In the *Research Notes* office that would involve quietly sliding its keyboard out of the reach of a fast moving fist).

Aim of the research being undertaken by Yaser Yacoob and Larry S Davis at the Computer Vision Laboratory is to recognise facial expressions from image sequences. The work has been prompted by the fact that visual communication plays such a central role in human communication and interaction. If successful, the research will allow computers to sense our moods, concentration and understanding, while also opening up possibilities for better video transmission of facial expressions across low-bandwidth systems.

According to the authors ("Recognising human facial expressions from long image sequences using optical flow", *IEEE Transactions on pattern analysis and machine intelligence*, Vol 18, No 6, pp. 636-642), low bandwidth transmission of facial data can be made more efficient by using mid- and high-level visual representation of the facial actions. Or as the researchers put it: "Send a smile and a few parameters that determine the mouth actions involved".

Previous researchers have analysed the six principal expressions of happiness, sadness, surprise, fear, anger and disgust, but have tended to concentrate on static "mug-shots."

However Yacoob and Davis have developed algorithms that use optical flow computation to identify the direction of rigid and non-rigid motions caused by human facial expressions, and have so far demonstrated recognition of the six expressions on a large set of image sequences.

Analysis involves tracking rectangles that enclose the facial features. Every rectangle encloses one feature of interest. Each of the 32 subjects so far tested was asked to display the expressions of emotion in front of a video camera, while minimising head movement – though subjects inevitably did move their heads during the experiment.

The experiments showed, through analysis of the optical flow field in the rectangles, that cues to detect the beginning of "fear" include the inward raising of the eyebrows and opening of the mouth.

Some confusion still exists between fear and surprise, anger and disgust and sadness and surprise. There is also some difficulty where one expression begins then transforms into another.

Despite that, in the more than 30 subjects that were studied in the laboratory environment, the researchers were able to report a "good" classification of facial expressions in a very large database.

For more information contact Yaser Yacoob at the Computer Vision Laboratory, Center for Automation Research, University of Maryland, College Park, MD 20742-3275, USA. email yaser@cs.umd.edu

Millimetre antenna has no moving parts

A prototype antenna that operates at millimetre wave frequencies and has no moving parts, no phase shifters and can be implemented in plastic has been built by researchers at Georgia Institute of Technology. The electronically-scanned device, which is believed to be the first Rotman lens to operate at a frequency as high as 37GHz, could offer an inexpensive, rugged, reliable and compact alternative to current millimetre wave antenna technologies.

Most antennas operating at millimetre wave frequencies use mechanical scanning or phase shifters, both of which have disadvantages. Mechanically steered antennas are slow in response and suffer reliability problems due to shock and vibration. Phase shifters are costly to fabricate and introduce considerable rf losses.

But in a Rotman lens, such as the Georgia Tech device, millimetre wave energy coming from a particular direction is focused by passing the electromagnetic energy through a pair of parallel plates shaped like a lens. Beam-forming or focal ports are located on one side of the plates, fed by a switch array. The array ports are on the opposite side, each connected to an antenna element. Energy fed into a specific focal port will emerge from the antenna elements and produce a beam along a particular direction. Switching the input from focal port to focal port steers the

continued on page 916...

Otto Rausch attaches wave guides to his prototype Rotman lens that offers a low cost and rugged method of electronically scanning millimetre waves.

beam electronically in one direction across a 45° arc, and can be accomplished with pin diode switches, which are also simple, reliable and inexpensive.

Previous Rotman lens antennas have been developed at frequencies of 18GHz or below, most in microstrip. Unfortunately microstrip is very lossy at high frequencies, and so is not suitable in the millimetre wave region.

Now, with help from colleagues, Georgia Tech senior research scientist Otto Rausch has designed and fabricated an antenna milled out of a solid block of aluminium.

Rausch's prototype required extreme machining and finishing tolerances, but the researcher says that production antennas could be hot-pressed in plastic, and then coated with a conductor such as gold. The antenna feed-horns and switch-array could be made the same way, keeping the costs down.

Besides the low cost, compact size and ruggedness, the lens antenna is also reported to offer very low throughput loss and sidelobe emissions. In the prototype, sidelobe power can be suppressed by a factor of one-thousand below the energy of the main beam, and power loss through the lens itself is less than 2 dB.

To fulfil its potential, Rausch says the antenna's operating frequency must be expanded, and the capability to scan in two dimensions added. however potential applications include autonomous aircraft landing systems, synthetic vision for ground vehicles and automobile collision avoidance systems

More information is available from Otto Rausch at the Georgia Institute of Technology, Atlanta, Georgia 30332-0828 email ekkehart.Bausch@gtri.gatech.edu

Architects get wise to electrochromic windows

One of the 'simplest' concepts for reducing air conditioning bills while keeping office buildings cool in summer is to install window glass that can be darkened or lightened automatically, or at the touch of a button. Unfortunately, how to produce practical systems with acceptable life and cost has proved anything but simple. However, work being carried out at the National Renewable Energy Laboratories in Colorado could help overcome many of the present technical barriers to electrochromic (ec) windows.

The breakthrough made at NREL ('Low-voltage electrochromic device for photovoltaic-powered smart windows', C Bechinger et al, *J. Appl. Phys*, Vol 80, No 2, pp.1226-1232) is in developing an all-solid state electrochromic device that can be switched over a range of optical transmissions by voltages of less than 1V. This voltage is smaller than any other device tested so far, and at these levels, the researchers say, it should be possible to power the devices by an integrated semi-transparent photo-voltaic (pv) cell, so removing the associated wiring costs that substantially push up investment in ec windows.

In the NREL system, indium-tin-oxide (ito)-coated glass forms the electrically conductive transparent substrate for the device, onto which thin films of WO_3, MgF_2 and V_2O_5 are deposited, topped by a semi-transparent gold electrode.

Colouration occurs by a complex reaction between the clear WO_3 and a light-absorbing compound of lithium and WO_3. The reaction involves injection and extraction of electrons and metal ions. But, according to the team, the key to the low voltage switching is inclusion of the MgF_2 layer which acts as the lithium ion conducting layer.

When electrical connection is made, the device transmission drops to about 40% of its bleached-state level in around 60s. To return to the original transparent state, the device simply needs to be short circuited to cause spontaneous bleaching within minutes.

In the tests, voltage was supplied by a semi-transparent photo-voltaic powered cell connected to the ec device. But the researchers say they expect a monolithic pv-ec device to function in a similar manner.

Degradation seems much improved over other types and the NREL devices are reported to have been cycled in air at ±1V with almost no change in optical behaviour after 5000cycles. Eventual degradation was thought to be due to corrosion caused by reaction of lithium with water that has penetrated the device. The researchers say that in practical devices the gold electrode would be replaced with a much thicker transparent electrode that would also control the water content of the device.

Current cost of ec windows is estimated to be somewhere between \$100 and \$1000/m^2. However the integration of the power source into a self contained window could make the NREL devices much more attractive than other designs and also allow smart windows to be retrofitted to existing buildings.

With the cost of energy becoming much more of an issue in building-economics, electrochromic smart windows could one day become a familiar part of architectural design.

More information contact: Clemens Bechinger now at the Universitaet Konstanz, D-78434 Konstanz, Germany. email clemens.bechinger@uni-konstanz.de ■

The route

In the penultimate article in this comprehenive series of PCB CAD reviews and discussions, Rod Cooper investigates *Quickroute* and the *Propak* suite.

PCB CAD review subjects

This review, which began in the September issue and continues next month, 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, (see October issue) £150 exc £10 p+p and VAT.
Electronics Workbench: Interactive Image Technologies Ltd (Canada), tel. 0014169 775550. UK Robinson Marshall, tel. 01203 233 216, (see October issue) £199 exc p+p and VAT.
CircuitMaker: MicroCode Engineering (USA) UK agent Labvolt, tel 01480 300695. Circuitmaker and Traxmaker cost £199 each excluding vat and p&p, see November issue.
Quickroute 3.5 Pro+: Quickroute Systems Ltd, fax or phone 0161 449 7101. *Pro* is priced at £249 while *Pro+ is* £399. Smartroute is £149 or £99 supplied with Quickroute.
Propak: Labcenter Electronics, tel 01756 753440, fax 01756 752857, £495 exc VAT.
Proteus: Labcenter Electronics.
EasyPC Pro XM: Number One Systems.

Note that although this set of reviews started in the September issue with a couple of smaller packages, this review is not in any order of complexity or competence.

Review 1 – *Quickroute 3.5*

Quickroute3.5 – *QR35* for short – is a development of the popular *Quickroute3* that was reviewed in *Electronics World*, January 1995.

Most of what that review said still applies, but there have been some major changes. For example, the manual that was criticised for being written in the wrong order now starts with schematic design, and works through pcb design to the autorouter – making it one of the most logically compiled manuals available!

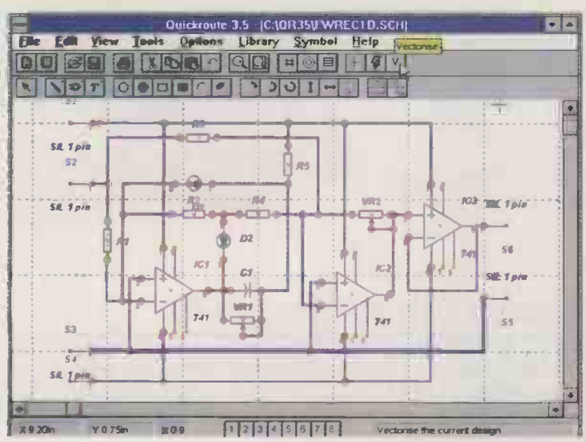


Fig. 1. Typical schematic screen when the parts bin is off, before processing so showing circles at junctions. Note the bubble-type help text on the Vectorise button.

I remember seeing *Quickroute* some time ago as a dos-based shareware program. The version was 1.5 and I believe it was written for the American market as the pricing was in dollars. It was then a tiny 256Kbyte in size and would run on virtually any pc. For historical interest a screen from this program is shown in **Fig. 7** and the similarities with the latest version will be apparent.

I used the top two versions, *Quickroute 3.5 Pro* and *Pro+*, for this review, priced at £249 and £399 respectively. Both *Pro* and *Pro+* are integrated schematic capture/autorouter packages, combined with manual pcb design, but *Pro+* has some extra features such as of *Spice* and *Spiceage* netlist export, DFX export to mechanical cad programs, Tango and Gerber net-list import, and copper fill.

Quickroute programs are intuitive and easy to use, and perhaps because of that are easy to review, and are thus firm favourites with reviewers. The ease of use comes not just from being in Windows but also from their relative simplicity. There is for example, no autosave or autopan, no autonecking of tracks, no snap-to function for drawing, and there is not much configuration to do on the autorouters. Simplifying the structure while retaining the essentials gives a program which will have considerable appeal to those starting out in cad.

To run *QR35* you need Windows 3.1, or better and a fairly powerful pc. Although the package will run on a 396SX with 4MB of ram, it will be noticeably tardy. It would not run at all on a 286. The recommended machine is a 486 running at 60MHz or higher with at least 8MByte ram. Like most of the Windows-based programs, if you use less than

to pcb cad

the recommended hardware, you may find parts of the program such as screen redraws and autorouting irritatingly slow.

The drawing area on a 14in monitor is about 7.5in by 5in with the parts bin on screen, and 9in by 5in without it. The parts bin takes up a lot of room, and it is difficult to understand why it is quite so big. It can of course be turned off, but if I were running *QR35* with the parts bin, I would be inclined to use a larger monitor with higher definition in order to see more of the circuit. The button bar has been increased to a double bar and this also diminishes the size of the drawing area. Some of these buttons you use only once per design – such as the 'New Schematic' and 'New PCB' buttons and could be easily dispensed with. I think a return to the original single button bar and a smaller parts bin would help those people with 14in and 15in screens.

Interesting features

QR35 has some interesting features. Starting with the schematic drawing section, it made a refreshing change to see a lattice grid used for layout instead of the usual dot matrix. The default colour for line drawing is a yellow initial line on a white background – very difficult to see, as any graphics technician will tell you. But mercifully the colours can be changed. I chose a grey background with blue lines.

The schematic drawing program is not orthogonal, permitting lines in any direction. I found it required sustained attention to maintain a neat orthogonal layout during long drawing sessions. After a while, it is tempting to take few short cuts and put in a diagonal line or two, but this instantly gives any schematic an untidy look.

There is no positive confirmation that a drawn line is connected – at least not at the time of drawing. To check connectivity, you press the redraw button after drawing and visually check each connection. Properly connected lines are given a circle symbol. Although this was acceptable on small designs, on large boards this became a very tedious process. It was easy to miss some connections. I fell into the trap of just scanning the schematic, which led to error messages at later stages, which in turn meant retracing my steps back to the schematic to correct them.

The schematic sections of *Ranger2*, *Propak*, *CircuitMaker* and *Electronic WorkBench* have means of confirming a connection at the time it is made combined with a strong snap-to function. I think this is the way it should be done.

Zoom in and out is controlled either from the button bar or by the function keys F1-7. Key F8 is a custom zoom option. These keys can also be used for panning by pointing the mouse to where you wish to pan and pressing the function key at whatever zoom level you are in.

Function keys are more helpful if you want to zoom or pan while you are already using the mouse to draw a line. You can also pan using the scroll bars. To centre the drawing and show it fully there is another function, 'Page View', which adjusts the zoom to fill the screen.

Many cad programs use the left mouse button to select or start something and the right button to stop it, but *QR35* uses the right button for various other actions. It can activate the library volumes from the button bar or pan the drawing area for example. This takes some getting used to if you have experience in other areas of cad.

The nominal drawing area is 32in by 32in. Multi-sheet schematics are supported, as are global nets. There is no map diagram showing where you are, but Page View can be used to find lost drawings.

Graphical library presentation

One of the best features of *Quickroute* is the graphical presentation of the library volumes. Clicking on the icon on the button bar gives a large screen of one page of a library volume, and you can see exactly what you are selecting from the high-quality symbols. This is a big improvement on text-only libraries.

If the library volume consists of more than one page, it is easy to flip though the pages.

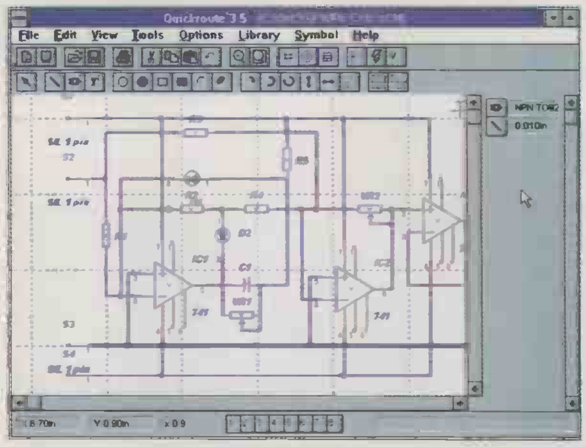


Fig. 2. Same screen with parts bin on, after processing, so many of the circles are now junction dots, indicating net formation. Note area taken up by parts bin.

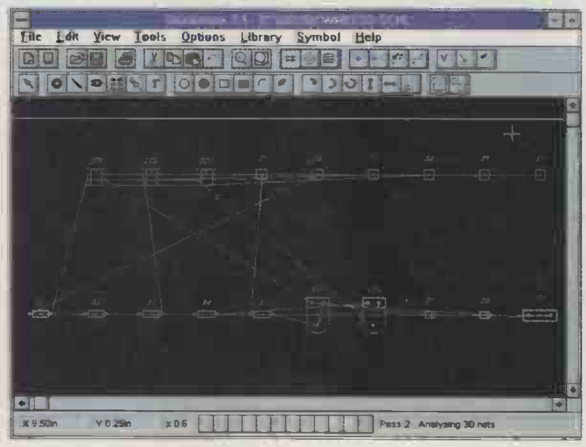


Fig. 3. The initial rat's nest formed from the above screen with components on a linear grid.

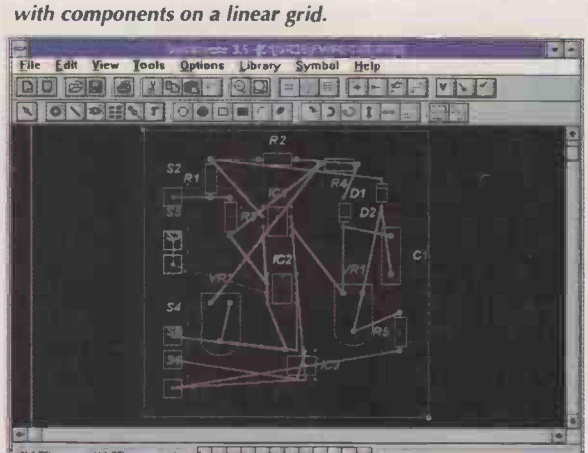


Fig. 4. Rat's nest after interactive editing. Note outline of board now inserted.

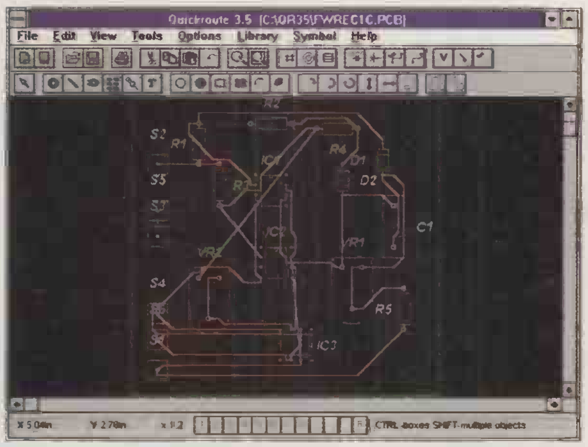


Fig. 5. Results of autorouteing with standard autorouter. Note that several ratlines cannot be turned into tracks by this autorouter. The grid has been left on in this shot.

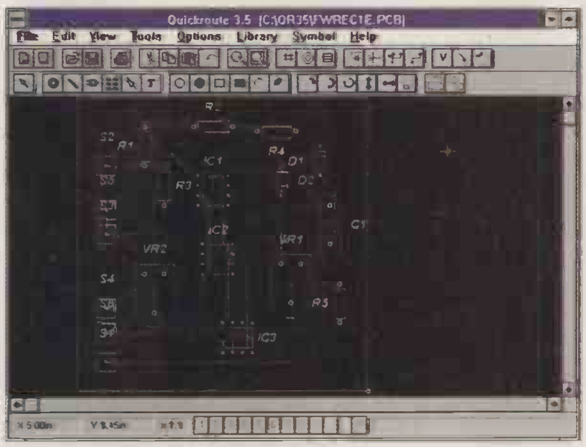


Fig. 6. Results of routeing exactly the same rat's nest with the more powerful new AR3 autorouter, completing the board. The beta version of the AR3 used here can only do thin tracks, the commercial version will not have this limitation. (Grid off).

Transferring to another volume was similarly quick and easy. For discrete devices like transistors, you do not get a long list of specific types, but a generic symbol with the package type. Information about the device is entered manually, so for this you would need a good memory or a data book. Component text is non-manoevrable so you may need to expand the diagram a little to avoid crossing lines, other components etc.

An interesting feature of the track libraries is that track thicknesses can be entered at the schematic stage and processed through schematic capture to re-appear in the finished pcb at the correct size. This is a good system, as you can check from the schematic stage the current ratings you have designed into various parts of the circuit.

You might think this leads to some odd-looking schematics, and perhaps it does, but it has great practicality. However, there is a limitation on this method at present because the standard autorouter puts a ceiling on the maximum size of the track. If the track width exceeds 60% of the grid, a smaller track is substituted. In effect, this limits track size to less than 0.03in with the standard autorouter, but with *Quickroute*'s new *AR3* autorouter, I am told this limit should disappear. It should be possible to route tracks of any size.

Code named *AR3*, the new autorouter may well appear with a different name. It is in the pre-launch stage at the time of writing, but I was able to test a beta version of it with good results.

Getting from the schematic to a rat's nest was very easy, the rat's nest being generated in linear fashion, as shown in **Fig. 3** This is step in the right direction, away from rat's-nest 'heaps' that have to be separated manually, but not as quick or easy to re-arrange as the systems used in *Ranger2*, *Propak* or *Traxmaker*.

I discovered that it was possible to 'lose' small components behind large-width rat lines. Sorting out the rat's nest required some care as it is possible to disturb the ratlines when picking components

The standard autorouter is very easy to operate, has only a few pre-run configuration controls, and was unable to route the test circuit completely, see **Fig. 5.** This puts it in category C. The new *AR3* autorouter was able to route the test circuit, putting it in category A, as shown in **Fig. 6**.

Note that the version of AR3 that I tested could not route all sizes of track, so those shown in **Fig. 6** are thin. It is a gridded autorouter with rip-up-and-retry added to its strategy bank. It also has increased configurability; each net can, if required, be configured individually.This autorouter has considerable potential.

Summary

Quickroute 35 is probably the most intuitive of the integrated schematic-drawing and autorouter products. However, do not think you can get away with not reading the manual from cover to cover – you can't.

Being comparatively easy to learn, *QR35* will be attractive to those seeking a less fraught introduction to pcb cad, to educationalists, or to those who design pcbs only occasionally.

The relative simplicity of *QR35* has its drawbacks. Professional designers – those designing pcbs for a living – may quickly reach the limits of *Quickroute 3.5* and may be frustrated by its lack of certain features. For example it would benefit from the addition of orthogonal drawing and inhibition of incorrect lines in the schematic program, and autosave. The standard autorouter is limited in power and ability.

However, *Quickroute* is being developed further, with a policy of responding to users' comments, so this observation may not apply for very long. For example, from what I have seen of the new *AR3* autorouter, this will be both powerful and versatile.

The most attractive feature of *QR35* is the excellent library presentation – quite the best of this set of reviews – while the extended library pack included with both *PRO+* and *PRO* versions gives better than average coverage of most of the commonly used components.

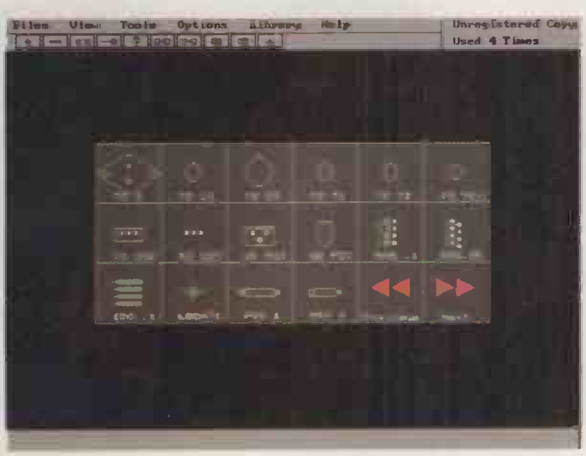


Fig. 7. One page from the early dos version of Quickroute showing even then the library presentation was exceptionally good. Note the single button bar and large available screen area for drawing.

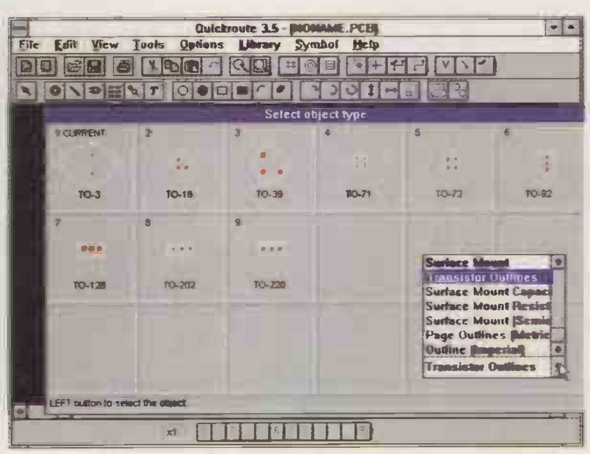


Fig. 8. For comparison, one page from the latest version of Quickroute.

Review 2 – *Propak*

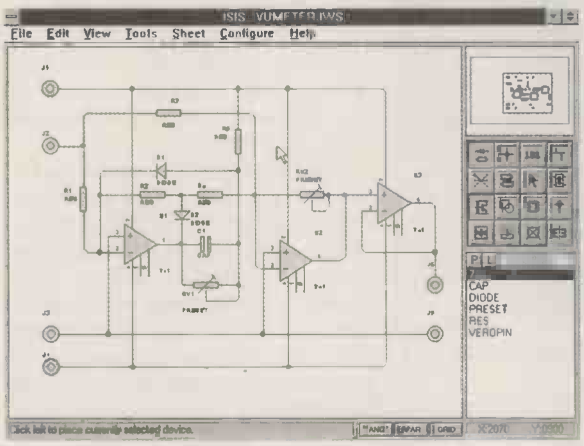


Fig. 9. Typical Propak schematic screen. Note 'map' at top right corner, icon box and parts bin. Any prompts appear on the bottom left of the screen.

There are two parts to Propak, which are integrated and both run under Windows. *Isis Illustrator+* is the schematic drawing and capture part of this program. It runs on a 386 pc running Windows 3.1 with 2Mbyte of ram, but more memory than this is recommended in the manual. It was not satisfactory on a 286 with 2Mbyte of ram.

Ares – the pcb routing part – is a full 32-bit application, so will work best on Windows 95 or Windows NT. However, it will also work with Windows 3.1 and the WIN32S extension that most readers will be familiar with.

Propak is supplied with WIN32S. I installed the whole package on a 386SX running at 20MHz, at first with 4Mbyte of ram. I thought this would be a reasonable minimum set-up for this type of Windows program as the handbook is not clear about the hardware requirements for *Ares*. Although it ran, I soon increased the ram to 8Mbyte to get it to run to my satisfaction. Needless to say, on the 486, it ran very quickly.

The manual for *Propak* is contained in a single volume with individual sections for *Isis* and *Ares*, emphasising the two-part nature of the product. For such a multi-featured program the manual is relatively short and to the point. It assumes a slightly higher level of knowledge of cad and computer literacy than the other programs and does not go into basics much, but this should not trouble most of the designers that *Propak* is aimed at.

Isis has a non-standard Windows format which gives a drawing area of 7.5in by 6in on a 14in moni, which is not very large. There is a menu bar at the top, but an icon area in a box to the right of the screen, see **Fig. 9**, replaces the customary Windows button bar.

Some of the icons are mode select buttons, which lead to groups of other buttons controlling graphics, symbols, pins etc. All these buttons are in a similar style and I found it very difficult to remember which were which. I only solved this by pinning an icon explanation chart next to the monitor, reminiscent of a practice common in dos.

Although there is a small icon text reference, it is at the bottom left of the screen – i.e. nowhere near the icons; *Labcenter* could improve this system by adopting pop-up help, like the other Windows packages, or re-organising the system into a standard Windows button bar, or better still, doing both.

Isis is a sophisticated program with automatic junction dots, adjustable autosave, auto name generation and a component finder – handy for very large schematics. It also has a type of autopan, and many other worthwhile features, some of which distance it considerably from other drawing programs.

Most noteworthy of these is the 'wire autorouter', or WAR, which enables drawing to be speeded up by putting in the drawn connections between symbols automatically. You just click on the pins you want to connect and the autorouter inserts an orthogonally draw line, putting in corners as required.

I timed myself on transferring a drawing from a rough sketch on paper and found it cut down the transfer time by about 30%. As the drawing fills up, and lines get more difficult to place, WAR gets slower just like a human operator, but it's still quicker than hand drawing. The results with WAR depend very much on the component layout, so if you need to present a good-looking schematic you may need to do some editing. Its chief advantage lies in speed.

Also of note is support for radiused corners, and this can give the drawing a smooth professional appearance if this is what you require. The ability to move component text – i.e. text such as R2, 100k, C5 etc – independently of the component also assists in making the schematic look neat and compact. Text stays upright during component editing.

The schematic drawing section is not orthogonal, but maintaining a neat diagram seemed easy due to the good snap-to system. Drawn lines can only be placed between pins; incorrectly drawn lines are inhibited just like *Ranger2* so you cannot accidentally hang lines in space etc. In this way, positive connectivity of pins is assured.

The small 's' that appears when you are in within drawing range of a pin is of great assistance, and is comparable to *Circuitmaker*'s SmartWire method. Snap-to distance can be set to suit yourself and I suggest it is one of first parameters to set before starting drawing in *Isis*. It is tempting with the 's' system to set the snap distance too small, as I did, to get more circuitry into a small screen, but then you will need to maintain a constant high level of concentration to draw. It then too easy to miss a connection and engage some other function with the mouse button. Increasing the snap distance solves this.

Another good feature is the electrical rules check – an automatic check for simple errors in design. I suppose everyone has made an embarrassing error like leaving an output pin disconnected at some time or other, only to discover it after making the pcb. If you are prone to such errors, this feature will definitely be of interest.

The sheet size can be varied from A4 to A1, and *Isis* supports multi-sheet designs in an interesting hierarchy of root sheets, which should contain the core of the design, and sub-sheets, containing peripheral designs. This could be useful for large schematics such as an active filter stereo audio amplifier. The left and right preamplifiers could be drawn on two root sheets, and three or more identical power amps per channel handling the high,medium and low frequencies, drawn on sub-sheets. Any circuit changes to one sub-sheet could then be automatically replicated in the others, a big saving in effort.

Visiting the library

Access to libraries was easy, and parts are transferred in the logical way, to the parts bin first, not to screen.. Note that in *Isis*, the parts bin is called the object selector.

Isis gives you a good graphical representation of the component before it goes to the parts bin. In most other programs, the libraries contain long lists of components. All the electrical and package information is included with each one and when you select a specific

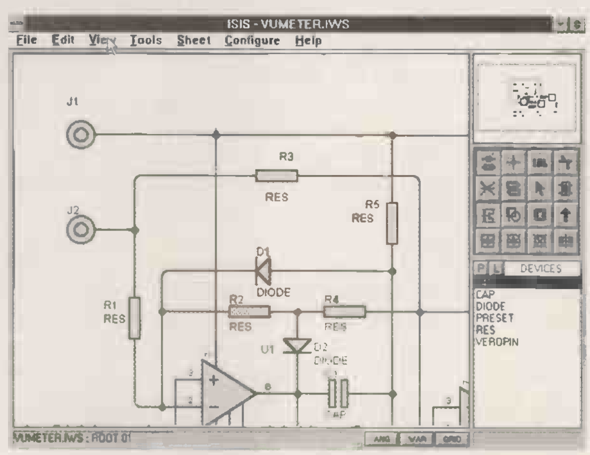


Fig. 10. Enlarged schematic showing graphics quality.

component, say a *BC108* transistor all this information is transferred with it to the netlist when the schematic is captured.

In Isis, the libraries are much shorter. There are indeed library volumes for analogue and digital ICs with transferable package information, but only generic library volumes for discrete components such as transistors, thyristors etc. When you select such a generic component, the package outline has to be selected manually from a drop-down menu at the ratsnest stage. So a transistor like the BC108 is represented by the generic n-p-n transistor symbol in *Isis*. It could in theory exist in any package from TO3 to TO92 at this point. The package information is entered later manually from the package selector as TO18.

The benefit of this arrangement appears to be much shorter and more accessible libraries. They will not be full of devices you never use, but it does mean an extra step to be done later. However, if you are moderately computer literate there is a system in Isis which can be set up to do this automatically. This is called 'Ascii Data Import', or ADI, and it means getting out the data books and entering in your most-used devices in a simple table in text in a file called Package.ADI. You can use Window's Notebook accessory to do this.

If you set up such a library, my strong advice is to copy it immediately so that your painstaking work will not be lost if your hard disk takes a holiday. When this file is activated on any specific schematic you have drawn, the outline for each device in Isis is then automatically provided for *Ares* to use.

I suggest that you try the two systems from the evaluation programs and compare both methods. It would be a good idea for *Labcenter* to provide as an optional extra some ready-made extended library packs like other makers, for busy engineers who do not have the time to sort out their own libraries.

The zoom control in *Isis* is easy to use, with seven levels, so is the autopan. Like other programs the zoom is a coarse control, but there is a custom zoom feature, and I found it very useful for making a schematic fill the screen. A map at the top right of the screen – called the 'overview window' by *Labcenter* – shows you where you are on the drawing area and assists in panning and finding lost drawings.

Generating a net list is also straightforward and can be in several formats besides *Labcenters*'s own SDF format – including *Tango, Spice* and *Futurenet*. I tried connecting to a third party simulator with the Spice net list and it was both easy and successful.

Although *Isis* and *Ares* are separate entities, the transfer of the schematic net list to *Ares* is painless; one click generates the netlist and triggers *Ares*, so the connection between the two for all practical purposes is seamless.

The *Ares* pcb layout format is very similar to the *Isis* schematic format and if you master one then the other will come easily. There are of course a few alterations as you would expect, but these are minor.

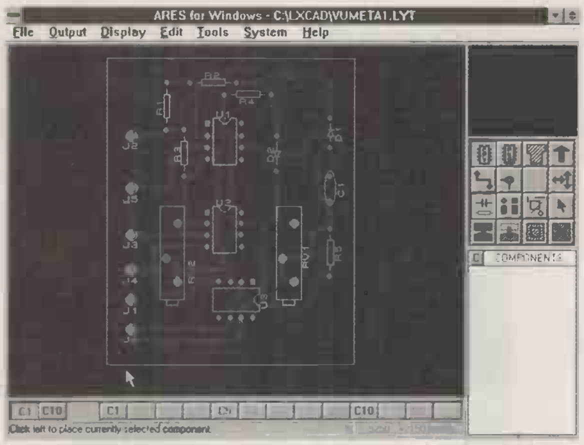


Fig. 11. Results of the Ares autorouter. Note the necked track at U1 putting this autorouter in category B.

Ares consists of two parts – a manual drawing program and an autorouter. The manual drawing part can be used on a ratsnest generated from *Isis*, or you can, if you wish, start from scratch in *Ares* and put the package outlines on the board manually, and then connect the traces. However, the latter would be a waste of *Ares*' resources.

If you start with a net list from *Isis*, the first thing to do is to position the parts on the board. This is done in a way similar to *Ranger2*, and is a good system. The parts are selected and placed one at a time from a parts bin, or 'Object Selector', in the desired position. The rat's nest can then be automatically generated with a couple of clicks in the 'Tools' menu.

Manual routeing from the rat's nest is accomplished by selecting a track size, and clicking on a component pad to start the track and tracing the track as you would in any manual system. When the far component is reached, clicking on a pad will complete the track.

There is no rubber-banding. You draw the track as you would normally in any manual pcb program. For some, this will be a most welcome feature. The rat line stays in place until the track is fully drawn, showing you the target pad for your track. Only when you complete the track does the rat line disappear.

If you make an error, on erasing the track the rat line re-appears, and you can re-draw the track. This is an excellent system, and for manual drawing from schematic capture it is the program I would recommend from those reviewed.

There is support for curved tracks, autonecking, and auto via placement. Also of interest is the plotter driver, which avoids complete reliance on the Windows plotter driver. The Windows driver is only used to draw straight lines, and *Ares* own plotter driver does the rest. This speaks volumes about the plotter driver provided in Windows 3.1.

The autorouter is moderately configurable, easy to set up and was comparatively quick. It is not a rip-up-and-retry or push-and-shove autorouter, so it would be unreasonable to expect too much of it. It worked best, as you would expect, on double-sided boards, but as the autorouter test shows, it could do a reasonable job on single-sided boards as well, falling into category B.

Summary

I spent more than the allotted time on assessing *Propak* and even then was still discovering interesting features tucked away in the program.

Isis would suit the professional designer who regularly uses it, particularly if large multi-sheet or multi-layer boards are involved. The user is unlikely to become frustrated by quickly reaching the limits of the system as it is a fully featured, sophisticated program. By the same token, anyone not using the package regularly will find the steep re-learning curve an obstacle after an absence from use.

On small boards, *Propak* would be a sledgehammer to crack a nut. For presentation of a schematic drawing, where appearance was important, *Isis* would be my choice from the programs reviewed.

The *Ares* part of the product is of particular interest to those who wish to avoid rubber-banding when manual routing from a rat's nest. It is the only schematic-capture type of manual drawing program I recommend.

The benefit of using schematic capture and then manual drawing is that you can use the built-in connectivity check to verify that your handiwork corresponds to the netlist and as a result, the schematic you have drawn. With this system it is difficult to make an unusable pcb.

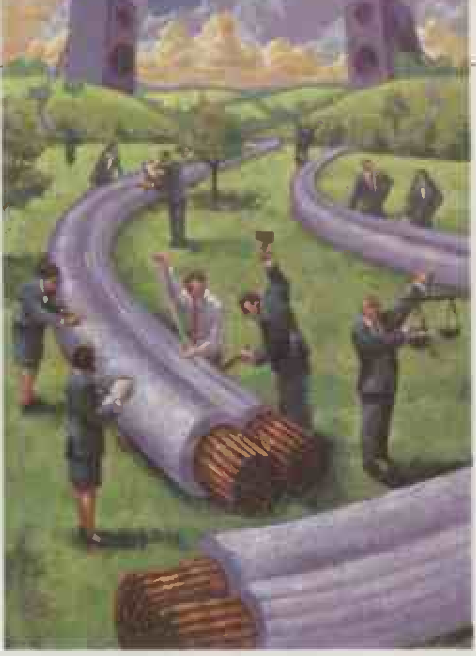
For double-sided boards that are not too dense or complex, the autorouter will usually be satisfactory provided you are prepared to put some time and effort into sorting the ratsnest. For single-sided boards some manual editing or reducing of the design rules may be needed. ■

Propak but cheaper

A similar package to *Propak* is produced by the same company in dos for about £100 less. The screen layout is in the same style and the control methods much the same.

Unless you are a hardened, blinkered Windows addict, this alternative is well worth considering, especially if your pc will not handle *Propak* for Windows.

An notable feature of this Dos version is that it overcomes the Dos memory barrier by using Expanded memory. Even if you have no expanded memory, it can be simulated from extended memory using software. MSDOS 6 for example has a facility for doing this.



Subjectivists claim to hear considerable differences in loudspeaker cable performance, but traditional distortion measurement methods do not bear this out. Cyril Bateman argues that traditional measurement methods are inappropriate.

Speaker cables

The claim that loudspeaker cables can and do cause distortions in hi-fi sound reproduction systems has resulted in two schools of thought. One school maintains that this is impossible since these distortions cannot be measured, the other disregards the measurement problem but maintains their ability to hear a different sound with change of cables.

Consequently discussions on these cable distortions have aroused more controversy than almost any other electronics design debate. Mystical diodes, over emphasised skin effect and magical properties of differing materials have all been proffered as reasons to explain these audible distortion effects.

Much of my working life has been spent measuring the s-parameters of anomalous components at all frequencies from dc to 3GHz. As a result, I fully appreciate how important load matching and characteristic impedance of cable or test jigging are – even for extremely short electrical lengths.

I had long assumed that cable characteristic impedance remained important, even at the lengths used for audio. This was confirmed on examining the measured results in Duncan's recent articles[1,2] and my own 42-strand cable test result.

This article, and a follow up, presents evidence that loudspeaker cables *do* behave as transmission lines and that the cable's characteristic impedance, propagation delay and mismatch behaviour is maintained down to audio frequencies.

I will also show that audible distortion results not from the cable itself, but principally from the amplifier, cable, loudspeaker combination's mismatched impedance. Simple, easily replicated methods involving both measurement and simulation confirm my results.

Hi-fi components interact

Since the combination of amplifier, cable, crossover networks and speakers all interact, speaker cables cannot be properly measured or evaluated in isolation.

Amplifiers have forward propagation delay around 1μs and considerable closed-loop feedback. Cables have characteristic impedance and one way transit delays around 6ns/m, while loudspeakers have extremely wide impedance/phase changes with frequency. Additionally – and perhaps most importantly – a moving-coil loudspeaker generates substantial voltage and current long after its drive signal has ceased, easily observed by physically disturbing a speaker cone.

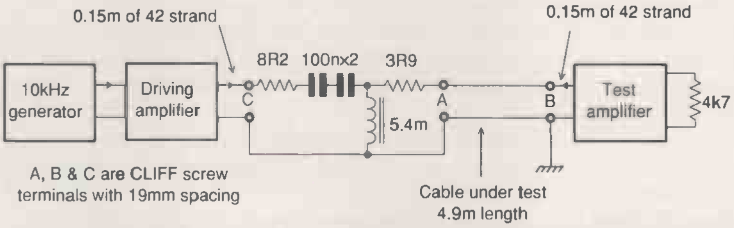
Conventional distortion measurements are based on a continuous sine wave. Many musical sounds however, those from pianos and cymbals for example, start as a fast transient and decay slowly. This envelope is similar to that of the exponentially-damped waveform included in the *PSpice* simulator. No doubt with electronic synthesisers the converse waveshape having instantaneous turn off, as used by Duncan[1] is also possible. Both transient signals should be evaluated.

Turn-off transient effects

Since badly matched or undamped loudspeakers generate a back emf into the amplifier,[3] my first test, which approximates to Duncan's, involved two amplifiers. These were configured back-to-back, but separated by the test cable and a load-sensitive voltage drive circuit.

One amplifier was driven at 10kHz by a signal generator. The test amplifier input was earthed via a 4.7kΩ resistor and both amplifiers were powered. The drive circuit was resonant at 10kHz, and current energised by the driven amplifier. The cable and test amplifier impedance damped the resonating voltage, which undamped attained more than 100V.

I made measurements of various test cables and observed the voltages at both cable ends. Care was taken to space both amplifiers as far apart as permitted by the leads of the two 250MHz scope probes used. The *ADC100* virtual oscilloscope was placed well away from



Test set-up for comparing loudspeaker cables. Channel A of the oscilloscope was connected to terminal A at one end of the cable under test and channel B was connected at the other end, on terminal B.

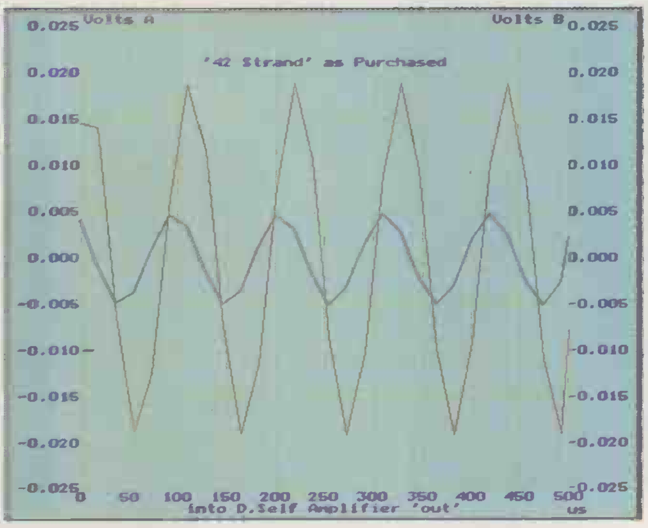


Fig. 1. Measured result of 42-strand as-purchased cable tested via a Douglas Self 50W amplifier.

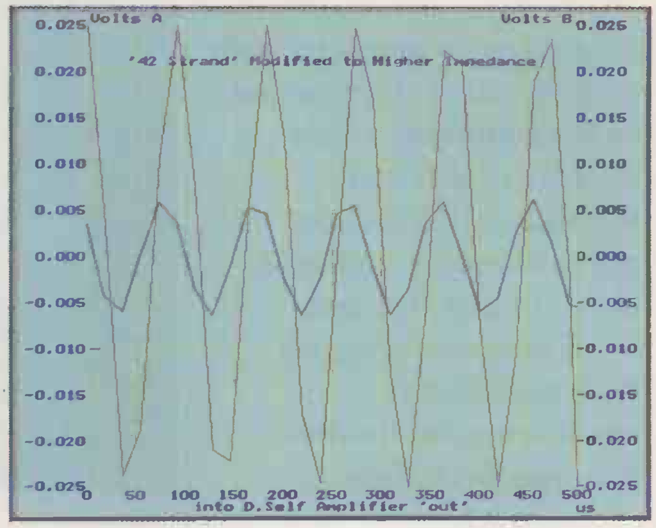


Fig. 2. Measured result of 42-strand cable modified to higher impedance using Douglas Self's test amplifier. Comparison with Fig. 1 clearly shows importance of the cable's characteristic impedance.

the computer to minimise stray pickup and the test cables were dressed in air in a wide U shape, similar to that used by Duncan. To avoid earth loops when using the *ADC100*, the scope probes were earthed to a single point at the test amplifier end of the test cable.

In each case, the driving amplifier was a low-cost mosfet design from Maplin (part No *LP56L*). I also carried out tests using Douglas Self's 'Blameless' class B[4] as the driven amplifier. It was built with better than 1% metal film resistors and matched semiconductor pairs. This was unhappy with less than 4.7kΩ input shorting impedance. Also, at 10kHz it had a somewhat higher output impedance than the mosfet design.

Since much debate has centred on the effects of the cable's resistance, inductance and capacitance, I bought a variety of readily available cables, all cut to 4.9m long. These represented a mix of known and unknown impedance and resistance, in both coaxial and figure-of-eight constructions. They ranged in style and cost from Duncan's bell wire to Jenving *Supra Ply* 2.0 constructions.

This mix of cable structures was deliberate; simple examination of their impedance equations confirms that low impedance cabling with both minimal inductance and minimal capacitance, is most easily manufactured using coaxial methods. On the other hand, twin-line or figure-of-eight cable, with its much increased inductance and reduced capacitance, is better suited to higher impedances.

While lowered impedance is possible using twin line, the penalty is a considerable increase of shunt capacitance, as with the *Supra Ply 2.0*.

While series resistance is important, I found the damping of the resonant voltage at the loudspeaker end to depend principally on the cable impedance. To confirm this, I took two equal lengths from a reel of 42-strand and arti-

Transmission lines

Transmission lines cables are made in two main formats each comprising two separated conductors. These formats are coaxial and line pairs.

In both cases, reduced conductor separation reduces series inductance, increases shunt capacitance and reduces the cable's characteristic impedance, Z0.

$$Z0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

which, from ref. 7, at high frequencies approximates to,

$$Z0 = \sqrt{\frac{L}{C}}$$

This characteristic impedance assumes an infinitely long length or a shorter length terminated by this impedance and produces no reflected wave. All other termination impedances (mismatch) produce a reflection which is returned to the source. If both ends are mismatched and the cable has no loss, these reflections continue indefinitely dependant on the degree of mismatch.

At low frequencies, since the inductive reactance is small and capacitive reactance is large, the characteristic impedance can increase. If $R/L=G/C$, the special case of a 'distortionless' line, then Z0 is frequency independent.

Certain constructs can be designed for characteristic impedance by their physical dimensions.

For coaxial cable,

$$Z0 = \frac{138}{\sqrt{\varepsilon}} \log \frac{D}{d}$$

where ε is the dielectric constant of the insulator. Capacitance C, also from ref. 7, is,

$$C = \frac{24.16\varepsilon}{\log \frac{D}{d}} \text{ pF/m}$$

For the line pair,

$$Z0 = \frac{276}{\sqrt{\varepsilon}} \log \sqrt{\frac{2D}{d}\left(1 + \left(\frac{D}{2H}\right)^2\right)}$$

where H is height above ground. Capacitance, see ref. 8, is,

$$C = \frac{12.07\varepsilon}{\log \frac{2D}{d}} \text{ pF/m}$$

Transmission lines have a propagation delay that depends on length and dielectric materials used. In practice this approximates to 6ns/m for commonly used plastics.

Resonant drive circuit

The resonant circuit comprised a 5.4mH inductor and 50nF capacitor. The inductor was in shunt to ground thus replacing the speaker voice coil, the capacitor was used to feed current from the driven amplifier via an 8.2Ω short circuit protection resistor. A second resistor of 3.9Ω used to simulate the voice coil resistance, was used to feed the inductor's voltage into the test cable and thus into the test amplifier.

Due to the very high unloaded 10kHz voltage and current which the capacitor must sustain, I used two in series 100nF, 400V Siemens polypropylene *B32650* (Electrovalue part 50.1400).

The inductor used was a 5.4mH super power low-loss 1mm wire having a Q of 15 at 10kHz, from Falcon Acoustics, Tabor House, Mulbarton, Norwich, contact Malcolm Jones. The two resistors were *HSA25* wire wounds.

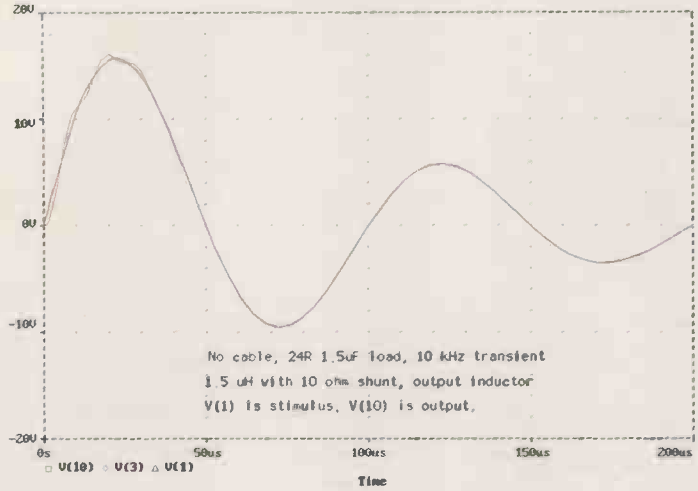


Fig. 3. Simulated behaviour of typical amplifier output configuration when driving into a capacitive and shunt resistor load. Voltage V(1) is taken as the location of the feedback connection.

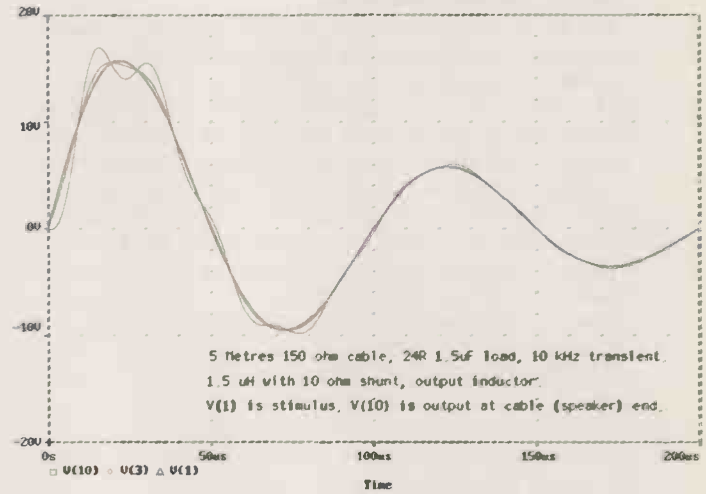
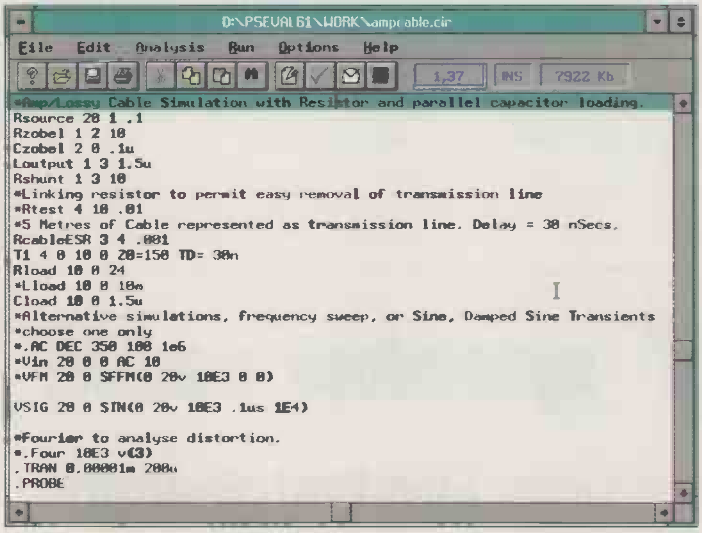


Fig. 4. Simulation of configuration identical to Fig. 3, except for the addition of 5m of high impedance Figure 8 style cable. This distortion should be clearly audible on transients. Voltage V(3) is waveform at amplifier output terminals for all simulations.




```
*Amp/Lossy Cable Simulation with Resistor and parallel capacitor loading.
Rsource 20 1 .1
Rzobel 1 2 10
Czobel 2 0 .1u
Loutput 1 3 1.5u
Rshunt 1 3 10
*Linking resistor to permit easy removal of transmission line
*Rtest 4 10 .01
*5 Metres of Cable represented as transmission line. Delay = 30 nSecs.
RcableESR 3 4 .001
T1 4 0 10 0 Z0=150 TD= 30n
Rload 10 0 24
*Lload 10 0 10m
Cload 10 0 1.5u
*Alternative simulations, frequency sweep, or Sine, Damped Sine Transients
*choose one only
*.AC DEC 350 100 1e6
*Vin 20 0 0 AC 10
*VFM 20 0 SFFM(0 20v 10E3 0 0)

VSIG 20 0 SIN(0 20v 10E3 .1us 1E4)

*Fourier to analyse distortion.
*.Four 10E3 v(3)
.TRAN 0.00001m 200u
.PROBE
```

Fig. 5. Basic PSpice Net-List as used for Figs 3 to 7. This can be simulated using the evaluation version of PSpice.

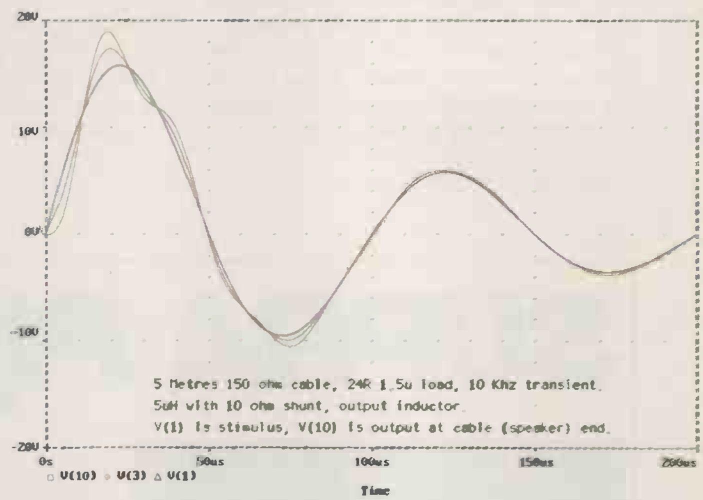


Fig. 6 Simulation of Identical configuration as Fig. 3, except for increased value of amplifier output inductor to 5μH. This distortion should be clearly audible on transients.

ficially increased the characteristic impedance of one by unzipping it. This increased its separation to around 8 mm, which was retained by laminating in adhesive tape. In this way, the two cables have identical resistance, but differ in impedance.

While initial measurements used a 100MHz twin-beam scope, the published plots were obtained using the Pico *ADC100* computer attachment, recently on special offer in *Electronics World*. With two channels operating, its analogue-to-digital conversion rate is 55 kHz – well above the Nyquist minimum for a 10kHz measurement. Care was also taken to ensure that at least two peaks were measured for both channels in each plot, **Figs 1,2**.

These results of two different cable impedances but with constant resistance, using only low cost and simply applied techniques, are similar to those reported by Duncan for his more complex AP test method. These results prove the significance of cable impedance in controlling overhang from the speaker for the bipolar and mosfet amplifiers used.

Slowly decaying transients

Audio power amplifiers are often tested with a load of 8Ω with 1.5 or 2μF in parallel. Continuous sine-wave simulations with and without 5m of a typical figure-of-eight cable show negligible distortion when 'Fourier' transformed. Since distortion of the first cycle was clearly visible however I changed the stimulus to simulate a transient using the exponentially damped sine wave in *PSpice*. This clearly shows the transient distortion noted, which would be audible within a music program, **Fig. 3**.

Further simulations to explore this show that distortion increases with increase of load resistance or output inductor value. Regardless of load resistance however, an inductive load caused smaller distortions, **Figs 4, 5, 6**.

Predictably these distortions reduced as cable impedance was lowered, even though the shunt resistor remained high. This is because the input impedance of the cable/amplifier combination, now provided the necessary damping, **Fig. 7**.

Applying the proof

These results prove that cable characteristic impedance is important in audio systems. With this in mind I will now examine Duncan's plots.

In two articles[1,2] Duncan concentrated on two cables. These were an undefined mains cable and Jenving *Supra Ply 2.0*. Both were tested at 1kHz using an unspecified Tannoy

15in dual-concentric loudspeaker.

In a *Studio Sound* article[5], he also used an unspecified 15in dual-concentric Tannoy loudspeaker with tests performed at 125Hz, 1kHz, and 15kHz on eight additional cables. Examination of the published test report of Tannoy's *D700* speaker system[6] indicates that if similar to Duncan's speaker, you could expect impedance of 3.1Ω resistive, 6.5Ω inductive and 5Ω resistive respectively. You could also expect resonant impedance peaks at around 45Hz/7Ω and 2700Hz/20Ω.

From his measurements, these cables have an estimated high frequency impedance of 79.6 and 37.5Ω respectively. At 1kHz, the inductive reactance is reduced and capacitive reactance is increased. Because of this, both impedances will be higher, but making some allowance for this also the missed peak in **Fig. 3** for reference 2, cable C, you can see that Duncan's voltage ratios closely follow the mismatch ratios at the speaker end of the line.

These results clearly demonstrate how transients can be distorted in speaker/cable systems while continuous sine waves are not. They could bridge the chasm presently existing between the two opposing schools of thought.

In my next article on this topic, I explore other published test methods. I also look at how all these results pertain to a complete amplifier, cable and speaker system and provide all measured results by plots and tables.

I would however ask that anyone wishing to shoot these findings down in flames – first repeat the experiments. ■

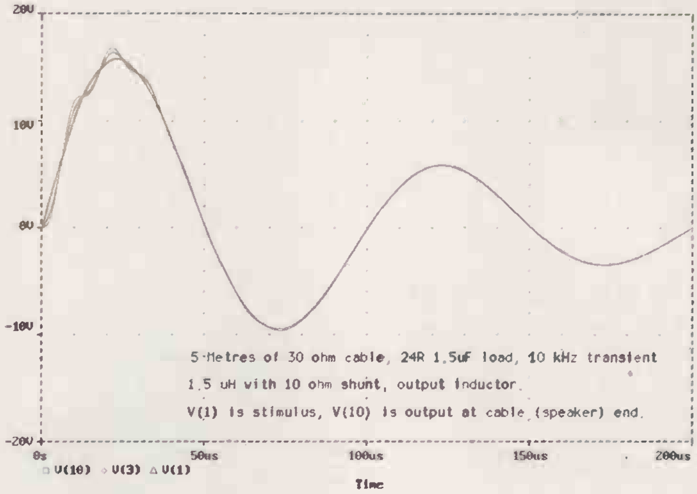


Fig. 7. Much reduced distortion resulting from change in cable impedance, otherwise circuit is identical to Fig. 4.

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Speaker cables **pulse tested**

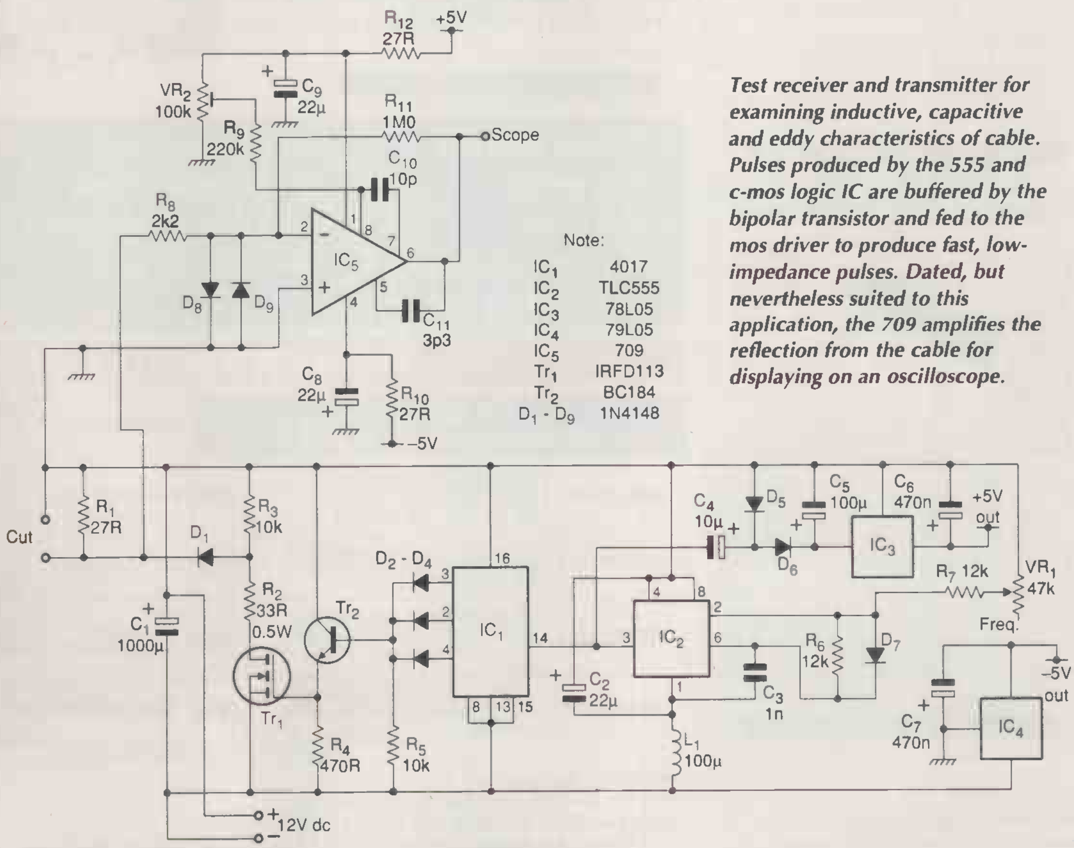
By feeding cables with fast pulses and looking at the resulting waveforms, Eric Foster has been able to illustrate clear capacitive, inductive and eddy differences between cables suitable for speaker driving. Sadly for the cable marketers though, these differences are too high in frequency to be audible.

Pulse induction is normally associated with metal detectors. However it can also be used as a unique method of testing loudspeaker cables to determine differences that may relate to audible effects.

The measurement waveform takes place after the primary pulse has ceased and is dependent on the cable inductance, capacitance and cross sectional eddy currents. In the system outlined, cable resistance is not of major significance as the pulse generator impedance is deliberately made high. This is done to limit the power supply current and to keep the test pulse amplitude constant over widely varying cable types and lengths.

Injecting a pulse

The essence of the method is to inject a current pulse into a known length of cable with the far end shorted.



Test receiver and transmitter for examining inductive, capacitive and eddy characteristics of cable. Pulses produced by the 555 and c-mos logic IC are buffered by the bipolar transistor and fed to the mos driver to produce fast, low-impedance pulses. Dated, but nevertheless suited to this application, the 709 amplifies the reflection from the cable for displaying on an oscilloscope.

At the termination of the current pulse a wide band op.amp. amplifies any low level decay effects due to induced eddy currents in the wire cross section or to polarisation signals in the insulating material – if they occur.

One metre lengths were chosen as these were easier to obtain, and the measured effect can easily be extrapolated to longer lengths. For the more readily available, and inexpensive, cables such as mains lead and coaxial, 5m lengths were measured in addition to the shorter ones.

This method is unique because the resultant waveform is solely due to the cable under test

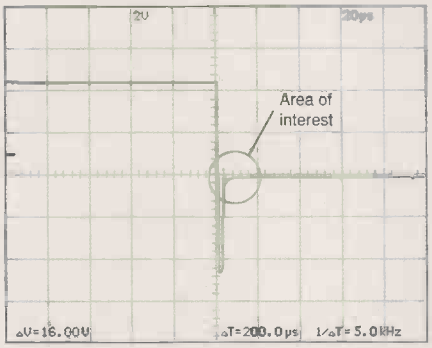


Fig. 1. Output from the 709 op-amp resulting from a test on a 1m length of mains cable. There is an initial positive excursion, followed by a short negative saturation period caused by the cable's reverse emf. This negative transition is the area of interest.

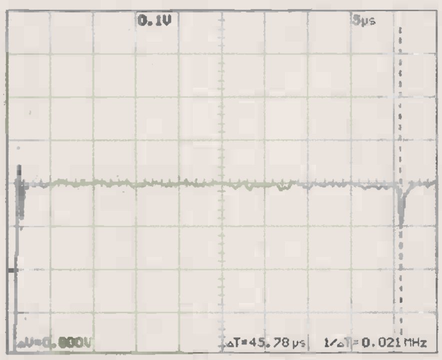


Fig. 2. Reference waveform. The nearer the cable test comes to this shape, the lower the inductance, capacitance and cross-sectional eddy currents.

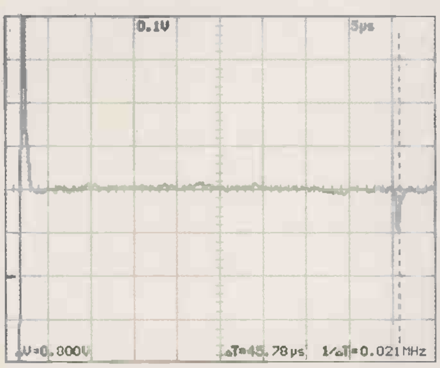


Fig. 3. Shark Wire is inexpensive speaker cable comprising 129 strands of 0.1mm oxygen-free copper.

and is not complicated by speaker impedances, reflections or power amplifier characteristics.

Implementing the test system

Transistor Tr_1 provides the current pulse to the cable via R_2 and D_1. Resistor R_2 limits the amplitude of the pulse to about 0.36A. This corresponds to the current that would flow for 1W peak in an 8Ω load.

Duration of the pulse can be varied between 50 and 150μs by means of VR_1 and the pulse frequency varies correspondingly between 5kHz and 1.5kHz. In practice, for the cables tested, the pulse duration and frequency had no effect on the recovery waveform as the cable time constants measured were very much faster. Diode D_1 isolates the cable under test from the drain capacitance of Tr_1 after switch off which would otherwise lower the cable's resonant frequency.

Resistor R_1, across the driven end of the cable, damps out any ringing which is due to the cable-under-test's inductance and self capacitance. Without the damping resistor the ringing frequencies measured in the range 10-20MHz for the 1m lengths. This is well outside the audible band.

Wide band amplifier IC_5 exhibits a gain of 400. Although the *709* is an early IC, dating back to the late 1960s, it has excellent gain, bandwidth and recovery characteristics. These characteristics are difficult to find in more modern ICs. This is no doubt due to its straightforward bipolar architecture.

The cable-under-test's recovery waveform is viewed on an oscilloscope connected to IC_5 output. As IC_5 is wired as an inverting amplifier the cable-under-test waveforms are inverted, but this is of no consequence in demonstrating cable recovery. If you want to pursue this further, you could re-connect IC_5 as a non-inverting amplifier or follow the existing circuit with a fast inverting buffer.

Figure 1 shows the output waveform of the test circuit with a 1m length of two-core mains cable connected as the cable-under-test. Initially, there is a positive excursion of 100μs where the amplifier is driven into saturation by the drive pulse. This is followed by a short negative saturation period caused by the reverse emf generated by the cable's series inductance.

The subsequent plots are triggered by this negative excursion and the circled area of interest magnified.

Reference waveform criteria

To generate a reference waveform, the terminals of the test unit are shorted by soldering them together. The initial negative excursion in this case is the amplified result of the back emf generated in the stray inductance of the pcb tracks associated with Tr_1 and its immediate components.

It is vital to keep this inductance to a minimum, so that the amplifier has returned to a flat baseline in 3-4μs. This constitutes the reference waveform, **Fig. 2**, with which to compare cable-under-test waveforms.

Cables with low inductance, low capacitance and low cross-sectional eddy currents will depart little from the reference waveform. The negative spike adjacent to the right cursor is a clock generator spike while the ripples and bumps are largely op-amp noise.

The cursor is set at $1/\Delta T$ of 21kHz, which corresponds to the highest frequency that can be obtained from a standard cd. Any transient or absorbed energy decay should have vanished well before this so as not to affect the audio band.

Measurement terminals of the test unit consisted of two 25mm lengths of 7/0.2, twisted as far as possible to minimise their inductance.

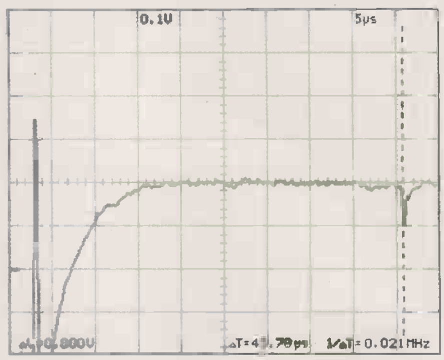


Fig. 4. Van den Hul CS122 speaker cable has seven bunches comprising 21 strands of 0.15mm silver-plated copper.

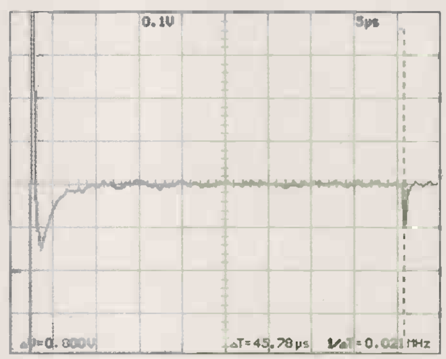


Fig. 5. Jenving Supra Ply 2.0 normally shows a small eddy current decaying within 10μs, but when twisted, the eddy current and time constant increase.

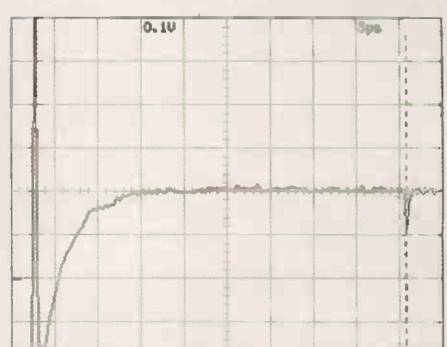


Fig. 6. When twisted, Jenving Supra Ply 2.0 performs less well under this test.

The cable-under-test was then soldered in turn to these to ensure good electrical contact. Proprietory speaker terminals or connectors were not used because they could contribute their own eddy current effects.

Figure 3 shows response from a 1m length of inexpensive speaker cable from Shark Wire Co. This is a parallel wire consisting of 129/0.1mm strands of oxygen-free copper and a conductor separation of 5mm. The negative excursion and overshoot due to the series inductance settles down in under 5µs and there is no evidence of cross sectional eddy currents. Having experience in pulse-induction metal detection, this came as no surprise to me. It is usual to use fine stranded wire in the search coil winding to minimise cross section effects.

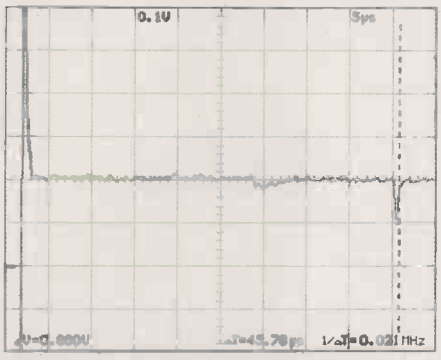


Fig. 7. Eddy currents are not a problem here, but Heywire gave the highest series inductance. Overshoot decay was short though, at 4µs.

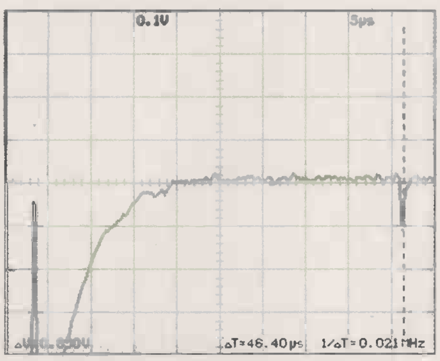


Fig. 8. Cable Talk 4 had the largest eddy-current loss, the signal taking 25µs to decay into the noise floor.

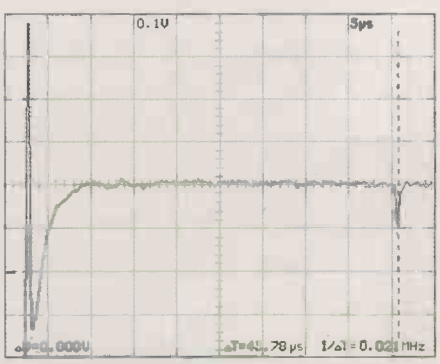


Fig. 9. Lawnmower flex performed surprisingly well, eddy currents dying away in 10µs.

By comparison, **Fig. 4** shows the response from 1m of Van den Hul *CS122*. The conductors in this cable consist of seven bunches of 21 strands of 0.15mm silver-plated copper encased in an inner conductive plastic material with a conductor separation of 11mm.

The exponentially decaying waveform is due to eddy currents in the overall wire cross section aided by the higher conductivity of the silver coating. Even so they have decayed away within 20µs, or 1/ΔT of 50kHz.

Jenving's Supra Ply 2.0 was an interesting cable to try, endorsed as it was by Ben Duncan in his tests[1]. **Figure 5** shows a small eddy current signal decaying within 10µs. If the cable is twisted or bent however, the braided 0.14mm strands make better contact with one another and the eddy current amplitude and time constant increases, as in **Fig. 6**.

Heywire from Heybrook Audio uses single solid copper cores of 0.6mm diameter. This is small enough not to exhibit eddy currents, but combined with the 8mm conductor spacing gave the highest series inductance. However, the resulting overshoot decayed in 4µs, **Fig. 7**, and is similar to Shark Wire cable.

Of the cables measured, *Cable Talk 4* had the largest eddy current loss – the signal taking a full 25µs to decay into the noise level, **Fig. 8**. The conductor bunches consist of 42 strands of 0.3mm copper separated by a 6mm spacing.

Non audio cables

Mains lead is often derided for audio use and I have never seen rf cable advocated for this application. So I tested 10A lawnmower flex and RG58C/U coaxial cable to see how they would fare.

The lawnmower cable, **Fig. 9**, with 32/0.2mm conductors spaced at 2mm, came out surprisingly well; the eddy currents dying away in 10µs. Type RG58 coaxial cable, **Fig. 10**, was the cleanest of all, showing no overshoot and the eddy currents in the braid decaying in 7µs.

Slightly less pick-up noise is also evident due to the screening effect of the coaxial braid. It is important to stress that the rf characteristics of coaxial cable have no bearing on these tests. It is simply the series inductance, capacitance and eddy current losses which affect the pulse induction tests recorded here.

Noise performance and inductance

Other waveforms can be observed with the test circuit. If the probe is connected across the damping resistor the back emf spike can be measured which relates to the series inductance.

Comparison of the parallel conductor cables with the coaxial cable shows the coaxial type to have the lowest series inductance. Compare **Figs 11** and **12**.

If the damping resistor is removed, the ringing frequency of the cable can be measured. Both the inductive spike and ringing are displayed on a time base ten times faster than the previous cable responses so you can see that the signal is well into the r.f. region, even for 5m lengths.

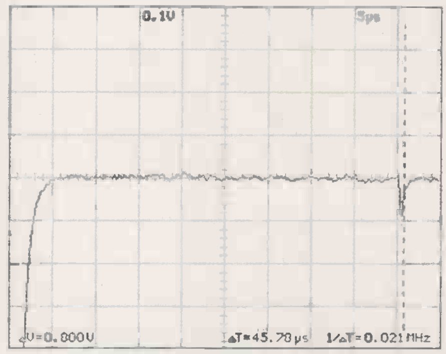


Fig. 10. Cleanest of all – plain and simple RG58 coaxial cable. There is no overshoot and eddy currents in the braid decayed within 7µs.

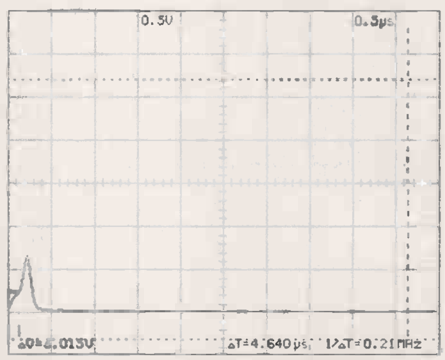


Fig. 11. RG58A/U coaxial cable again, but tested for series inductance. Compare this with Fig. 12.

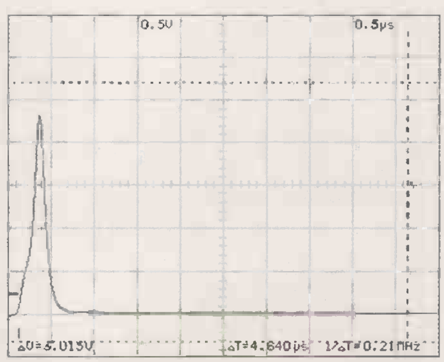


Fig. 12. Inductive spike resulting from Heywire shows that it performs less well relative to coaxial cable in this test.

While the 5m lengths were connected to the test unit, it was interesting to observe the relative noise pickup. All the tests were conducted in an electronics workshop on an industrial estate, where there is a fairly high electrical noise level.

As you can see from **Figs. 15** and **16** the coaxial cable braid affords considerable screening of rf noise. The larger overshoot spike is because we now have more series inductance resulting from the greater length.

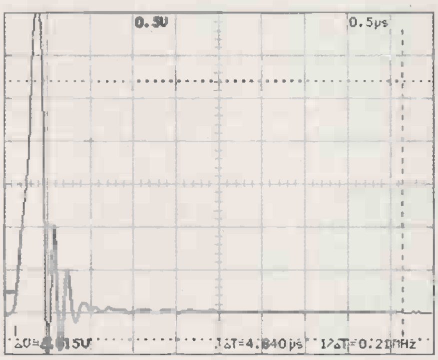


Fig. 13. Performance of a longer length of lawnmower cable – 5m – with no damping and a ten times faster time base indicates that the frequencies involved are well outside the audio range..

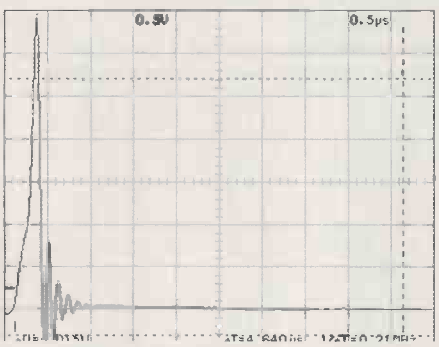


Fig. 14. RG58 coaxial cable performance for a 5m length with damping removed.

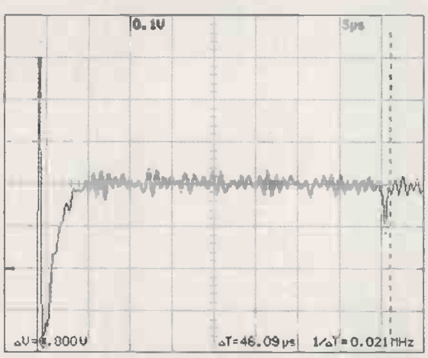


Fig. 15. Noise pickup of lawnmower cable in a noisy environment, length 5m.

Copper oxide and diode effect

Two forms of distortion mentioned in other articles on speaker cables are current jumping between strands and a diode effect[2] due to copper oxide on the strand surface.

No evidence of these phenomena were seen on the foregoing waveforms. However some tests were conducted on deliberately oxidised cable to see if there was any measurable effect.

Experiences with underwater pulse-induction metal detectors have shown that leakage of salt water into a cable very quickly causes oxidation of the strand surface, which takes on a dark red mat appearance. Under such conditions the conductor acquires a surface layer of copper hydroxide and copper chloride.

I injected salt water under pressure into a 1m length of lawnmower cable until it emerged from the strands at the far end. The cable was left for a couple of days and then tested. There was no change in the oscilloscope waveform.

On the third day the cable was immersed in salt water which was heated to 50°C and left overnight. The dull red coating was now in evidence to show oxidation was taking place. Again there was no measurable difference in the waveform which was again checked after one week, **Fig. 17**.

Some of you may object that the salt water test is not realistic, and that the oxide layer is not the same as would occur naturally in a speaker cable. However it is interesting that such a drastic contamination with a corroding electrolyte had no measurable effect on the waveform.

Another rather different oxidising test was done. This was to strip all the insulation off of a metre of one conductor of lawnmower cable and measure its eddy-current response, **Fig. 18**. The smaller amplitude is due to the shorter length but, as stated previously, the decay time is independent of this.

Using a butane blow torch, the cable was heated along its length until the strands took on a black appearance and the wire was in a softer annealed state. The response was then as in **Fig. 19**. In this case the oxide layer has broken up the eddy current paths between strands and all but removed that part of the response.

It appears, therefore, that the formation of a normal oxide layer on the strands of a speaker cable will do very little to alter the cable's characteristics. Over the long term, however, it could even serve to improve the high frequency response of a cable, if only at ultrasonic frequencies.

In summary

This relatively simple method, derived from the front end circuit of a pulse induction metal detector, can give valuable information about the characteristics of loudspeaker cables.

The signals being examined result purely from the cable itself, and occur after the drive pulse has ended. In particular, this method clearly shows the effect of eddy currents in the cable cross section.

All of the waveforms, except where otherwise indicated, are for 1m lengths which are obviously shorter than would normally be used in a hi-fi system.

Tests on 5m lengths of lawnmower flex and coaxial cable show that all the effects increase in proportion to length. As the length increases so do the series inductance and capacitance,

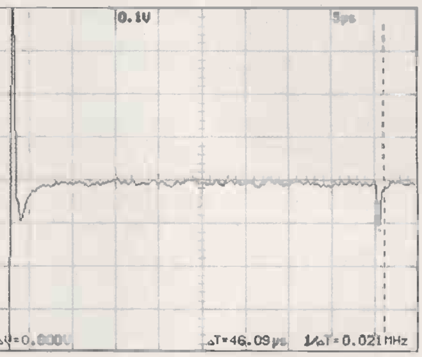


Fig. 16. In the same environment used for Fig. 15, the same length of coaxial cable picks up far less noise.

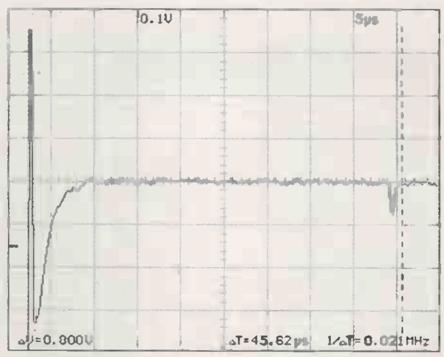


Fig. 17. Some hi-fi enthusiasts advocate the use of oxygen-free copper in audio cables. Here, lawnmower cable was injected with salt water, left for three days and tested again. No change is apparent in these tests.

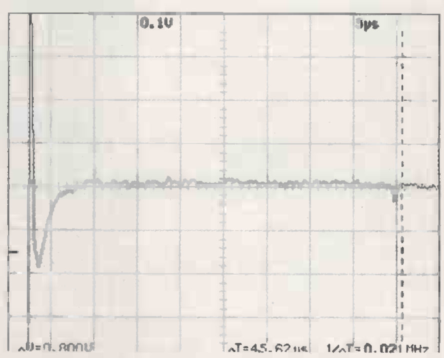


Fig. 18. A 1m length of lawnmower cable with its insulation removed.

and they affect the amplitude of the inductive spike and ringing frequency. Cross sectional eddy currents increase in amplitude but the decay time constant remains the same.

Increasing the pulse current to simulate higher wattages will increase the inductive spike and eddy current amplitudes proportionally. There is no evidence of dielectric polarisation or diode effect which, if it existed, would be expected to show with this method which can resolve signals down to 50-100μV across the cable.

There are obvious measured differences between cables using the pulse induction technique. But I will leave it to professional audio engineers to decide whether these effects can in any way impinge on what we actually hear, as they all occur well above the audio band.

If I had to buy a dedicated speaker cable I would probably opt for the Sharkwire at around £2.50 per metre. This displays no cross sectional currents and has a reasonably low series inductance due to its 5mm conductor spacing. Its dc resistance is 0.04Ω/m, which falls midway between Van den Hul at 0.012Ω/m. and *Heywire* at 0.119Ω/m.

Currently, however, I am using RG58. It embodies all of the characteristics that I consider a good speaker cable should have. The

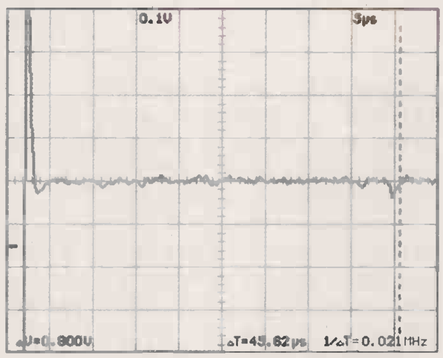


Fig. 19. Lawnmower cable stripped and subjected to a blow torch indicates that older, oxidised cable may even perform better at high frequencies.

coaxial configuration gives not only the lowest series inductance but also screening from external interference which can find its way to the amplifier input via the feedback loop.

The 0.1mm strands in the outer braid and the 19/0.18mm core, both of which are tin plated copper, give a low eddy current loss and a d.c. resistance of 0.053Ω/m. The insulation between the outer braid and core is solid polyethylene and the capacitance 100pF/m. Best of all, the retail price is about 50p a metre.

These few tests have hardly scratched the surface in terms of the variety of cables on the market, in fact none of the cables tested falls into the super-cable class. The most expensive one tested is the Van den Hul at £9.50/m.

Cables are available that cost £100s and even £1000s per metre. It is not at all clear what measured improvement one would see that could possibly affect audio quality. The only electrical parameters that can be changed are the series inductance, parallel capacitance, resistance and eddy current losses.

If a perfect cable *were* available you would simply end up with a response identical to the reference waveform in Fig. 2. Cheap cables already come close to this. Perhaps suppliers of really high end cables would loan one for a few days for the foregoing tests to be done; or perhaps construct their own test circuit and publish the results. ■

References

1. Duncan, B., What a Difference a Wire Makes, *Stereophile*, Dec. 1995.
2. Duncan, B., Modelling Cable, *Electronics World*, Feb. 1996.

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General

Frequency range	10Hz to 1MHz
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Output waveforms	sine, square
Output impedance	600Ω
Accuracy	±5%+2Hz, 10Hz-1MHz
	±3%+2Hz, 100Hz-100kHz
O/P floating voltage	within ±1.5dB

Sinewave characteristics

Distortion	<0.05%, 500Hz to 50kHz
	<0.5%, 50Hz to 500kHz
Output voltage	8V rms, max
Output flatness	±1.5dB (1kHz)
Output impedance	600Ω

Squarewave characteristics

Output voltage	15V pk-pk, min
Rise time	0.5μs

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Input impedance	10kΩ
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Cable science?

Geoff Williams **believes that audio signals passing through a cable are affected not just by copper cross-section, but also by a complex combination of field and semiconductor effects.**

Transmission of alternating current through a cable produces a magnetic field, an electrostatic field and these are affected by the physical structure of the wire.

Magnetic field considerations

Electrons exhibit a rotating magnetic field and all magnetism derives from this. The field round a wire radiates outward in concentric circles from the centre. At the centre, the field is zero, reaching a maximum at the wire surface. It then falls off inversely proportionally to distance, **Fig. 1**.

Relevant expressions are inductance L which is change-of-flux divided by change-of-current, and impedance R in ohms which is $2\pi fL$ where f is frequency. In an ac circuit, the flux (field) and the current both change together with frequency. Since flux is greatest at the surface, it follows that the change of flux is also greatest at the surface for the same change of current. Consequently, the inductance will be greatest at the surface and so will be the impedance.

This increasing impedance results in a loss of efficiency as frequency rises. Considering also the eddy currents set up in the wire, the situation worsens. Eddy currents force electrons toward the surface, and the higher the frequency, the more they are forced outward into this region of high impedance, decreasing high frequency efficiency. This is the skin effect, whereby high frequencies travel down the skin of the conductor.

In **Fig. 2**, the circle represents the conductor and its associated magnetic field. The direction of rotation is as if the current is going into the paper as depicted by the cross in the middle. Though the field is made up of concentric circles, at an arbitrary point A, the electrons see the relative flux and direction as shown. Electrons are moving into the paper, so to speak, through a magnetic field at right angles relative to the current. From Fleming's right-hand rule, the electrons move in the direction shown. Arbitrary point A can be considered anywhere in the conductor and the direction of motion is always toward the outside of the conductor.

Flux changes with frequency so, the higher the frequency, the greater the change of flux in a given period of time and the greater the tendency for electrons to be forced to the surface. Because the flux density is stronger and electrons are effectively cutting a faster moving flux at the surface, this effect is intensified at the surface.

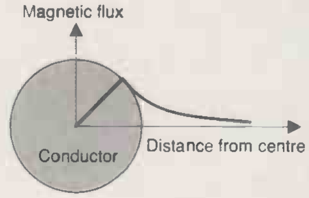

Fig. 1. Magnetic field around a wire radiates outward. It is zero at the core, maximum at the surface of the wire, and falls off exponentially as it radiates outward.

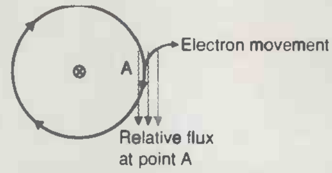

Fig. 2. High frequencies travel along the surface of a conductor – a phenomenon known as skin effect. This diagram illustrates how electrons are forced toward the skin.

Transients and high frequencies

Because of the skin effect, if you increase the surface area of the conductor, for example, by having a rectangular cross-section, you will improve the high-frequency performance and transient response. But this is not an elegant solution. What is best is to prevent the eddy currents using Litz wire. Being made up of separately insulated strands, Litz wire effectively prevent eddy currents moving from the centre to the outside of the conductor. Each strand however can still be considered as a solid core with its own internal eddy currents, these are tiny compared to what they would be in one large solid-cored wire.

To achieve maximum efficiency, the strands

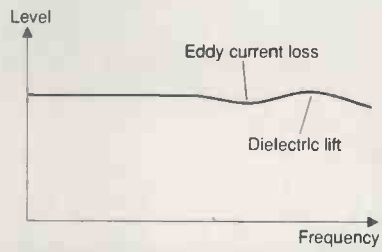

Fig. 3. Frequency response of a solid-core cable with plastic sheath. In listening tests the response dip is audible.

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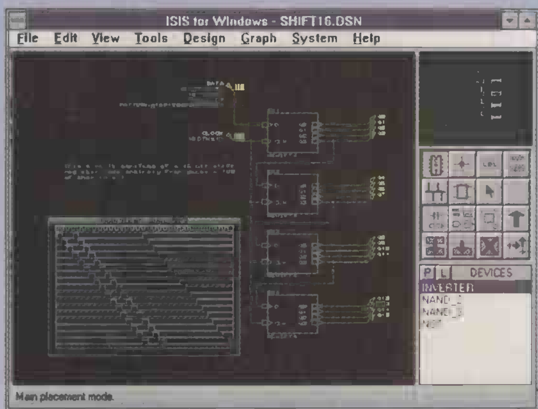

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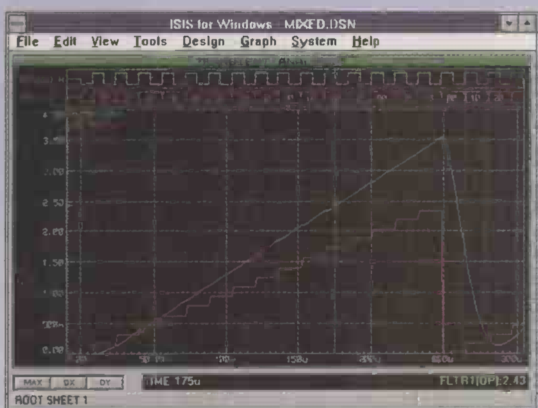

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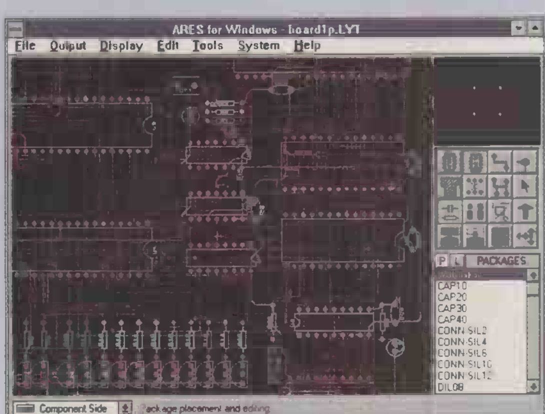

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need to be bunched into the minimum cross-sectional area, meaning a circle.

Fields and insulation

Looking at the electrostatic field around wire carrying a current, the flux is considered to emanate from the positive (protons) and go to the negative (electrons) The strength of the field (voltage) falls away inversely proportionally to the distance from the surface, as in the magnetic situation.

Things change, however, when you consider the effect of encasing the wire in a plastic insulating sheath. The plastic acts as a dielectric and effectively suppresses the extemal electrostatic field, reducing the voltage detected at various distances from the wire.

The amount of suppression by a material is related to its dielectric constant – relative permittivity. Basically, the higher the dielectric constant, the greater the field suppression.

All insulators exhibit dielectric loss. This means that the insulator retains a small amount of electrostatic charge when excited by the signal. It does so in much the way steel retains its magnetism when it is subjected to an external magnetic field. Consequently, the insulator must be forcibly discharged by the signal when it changes polarity. This leads to signal loss and cancellation. The smaller the dielectric loss, the better.

From the above, you would expect that a material with low dielectric loss and high dielectric constant would be the best material to use as an insulating sheath for an audio cable. The best materials are polypropylene, polyethylene, teflon and, slightly down the scale, polyester. PVC is lower still and inferior. The worst insulators are probably rubber-based compounds, including polyolefins. So although the relevant electrostatic field lies outside the wire bounderies, whether you place something next to it or not can have a serious effect on the sound quality where loudspeaker cables are concerned.

The dielectric is charged and discharged by the electrostatic field of the audio signal. The more the dielectric suppresses the field, the less it is charged and discharged. The lower the dielectric loss, the less tendency there is for the material to remain charged when the accompanying field in the wire has long been and gone.

Conductivity of metals

Silver	$1.620\mu\Omega/cm^3$
Copper	$1.682\mu\Omega/cm^3$
Gold	$2.420\mu\Omega/cm^3$
Aluminium	$2.825\mu\Omega/cm^3$
Rhodium	$5.100\mu\Omega/cm^3$
Zinc[1]	$6.000\mu\Omega/cm^3$
Iron	$9.800\mu\Omega/cm^3$
Platinum	$9.970\mu\Omega/cm^3$
Nickel[2]	$10.900\mu\Omega/cm^3$
Tin[3]	$11.500\mu\Omega/cm^3$
Chromium[4]	$13.100\mu\Omega/cm^3$
Lead[5]	$20.650\mu\Omega/cm^3$

[1] used in brass
[2] used in resistance wire and screening
[3] used in solder and in plating copper
[4] used in nichrome resistance heating wire
[5] used in solder

The difference in sound I perceive between bare wire and insulated wire indicates that a bare solid core wire has a curtailed top end compared to a sheathed piece of the same. **Figure 3** represents the frequency response of a solid-cored cable with a plastic covering. My listening tests bear this out, with a noticeable dip in the response. The thicker the wire, the more apparent the effect. However, the eddy current losses are greater than the dielectric lift and the response stars to fall off again at higher frequencies.

Unfortunately, it is not possible to use the dielectric properties of the insulating sheath to correct the drop in response caused by eddy current losses. The electrostatic repulsion does not penetrate far enough into the wire, and we end up with the characteristic dip in the response. The magnetic effect is stronger than the electrostatic effect.

For audio cables, copper needs to be of a higher purity than the standard 99.99%. Impurities affect electrical transmission of complex waveforms. Non-copper atoms can cause undesirable semiconductor activity. Each crystal junction has a strong electrostatic plane (it is these electrostatic forces that create the crystal structure in the first place) and it is reasonable to assume that these planes will deflect somewhat the electron flow.

Wire with larger crystals has fewer junctions. Such wire is often advertised as monofilament or linear crystal.

Directional cables

A cable with directional qualities is undesirable. If a cable has a lower impedance in one direction than the other, it is acting to some degree as a diode.

Copper oxide is a semiconductor. Early rectifiers used copper oxide. Attempts have been made to limit the amount of oxygen in the copper in the production process, but it is impossible to eliminate all of it. Much so-called oxygen-free cable is in fact anything but oxygen free. Many of these cables have managed to eliminate surface oxidation only.

The wire surface needs to be gas-tight to avoid oxidation after the wire has been sitting for a few months. Enamelled copper wire is gas-tight, but even this acquires a small amount of surface oxidation in the enamelling process. Plating the copper with a metal that resists oxidation might appear to solve the problem. Metals commonly used are tin, silver, gold and, more recently, rhodium. This is all very well, but there is a body of opinion that asserts that plated wire is not as good as unplated.

As far as I know, there are three aspects to consider: thermoelectricity, conductivity and crystallinity.

Thermoelectricity and conductivity

A junction of dissimilar metals makes a thermocouple. Copper is one of the commonest thermocouple metals.

If there is a temperature difference between the metal's junction and another part of the circuit, a small voltage is developed across the junction. Loudspeaker cables are heated slightly by the current flowing in them, but I think that this thermoelectric problem is very small and not one to worry unduly about.

Table 1 is a list of conductivity, as specific resistivity, of metals used in electronics. You can see that silver has only a very slightly better conductivity than copper but is far more resistant to oxidation than is copper, and this is where it scores.

Plating interferes with the skin effect. Tin-plating is a disaster, increasing even further the high-frequency resistance at the surface. Plating introduces another set of crystal boundaries which will deflect and reflect the signal, and adds credence to the arguments for non-plated wire.

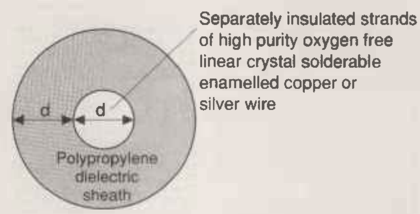

Fig. 4. Preferably, dielectric thickness should be greater than the total wire diameter.

Solid versus stranded

Early audio cable, particularly speaker wire, was made of separate strands, bunched and sheathed. These strands had a certain amount of surface oxidation contributing to the semiconductor effect. When people switched to solid core, the reduction of oxidation increased the clarity of the signal.

I have found that stranded cable outperforms solid-cored at higher frequencies. This is due to the reduction of eddy currents and the greater surface area, but this top end is certainly confused. Hence we have definite but different advantages for both types of cable and, as one would expect, both types of wire

Proximity effects

How audio cables are arranged in space is important. As a rule, cables that are adjacent to each other carrying current in opposite directions must be at least ten times the wire diameter apart to avoid signal cancellations due to magnetic coupling. This does preclude the use of non inductive (bifilar) winding for audio purposes. Such an arrangement causes signal loss due to phase cancellation and is clearly audible.

Consequently, it is better to have signal and return wires separate rather than combined into one cable. Avoid twisting cables together because this will create inductive turns.

are on the market.

The only real answer is a Litz-type cable, which combines the advantages of both while eliminating the disadvantages. Litz cable has a very coherent top end, and a superior transient response.

Current density

Loudspeaker cable cable should not have an appreciable rise in temperature and integrity of the waveform should be preserved.

Transients are the most troublesome waveforms. Although a moving coil loudspeaker is a voltage-driven device, it is current that makes it work. Maximum current occurs is when the drive unit changes direction or starts moving from rest. In practice, an 8Ω, 50W continuous bass driver could take more than 10A peak when changing direction under a transient. The peak power handling of the cable will need to be much greater than the speaker rating in order to avoid power loss. The audible effect of this is a shortening of the bass and a slowing of transients.

Peak current output of a fast, powerful amplifier will easily exceed 10A. If you assume a perfect amplifier operating under ideal conditions, a cable rating for bass purposes may well need to be of the order of 50A continuous. For a 2m run, my experiments indicate a cross-sectional area of at least $4.5mm^2$, a longer run requiring $6mm^2$ or more for a mean power handling of only 50W rms.

Antenna and proximity effects

To a much lesser degree, there is the possibility of the screen acting as an antenna, introducing rf into the signal ground. For very low level signals, some sort of screening is essential if a balanced line is not used, ie for moving magnet or moving coil cartridges. One possible answer is the use of a carbon loaded screen. The high resistance will curtail considerably any eddy currents induced into the screen. It is also possible to use a Litz type braided screen where the screen is made up of separately insulated strands.

The final aspect of audio cables is their arrangement in space. As a rule, cables that are adjacent to each other carrying current in opposite directions must be at least ten times the wire diameter apart to avoid signal cancellations due to magnetic coupling. This does preclude the use of non-inductive (bifilar) winding for audio purposes. Such an arrangement causes signal loss due to phase cancellation and is clearly audible.

Consequently it is better to have signal and return wires separate rather than combined into the one cable. Avoid twisting cables together because this will create inductive turns.

Most hi-fi amplifiers and speakers are unable to respond accurately to fast transients, and changing to larger cables will not necessarily bring an improvement in sound quality.

In summary

First of all, a Litz arrangement is necessary if we are to get the best transient response, high-frequency coherence and power handling. Second, insulation is needed and one of the best dielectrics is polypropylene.

Following is a suggestion for a set of practical cables.

For a bass cable, strand diameter should be of the order of 0.1-0.2mm. Taking 0.15mm as an example, a cross-section of $4.5mm^2$ requires 254 strands in a circular bunch, whereas $6mm^2$ requires 339 strands, etc. For a treble cable, strand diameter should be smaller, at around 0.8mm. Area can be derated to about $1mm^2$. This will require 200 strands.

Clearly, the best speaker cable is no cable at all, so runs should be as short as possible – 1.5m to 2m at most. Any longer and the cable diameter may need to be increased.

Dielectric thickness should preferably be greater than the total wire diameter so, for a $4.5mm^2$ cable, the insulation thickness should be at least 2.7mm. Total cable diameter will end up at about 9mm. For a $1mm^2$ cable, insulation thickness should be at least 1.7mm. ■

Hands-on Internet

Cyril Bateman discusses a standardised document format and presents this month's findings – among them an electronics manufacturers directory and design software.

As the Internet Web pages continue to grow in number and sophistication, many electronics manufacturers use them to provide their traditional data packs. With the final on-screen appearance being under the control of the users Browser, not the creator of the script and the limited page formatting capability of HTML, the Adobe PDF format was plugged into Netscape to provide full page control.

Adobe's Acrobat 2.1 reader[1] for PDF, gives access to documents in their original form independent of the users computer platform, can be downloaded from most Web pages using PDF format.

An offshoot of Postscript, Portable Document Format uses the ATM font technology to render the document in your browser, ensuring WYSIWOG – an acronym for what you see is what others get. It is compatible with Netscape 1.1, Spyglass Mosaic 2.0 and newer equivalents, **Fig. 1**.

To date PDF usage has been restricted due to the software needed. While the reader is now freeware, the production suite was costly. All this is about to change. The beta version of Acrobat 3.0 (Amber Beta) has been available since end May. Acrobat 3.0, with a full suite of tools, is due to release in USA this October at the incredibly low cost of $295. It provides PDF generation from your word processor and even from scanned documents.

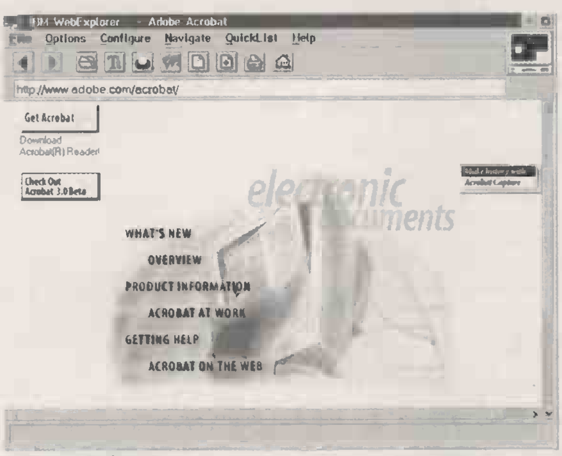

Fig. 1. Adobe Systems provides new uses for paper documents. Software for PDF document reading and creation.

The version 3.0 reader, available for most browsers and operating systems, provides searching and linking as with HTML. Being fully WYSIWOG does have a down side though. HTML, unless specifically formatted, wraps a text line round if your browser width is less than the designed page width. PDF on the other hand simply chops it off. By design it cannot wrap text lines for you.

The Argus Clearinghouse[2] claims to be the premier Internet Research Library, and can be a most useful data source and Internet search tool. It is managed by librarians, and founded on their belief that to encompass ambiguities of language and ideas, human effort and qualitative assessments must be combined with searching and browsing techniques, **Fig. 2**.

This month's bookmark site just has to be found at eenet.com, home of the Electronics Industry Inforum and Interactive Workplace[3]. A sample search on 'capacitors' resulted in details of some 60 capacitor makers, mostly not having their own Web presence. This site includes a facility called Info Fax. With this facility, any company wanting an Internet listing needs only a fax machine to receive and send data requests. The facilities offered by *eenet* provide services both for designers and marketeers. They should be sampled, words alone are inadequate, **Fig. 3**.

Webscope.com[4] is among the top 5% sites and offers two directories of Internet resources, in addition to its main role as a provider. While the guide to hotels and travel is interesting, Webscope's unique directory of electronic manufacturers is an essential directory service. It is indexed by manufacturing categories, and is most relevant, **Fig. 4**

Simulation software

The AVX *SpiCap* software[5] calculates the effective capacitance, esr and self inductance parameters of AVX ceramic multilayer range by frequency, temperature and applied voltage.

Described last month, this software is now available on two 3.5in disks, facilitating its use by all spice designers. Copies can be ordered on-line or from the company's sales offices. Obviously while targeted to spice users, these same parameters can be applied to any simulator, whether frequency or time domain.

Readers wanting further clarification of the need to derive capacitor models with parasitics, are directed to two useful papers, the Microsim FAQ[6] and a piece called '12 Simulation program tips/tricks/bugs.

Should you want to try out a frequency domain rf simulator. or need S parameters for Hewlett Packard rf semiconductors, a three-disk freeware package called

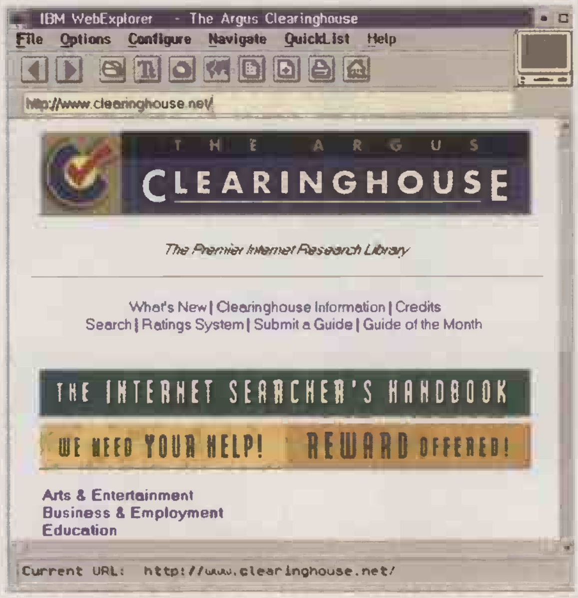

Fig. 2. Argus Clearinghouse – a value added central access point. Provides topical guides to Internet only based resources.

Fig. 3. EENET Corporation service for electronics. Provides listings of Internet and non-Internet based resources.

Fig. 4. Webscape division of Stetcom provides an exclusive directory. This is a good directory of electronic sources by product category.

AppCad is available. Its HP part number is HAPP-0001, and it has proved invaluable to me.

This small-scale package is described as a "unique combination of application notes and rf design tools combined with an interactive product selection guide". Its capability ranges from simple two port S parameter analysis to design of printed circuit spiral inductors. It can be downloaded from Internet. Archie located the files only at ftp.funet.fi but FTP Search[7] at Norway found two more sites both having newer files.

A rather different but equally useful catalogue on disc is available for K&L Microwave Inc's rf signal resonator filters. Choose the desired characteristics, view the passband response to be given their catalogue number.

Having designed and simulated your circuit you need a printed circuit board layout package. PADS Software Inc. supplies professional circuit design software at suitable prices[9]. The company also offers a more restricted but perfectly usable shareware version with schematic editor and autorouteing, which I have used. The Electronic Design Software page mentioned in the last issue, describes its download from the SimTel archives, **Fig. 5**.

Now that prices have settled, I have finally replaced my 14.4kbit/s modem used for the past two years with a a 28.8k alternative. However, I still use 57,600bit/s serial port rate, not having upgraded to a 16550-type uart. Since most data downloaded is already fully compressed, when Internet permits, the modem runs at full speed. Mostly, however, Internet is much slower, so it seems unnecessary to upgrade the serial card – at least until Internet access improves for the UK. ■

Fig. 5. PADS Software home page for pcb layout software. The company's shareware software can be downloaded or bought from shareware libraries.

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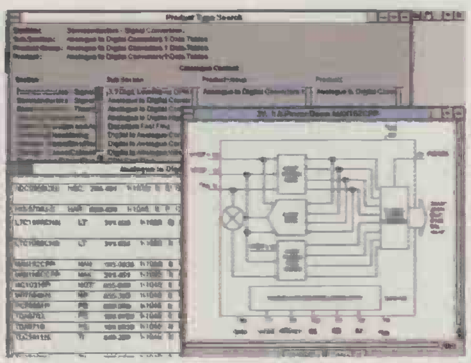

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Reference number 234-4857

Your pc is a programmable event timer capable of precision gating up to 55ms. Alan Bradley describes how to configure it.

Event timing via the pc

Timer channel 2 is present in all pcs. It is normally used as a variable frequency square wave generator for the pc's speaker. But this timer can also be used as an interval timer that is independent of the processor type and speed. This article describes how.

Overview

Timer 2 is within the pc's programmable universal counter/timer. This IC contains three counter/timers each with an associated control register. The original IBM pc used an Intel *8253*, the IBM AT an Intel *8254*. Modern clones may use custom ICs, but all have the same programming model. This universal counter/timer operates at 1.193MHz irrespective of the processor's type or clock speed. All three counters are 16 bits wide.

The three counter/timer channels, namely 0, 1 and 2, are accessed through ports 40_{16}, 41_{16} and 42_{16} respectively within the pc's i/o port address space. The command register is located at port 43_{16}. It selects the mode for reading and writing values to the chosen channel, selects the type of use for that channel, and selects the channel to which the previous selections apply. Examples of uses for the channel are square wave generation, one shot pulse production and terminal down count.

Applying the counter/timer

Timer channel 0 is used to calculate the time of day. This channel is set up by the bios to give 18.2 pulses per second. Each pulse causes the timer interrupt, IRQ 0, after which the counter is reset. A four-byte counter for these timer pulses is stored in the bios data area at 0040:006C$_{16}$. This counter also synchronises disk operations. Reprogramming it might therefore damage disk reads and writes.

Timer channel 1 is used by ram refresh and also by disk operations. Reprogramming this channel may also cause loss of disk data.

Timer channel 2 is connected to the pc's internal speaker, generating the variable frequency square waves necessary to make simple sounds. The speaker can be turned on and off via the pc's parallel-peripheral interface chip. As this channel controls no vital hardware, and the speaker can be turned off, it can be set up as a timer. A possible use is determining the waiting period for an analogue to digital conversion.

The 8255 programmable peripheral

Timer 2 is also controlled by the pc's *8255* peripheral interface chip, or PPI. This device

Applying the timer

This pseudo-code program illustrates how the pc can form a monostable multivibrator by using timer-channel 2 in conjunction with the parallel printer port. The printer port is provides the digital i/o lines for the trigger and o/p.

This pc monostable is not retriggerable, although it could easily be made so. It has a timed period of 40ms. The parallel-port input line that normally signals printer error, abbreviated PE, is used as the monostable trigger input. If it goes low, the monostable is triggered. Parallel port output line D_0 is used as the monostable output. It goes high when triggered, remains high until chosen time period has passed.

Pseudo code for a 40ms monostable multivibrator

```
Find location of printer port registers.
Reset monostable: set its output low: ie set printer port
    output data line D0 low (pin 2 on D connector).
Set up PPI B register to allow timer-channel 2 to be used
    as a down counter.
Set up Timer channel 2 to select down count mode, a binary
    count, and READ/WRITE msb and lsb consecutively mode.
For a downcount from FFFF16,
    Calculate FinalTimerDownCount for a 40ms delay.
Print title message.
WHILE (forever).
        IF printer port input pin PE (pin 12 on D
    connector) is low then:
    Trigger monostable output: ie set printer port data
    output line D0 high.
    Load counter with maximum count value (FFFF16) and
    start down count.
    Print "triggered: output (D0) goes high"
        Wait for 40ms.
        Reset monostable: ie set printer port D0 (pin 2
    on D connector) low.
        Print "Reset: output (D0) goes low"
                END_IF
END_WHILE
END
```

The pc parallel port

A pc can have up to three parallel printer ports LPT1, LPT2, and LPT3. Each port interface has three 8bit registers, the data latch, the status register and the control register.

Data latch: writing to this register causes the byte sent to be latched and appear on the parallel port's 25-way D connector on pins 2 to 9. Normally reading this register returns the contents of the latch.

Status register: this register represents input lines from the printer with functions as follows: b_7 BUSY, b_6 ACK, b_5 PE b_4 SLCT and b_3 ERR. Bits $b_{2\text{-}0}$ are unused. This is a read only register. The BUSY input is inverted between the D connector and the register.

Control register. Bit functions of this register are, b_4 IRQ DISABLE, b_3 SLCTINP, b_2 INIT, b_1 AUTOFEED, b_0 STROBE. Bits $b_{7\text{-}5}$ are not used.

This is a latch holding printer control signals. Interrupt is disabled on a falling ACK input when b_4 is low. I always disable this interrupt as it is rarely used by printer software so the associated IRQ channels 5 and 7 are considered free, and available for other expansion cards.

STROBE, AUTOFEED and SLCT INPUT are inverted between the register and D connector output pins although this inversion is corrected again when the control register is read.

controls the keyboard and is used to obtain information about the pc's configuration. It also controls the pc speaker and the speaker's associated timer on channel 2.

Port A of the PPI is a read/write port associated with the keyboard. Port B controls the reading mode for ports A and C. It also controls the speaker and timer channel 2. Port B is located at port 61_{16} in the pc's i/o address space.

Using timer 2 as an interval timer

I wrote the interval timing code in a mixture of C and assembly language. This is because the C compiler generated a much slower shift-by-8 loop. It did not make use of the *80x86* processor's ability to treat 16-bit data registers as 8-bit pairs, ie AX=AH+AL, BX=BH+BL, CX=CH+CL and DX=DH+DL.

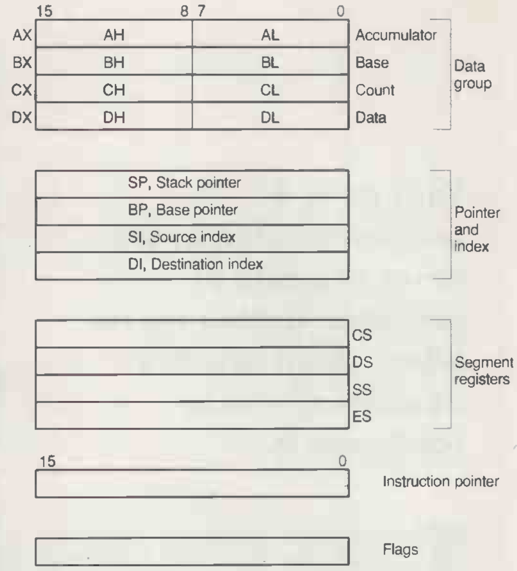
The *80x86* has four more registers, SP, BP, SI and DI. These are normally used as pointer and index registers. In my program I used the DI register simply to store 16-bit data. Turbo C uses SP, BP and SI itself. The DX data register is also used in some IN/OUT instructions results and so cannot be used by my program.

The *8086* has four segment registers, namely CS, DS, SS, ES. These allow addressing over 64K. The C compiler sets these to appropriate values automatically. The *8086* has an instruction pointer, similar to a program counter. It also has a FLAGS register, recording the result of instructions such as NON-ZERO and OVERFLOW.

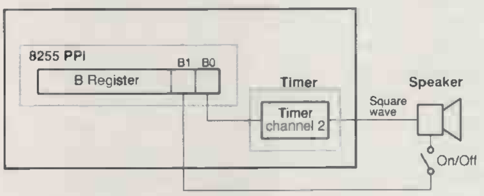
Counting is interrupted if the GATE2 input is switched to a low level and restarted when the GATE2 input is switched back to a high level. Hence GATE2 should be high for a down counting interval timer.

Therefore my program sets bit 0 of the PPI B register to logic 1. I also disable the pc speaker by setting bit 1 of the PPI B register to 0. **Inset 1** shows the Timer control register bit pattern required to select down count mode for Timer channel 2 and the timer control register bit pattern required to perform a latch operation on Timer channel 2.

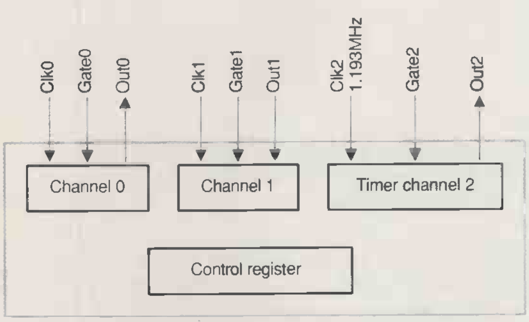
After the latching command has been writ-



80x86 registers, common to all IBM pcs. My C compiler could not treat 16-bit registers as 8-bit pairs, and a shift-by-eight loop is much slower than it needs to be. I used assembly language instead.



Standard on all pc compatibles, Timer channel 2 of the 8253 universal counter/timer ic forms the speaker driver which is controlled via Port B of the 8255 programmable peripheral interface ic but, as can be seen, the speaker can be switched off and the timer put to better use.



Block diagram of the pc's 8253 programmable universal counter/timer. Timer channel 2 counting is enabled when GATE2 is taken high.

Programmable peripheral interface

B register bit usage

PPI B register PC i/o address is 061_{16}.

Bit	Purpose
0	Set Timer channel 2 gate i/p high or low
1	Link/unlink timer 2 o/p from speaker: 0=off if unlinked
2	Must be 0
3	Read high or low dip switches
4	0=enable ram parity check, 1=disable
5	0=enable i/o channel check
6	0=hold keyboard clock low
7	0=enable keyboard, 1=disable

Control register bit usage for the pc's 8253 timer ic

PC I/O address of timer control register is 043 hex.

Location	**Bits 7,6**	**Bits 5,4**	**Bits 3,2,1**	**Bit 0**
Function	Select counter channel	Select latch operation or type of read/write	Mode	Select binary or BCD count
Code	Number of the channel to be programmed (0, 1 or 2)	00 Latch current value of counter (done before a read operation) 01=Read/Load lsb 10=Read/Write msb 11=Read/Write lsb followed by msb	Select counter/timer mode 000=Terminal down count 001=Programmable one shot x10=Rate Generator x11=Square Wave Generator 100=Software triggered strobe 101=Hardware triggered strobe	1=BCD 0=Binary

C pseudo code for pc timing

Calculate final count value for a 10µs delay. Calculate number of clock ticks in a 40,000µs delay.
PRINT"Preparing Count Down"
FINAL COUNT VALUE FOR 40,000µs DELAY:=FFFF–(number of clock ticks in a 40,000µs delay)
Now set up Port B of the PPI so that Timer2 can be used as a terminal down counter and disable speaker: ie set Timer gate 2 high (via PPI Port B, bit 0) (allow counting in Timer channel 2) and disable speaker (via PPI Port B, bit 1)
Set Timer Gate 2 HIGH (allow counting)
Now set up channel 2 of the timer to count in binary, perform a terminal down count and choose option: read/write lsb, msb one after the other, by writing appropriate value to the timer control register.
PRINT"Starting Count Down"
write FF_{16} (lsb) to timer channel 2
write FF_{16} (msb) to timer channel 2
REM: down count from $FFFF_{16}$ has now begun.
Loop until 10µs has passed
Print"Ten microseconds have now passed"
Loop until whole 40,000µs delay has elapsed.
PRINT"Entire chosen timed interval of 40,000µs=40ms has now passed"
END

ten to the timer control register, the latched value can be read from timer channel 2 (042_{16}), least-significant bit first. According to the *8253* data sheet, a counter value of 0000 can not be read.

Programming the chosen delay

First calculate the number of counter clock ticks that equal the chosen delay interval. This is the number which the counter must count down past before the chosen interval has passed. The number of timer clock ticks before interval has passed is equal to the chosen delay interval in microseconds, multiplied by 1.193MHz.

I always start the down count from $FFFF_{16}$. In this way, when the current counter value is less than or equal to $FFFF_{16}$ minus the number of clock ticks before interval has passed, then the chosen delay interval will have expired. For example, for a 40,000µs delay:

No. of clock ticks=
$40{,}000\times1.193=47720=BA68_{16}$

Final timer downcount=
$FFFF_{16}-BA68_{16}=4597_{16}$.

The maximum delay is 55ms.

Example timing program in C

This timing program example is derived from my printer port sound sampler program, where I needed to wait 10µs for the a-to-d converter to complete a conversion, process this value, then wait until the end of the sample period before repeating the loop.

Outlined in the timer software panel **Inset 2**, this routine waits until the first 10µs of a 40,000µs delay has elapsed, then waits until the whole 40,000µs delay has passed.

C and Assembler details of Timer.C

The program compiles under Borland Turbo C++ and Borland C++. This allows the *80x86* registers to be used by name within a C program's asm{ } assembly blocks. Registers can also be accessed from C by preceding the register name with an underscore, eg _AX, _AH, _AL...

The program uses # defines to give PPI Port B, and timer control register and timer channel 2 port addresses meaningful names.

Timer channel 2 is read by sending a latch command via the Control register, then simply reading the lsb, then the msb from Timer channel 2, port 042_{16}. ■

Software on disk

The Timer.c routine and the full monostable example in c can be obtained by sending a cheque of postal order for £7.50 to *Electronics World*'s editorial offices. Please mark the envelope Timer software and make your cheque payable to Reed Business Publishing Group.

Timer control register usage for interval timing.

PC i/o address 043_{16}.
Using terminal down count mode, this is timer control register bit usage to set up a down count.

Bit	7	6	5	4	3	2	1	0
Setting	1	0	1	1	0	0	0	0
Function	Select timer channel 2		Select type II read/write operation: LSB is first written to timer 2 (042_{16}) then MSB is written to timer 2 (042_{16}) counting begins as soon as MSB is written		Select mode 0: terminal down count			Select binary counting

Timer control register bit usage to perform a latch operation, current counter value prior to a read operation.

Bit	7	6	5	4	3	2	1	0
Setting	1	0	0	0	0	0	0	0
Function	Select timer channel 2		Select latch current value of counter operation		Select mode 0: terminal down count			Select binary counting

Accuracy of the pc as a timer

Instructions for reading and checking the current value of timer channel 2 take a finite amount of time, adding inaccuracy to the timing. I have calculated the worst-case delay between timer-channel 2 reaching its chosen final count value. With the program Timer.c, described later, the worst case inaccuracy for an 8MHz ISA i/o bus pc should be 7.144µs:

Calculation of Timer.c program timing limits:

	80x86 instr	8MHz i/o cycle	80386 cycle
START TIMER channel 2 count:	mov reg, immed		2
	OUT immed,al	10	
	OUT immed,al	10	
Send Counter latch command:	mov reg,reg		2
	OUT immed,al	10	
Read and store timer lsb:	in al, immed	12	
	mov reg, reg		2
Read and store timer msb:	in al, immed	12	
	mov reg, reg		2
Compare msb:lsb of current timer value with FinalTimerDownCount:	cmp reg, reg		2
'WHILE': (no jump occurs)	ja 8bitdisplacement		3

Total clock cycles=54 i/o clock+13 processor clock cycles
For a 33MHz 386 pc this would give a worst-case error of:
inaccuracy = i/o clock delay+processor clock delay
= 6.75µs+0.4µs =7.144µs

According to my assembly language book, IN/OUT 386/486 instructions vary in the number of clock cycles they need. I have used the slowest timing, which is similar to that of the 8086/8. The 286 IN/OUT instructions are about twice as fast as those of an 8086/8.

Greater accuracy in small delays would need interrupt programming, which is more difficult to write. This would involve reprogramming timer-channel 0, which needs care to avoid affecting disk operations; timer-channel 2 has no associated interrupt.

Small delays are often needed. When reading an a-to-d converter value for example, the 7µs inaccuracy can be important. In longer delays the 7µs may be insignificant. The inaccuracy should reduce on local-bus machines and on fast ISA buses that unofficially run at 11MHz.

C code for controlling the pc's timer

This program, Timer.c, demonstrates using timer 2 as a down counter to measure time intervals. Written in Turbo c with in-line 8086 assembler. Small memory model: 64K code 64K data and stack. Register keyword enabled.

```
#include <stdio.h>
#include<dos.h>
#include<conio.h>
#include<stdlib.h>
#include<io.h>

/* Prog PPI port B, TimerControl, & Timer2 regs */
#define PPIportB      0x061
#define TimerCtlReg   0x043
#define Timer2        0x042

/* 'register' vars: #defs for direct access to  */
/* DI,CX,CH,CL via meaningful names */
 #define FINALTIMERDWNCOUNT DI
 #define MSB CH
 #define LSB CL
 #define COUNT CX

/* if counter starts at FFFF16 then : */
/* (val of cntr after 10µs)≥FFFF-(10µs*1.193MHz) */
/* thus tenMicroSecDwnCount=(FFFF-C)hex=FFF3hex */
#define tenMicroSecDwnCount  0xfff3

/* clock frequency is 1.193MHz */
/* #def to set No of 1.193MHz clock tick decrements)*/
/* to pass before chosen timed interval has passed: */
/* noofclockticks=chosen interval in µs*1.193MHz */
/*              =  40,000*1.193=47720dec=BA68hex */
#define NoOfClockTicks_inFortyMilliSecDelay  0xba68

/* temporary store for B register of PPI IC */
 unsigned char breg;
int main() {
   puts("\nPreparing count down\n");

/* set FINALTIMERDWNCOUNT: /*
/* = 0xffff - NoOfClockTicks_in... delay */
   asm {
      mov ax, 0xffff;
      sub ax, NoOfClockTicks_inFortyMilliSecDelay;
      mov FINALTIMERDWNCOUNT, ax;
   }

/*Set portB of PPI for timer2 as down counter instead
of driving speaker */
/* 1st get a copy of PPI port's B register */
   breg = inp( PPIportB  );

/* logic OR with 0000 0001 to set bit 0 (timer gate)
high */
   breg = breg | 0x01;

/* AND with 1111 1101 to set bit 1 (spkr data) off */
   breg = breg & 0xfd;

/* set up 8255 PPI port B for speaker off & timer gate
high */
   outp( PPIportB , breg );

/* Now set up channel 2 (Timer2) of Timer chip:—  */
/* send 1011 0000 to Timer control reg to select: */
/* Channel2,oper 11 (r/w both h&l
bytes),terminalcount,binary data */
   outp( TimerCtlReg, 0xb0 );
   puts("\nStarting count down\n");

/* set value (FFFF) from which timer counts down */
   asm{
/* first o/p count low byte (FF) */
     mov al, 0xff;
     out Timer2, al
/* o/p high byte (FF); timer starts on writing high
byte */
     out Timer2, al
   }
/* down count from ffff has now started */

/* now wait until ten microseconds has passed */
/* 10        00              000            0 is 8 hex*/
/* 10:ch 2, 00:ctr latch, 000:term cnt, 0:bin data*/
/*store above in ah for speed*/
   asm{ mov ah , 0x80 }

/*loop until 10µs or more has passed */
   label1DO: asm
   {
/* read ctr latch command from ah into al for I/O
instr */
        mov al, ah
/*now send latch command to timer*/
        out TimerCtlReg, al
/* now read lsb from timer2 */
        in al, Timer2
/* now store lsb */
        mov LSB, al
/* now read msb from timer2*/
        in al, Timer2
/*now move msb into highbyte of COUNT */
        mov MSB, al
/* while COUNT holds value > tenMicroSecDwnCount */
/* ie while timer2 value  > tenMicroSecDwnCount*/
        cmp COUNT, tenMicroSecDwnCount
        ja label1DO
   } /* WHILE COUNT > tenMicroSecDwnCount */
   puts("\nTen microseconds has now passed\n");

/* now wait until end of chosen interval */
/* (wait for count down past FINALTIMERDOWNCOUNT)*/
/* 10:chann 2, 00:counter latch command, */
/* 000:terminal down cnt, 0:bin data */
/* store above 10000000b byte in ah for speed*/
   asm{ mov ah , 0x80 }
   label2DO: asm
   {

/* read ctr latch command from ah into al for i/o
instr */
        mov al, ah
/* send latch (0x80) command to Timer*/
        out TimerCtlReg, al
/* read lsb from timer2 */
        in al, Timer2
/* store lsb in low byte of count*/
        mov LSB, al
/* read msb from timer2*/
        in al, Timer2
/*move msb into highbyte of count */
        mov MSB, al
/* while timer2 value > FINALTIMERDWNCOUNT*/
        cmp COUNT, FINALTIMERDWNCOUNT
        ja label2DO
   }
/* NOTE ! timer count value of 0000 cannot be read */

   printf(
   "\nEntire chosen timed interval of 40,000µs =
     40 msecs has now passed\n\n");

   return 0;
}
```

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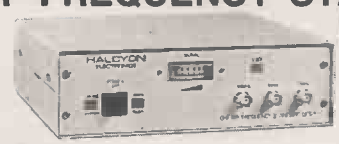

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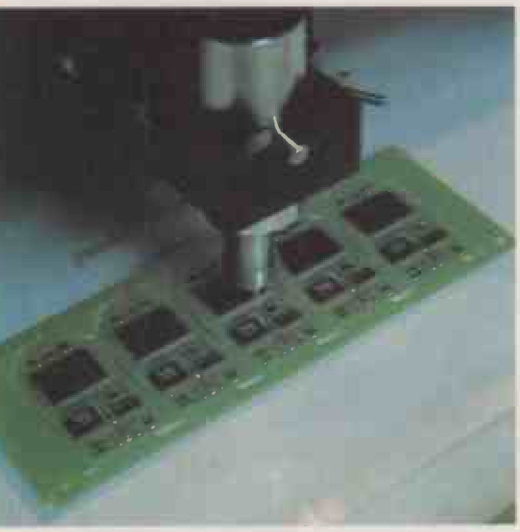
Finding faults with sound

Once a component is packaged, it is notoriously difficult to check the integrity of the package's content. Steve Martell describes a new ultrasonic defect detection method that allows surprisingly detailed board inspection.

Fig. 1. Scan head visits each on-board component to perform non-destructive acoustic imaging for hidden internal defects.



The term 'hidden internal defect' has particular meaning to companies who manufacture or mount plastic integrated circuit packages. Hidden defects are defects in, or related to, the physical structure of the package; they include delaminations, disbonds, voids, cracks, and the like. They cannot be seen optically, and few can be detected by x-ray. Still, it is vital to find these defects. They frequently worsen due to thermal cycling, causing the system they are installed in to fail unexpectedly. In short, hidden internal defects are flaws just waiting to turn into field failures.

Understandably, much research has gone into the characterising of the numerous types of hidden defects which may be lurking in an IC package. Delaminations in the die attach material are one type. Military and commercial specifications generally state, for example, that small delaminations in the die attach are not sufficient cause to reject the IC package – unless the delaminations happen to be at the corners of the die.

Even small corner delaminations, experience has shown, will grow because of the stresses located there. Eventually they detach so much of the die from the die paddle that heat sink capability is lost. The die then overheats and fails. Other hidden defects – die face delaminations of the molding compound, for example, or voids in the underfill near a flip-chip bump – are considered lethal in virtually all applications.

The sound option

Acoustic microscopes are by far the most useful tools for finding and characterising hidden internal defects. Almost all such defects consist of gaps in material, and very-high-frequency ultrasound is extremely sensitive to gap-type defects.

Failure analysis laboratories use acoustic microscopes to image the interior of IC packages for 'popcorn' cracks, lead frame delaminations, voids (bubbles) in the molding compound, cracked die, and many other defects. Some defects are imaged even though they do not consist of gaps: tilted die and irregular distribution of filler particles in the molding compound epoxy are two examples.

Finding hidden defects as early as possible in the production process is important to makers and users of IC packages. Failure analysts therefore often look at packages fresh from the mold machine which has encapsulated the die-lead frame assembly in epoxy. But failures can occur at many points in production, and it is not unusual for a manufacturer to be faced with a large quantity of populated boards some of whose IC packages are known to harbour hidden defects. This is a very significant inspection problem; no one wants to remove all of the packages from all the boards and submit each package to acoustic inspection.

A scanner for board-level inspection

A new system performs acoustic microscopy inspection on IC packages while they are still mounted on the board. It handles different types, sizes and elevations of IC packages on the same board, and can also image ceramic chip capacitors and some types of resistors.

The system operates automatically, can handle any number of components per board, and can handle two-sided boards. Its output shows both good and bad components and the locations of internal defects. Sonoscan, Inc. of Bensenville Illinois, the firm which developed and manufactures the system, call it *UltraBoard*.

Observing the system in operation, you see the board being inspected resting in a shallow water bath; a fluid is necessary to acoustically 'couple' the components to the transducer above the board, since very-high-frequency ultrasound does not travel through air.

The transducer is guided by software which has learned the coordinates of each IC package or other component it will inspect. Following this route, the transducer arrives at each component and then, because components are sometimes not placed precisely, uses ultrasound to find the actual location of the component. It then spends about 15s scanning the component.

As the head scans, very high frequency

ultrasound – generally between 10MHz and 100MHz – is beamed into the component. The return echoes from the interior of the component are collected by the same transducer for analysis.

When ultrasound is emitted by the transducer, it travels through the water couplant and enters the top surface of the IC package beneath the transducer. The speed of ultrasound through the various materials inside the IC package varies from about 3000m/s to about 9000m/s.

In a typical IC package, ultrasound travels first through the epoxy at the top of the device, and then encounters the face of the die. At this point some of the ultrasound is reflected back to the transducer, which has already switched over to its receiving mode. Data in this return echo is used to image the die face. At the same time, some ultrasound passes downward into the die itself, where it successively encounters the die-to-die attach interface, the die attach material itself, and the die attach-to-die paddle interface. Each interface in turn sends its return echo back to the transducer.

Returned signal

Each echo arrives back at the transducer bearing a given amplitude, or intensity, as well as polarity information. Polarity describes the change in acoustic velocity between two successive materials. If the ultrasound passes from a material of lower acoustic velocity to a material of higher acoustic velocity, the polarity change is positive; if the reverse, the polarity change is negative.

If no defects are present in the IC package, the pseudocolor image which appears on the monitor will show the die, the die paddle, the lead frame, and any other normal internal features. If a hidden internal defect is present, though, something quite different occurs.

Suppose there is a delamination at the top of the die, between the die surface and the molding compound. When ultrasound strikes this

Fig. 2. Digital image analysis of a single UltraBoard image. Original image with 256 grey levels – here in pseudocolor – is reduced to two levels at left for analysis. 'Window' refers to whole area of the chip. 34.6% of whole die attach area is delaminated, as is 75.0% of the upper left quadrant of the chip. 'Large' gives percentage covered by largest delamination in each area; i.e., the large delamination in the top-left quadrant covers 19.5% of chip area.

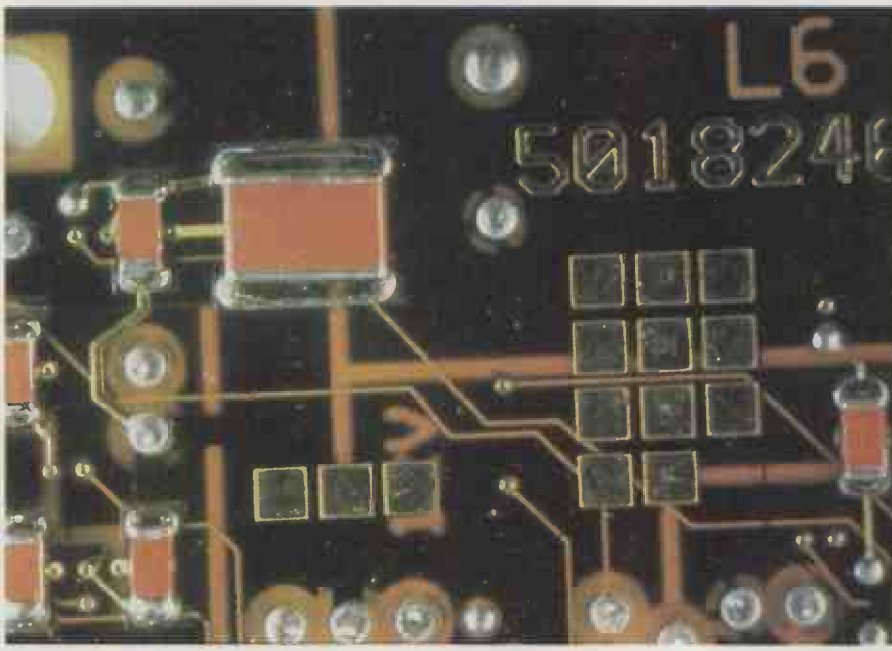


Fig. 3. Optical photograph of ceramic chip capacitor mounted on board.

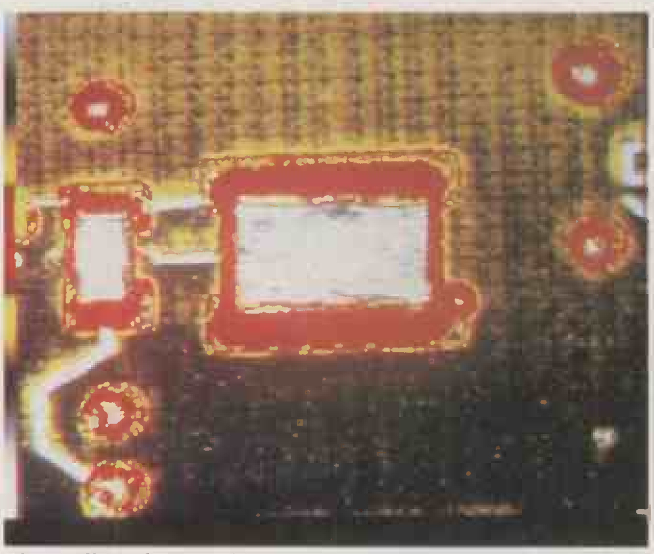


Fig. 4. Effect of electronic gating to limit internal level being imaged: when gating is near top surface, multilayer ceramic chip capacitor shown in Fig. 2 displays only merest suggestion of an internal crack at its lower edge.

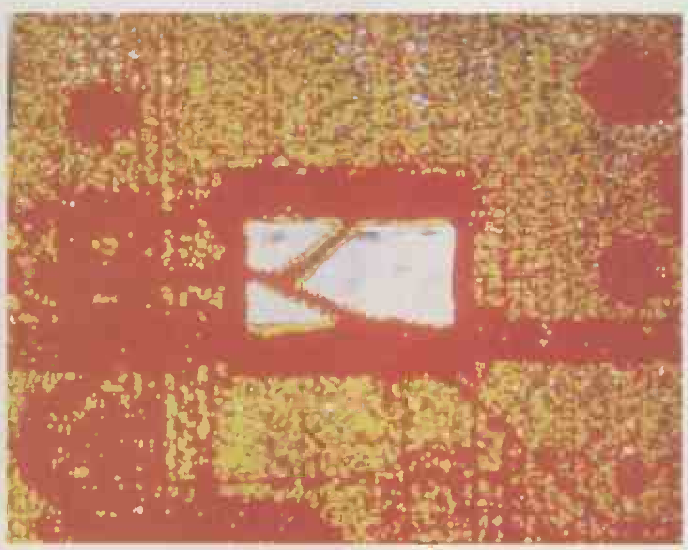


Fig. 5. When gating is lowered to mid-point of capacitor, substantial internal cracking becomes evident.

delamination – which is a gap – *all* of the ultrasound is reflected back to the transducer. Just as very-high-frequency ultrasound will not travel through air, it will not travel across an internal gap. The thickness of the gap is unimportant; if two internal layers are in contact but not bonded, all of the ultrasound is still reflected.

The amplitude of the echo returned from a gap is of course high; this is a very energetic echo. The echo also contains its own polarity information. As the transducer scans back and forth over the area of the IC package, it is collecting data points from hundreds or thousands of return echoes, including those echoes returned by gap-type defects at interfaces or in the bulk of a material. The data points are assembled electronically to produce the visible crt image of the interior of the IC package, and to analyse the package in various ways.

The echoes returning from the interior of the package are also separated in time as they arrive back at the transducer. In most applications, the echoes are electronically gated to accept echoes only from a defined level within the package and to ignore all other echoes. The die attach, for example, may be a suspected location for defects such as voids or delaminations.

Return echoes are then gated to accept echoes from the bulk of the die attach material and from the two interfaces at top and bottom of the die attach material. In other situations, gating may be wide or narrow, depending on the thickness of the zone to be inspected. Multiple gates – die face plus die attach, for example – can also be used.

And for smaller defects...

In addition to large defects, such as a delamination covering the entire face of a die, very-high-frequency ultrasound is capable of imaging very tiny defects and of detecting even smaller ones. Ultrasound of 100MHz, for example, is used analytically to map the distribution of individual filler particles in molding compounds.

Sonoscan has recently developed and introduced a long-reach transducer which puts out ultrasound at the very high frequency of 180MHz. This transducer was specifically designed to image the solder bumps and underfill which lie beneath the die in flip-chip devices. Its resolution is so good that it has imaged voids and cracks in the interior of individual solder bumps.

Output methods

Information from a board whose components have been scanned by the system takes several forms. The acoustic representation of each image is stored; this image is not normally viewed, but is available for analytical purposes if it is needed.

If a defect is present, the data is also used to perform an area analysis of the defect. The analysis is based on definitions set up by the user of the system. A die attach delamination, for example, may be acceptable if it covers less than a given percentage of the die attach area, or if it is in a given location, for example, anywhere other than a corner. Similar definitions can be set up for die face delaminations, cracks in the molding compound, delaminations along the lead frame, and numerous other defect types.

Software can sort the components on the board into any defined number of accept/reject categories. Often three categories – accept, marginal, and reject – are used, because this gives the user the opportunity to examine the images of marginal components before making a decision about rework.

The system also prints out a table for each board, showing the location of each inspected component and its accept/reject status. The table then travels with the board as a guide to the rework which will transform it into a defect-free board. ■

Sonoscan, Inc. is at 530 East Green St, Bensenville IL USA 60106, phone: 630 766-7088, Fax: 630 766-4603, E-mail: sonoscan@worldnet.att.com.

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CIRCLE NO. 140 ON REPLY CARD

When is a gate not a gate?

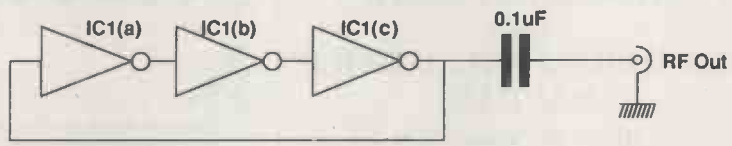
Ian Forster has found that AC logic gates can be used to form simple, cheap yet repeatable rf oscillators.

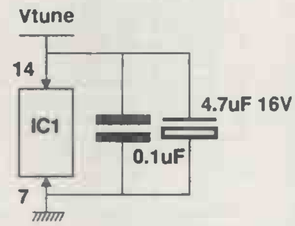
In a recent article in *Electronics World*[1] I showed how *74AC* series logic gates could be used in power conversion and switching applications. This article makes use of another useful feature of this logic gate series – namely their fast response speed and low propagation delay – to implement a series of vhf oscillators ideal for the experimenter.

All the following circuits have been tried with dual-in-line parts from different manufacturers and have proved very reliable. Good vhf construction techniques need to be used, as, linearly biased, the gates act as high-gain high-frequency amplifiers.

Most of the following circuits would not be well suited to battery powered applications. They tend to be current hungry. In addition, care must be taken when using multiple gates in one package not to exceed the maximum dissipation limits – 74AC gates are tough, but not indestructible.

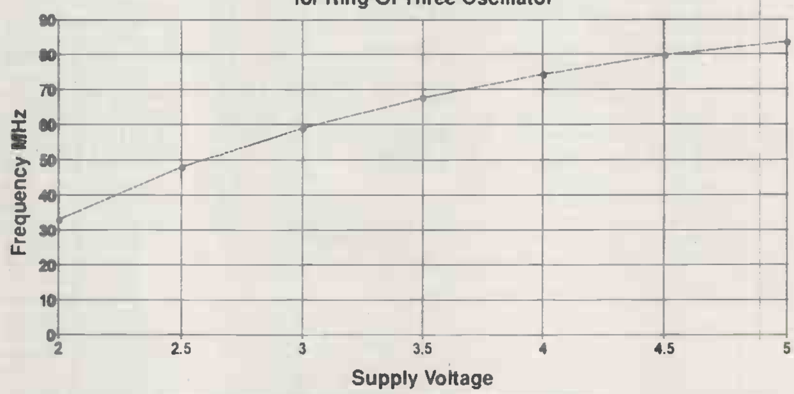
Ring-of-three oscillator for high frequencies





AC gates can be used to produce a high-frequency equivalent of the standard 'ring-of-three' type oscillator. Again, operating frequency is controlled by varying the supply and hence the propagation delay of the gates. Power output is approximately 8.3dBm at 2V and +17dBm at 5V, with the third harmonic at –10dBc and the fifth at –16dBc, corresponding to +1.5dBm at 417.5MHz.

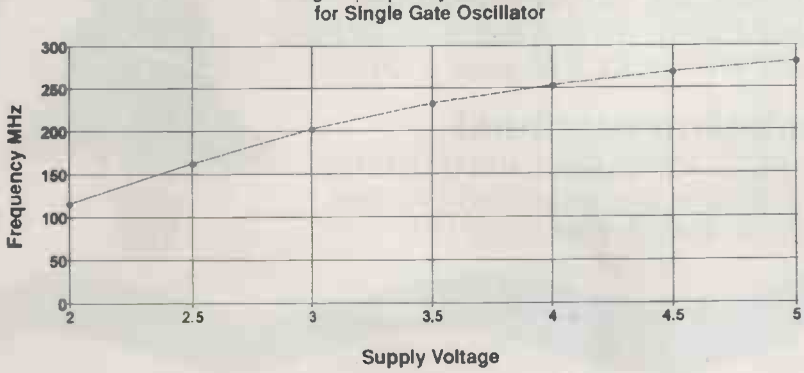
Voltage / Frequency Characteristic for Ring Of Three Oscillator

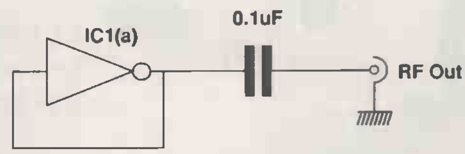


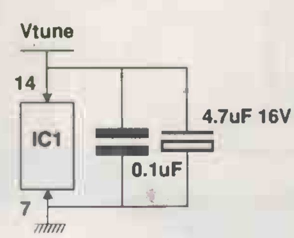
Oscillator for vhf

This is the simplest implementation of a vhf oscillator using a single inverter from a *74AC04*. Oscillation occurs at the frequency at which the delay of the gate is equal to 180° phase shift. Output frequency is controlled by varying the supply, and hence varying the propagation delay of the gate. Power output is approximately +6.5dBm at 2V and +16dBm at 5V, with the third harmonic at –16dBc (corresponding to –4dBm 840MHz at 5V).

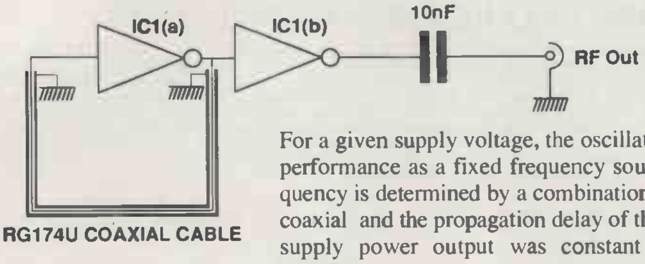
Voltage / Frequency Charactersistic for Single Gate Oscillator



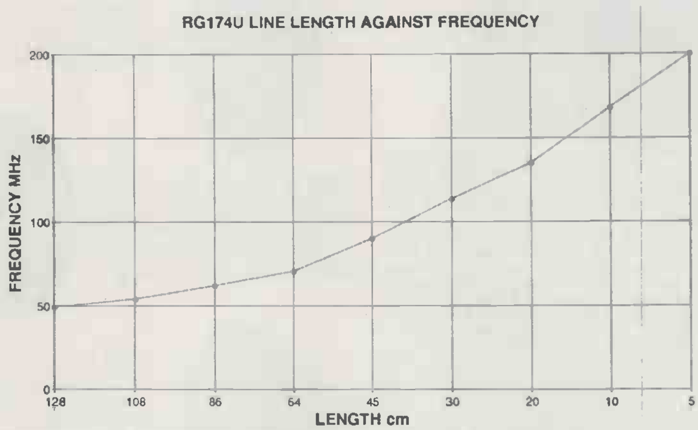




Oscillator uses coaxial cable



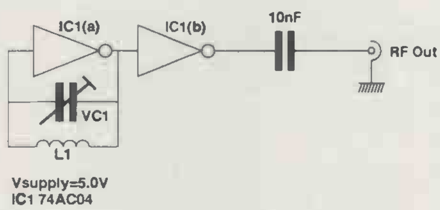
For a given supply voltage, the oscillator here gives good performance as a fixed frequency source. Operating frequency is determined by a combination of the delay in the coaxial and the propagation delay of the gate. Using a 5V supply power output was constant at approximately +16dBm.



LC oscillator

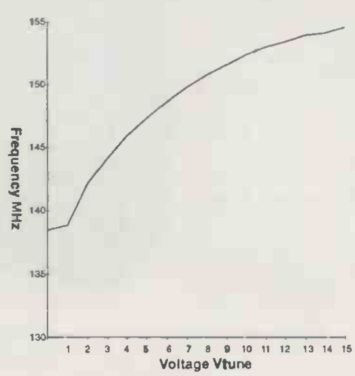
For a more compact oscillator the circuit is more suitable. This is a fairly standard *LC* type oscillator, with the output frequency being a function of the inductance, stray and wanted capacitance and gate delay. With L at 39nH and C at 1.5pF, measured noise was –90dBc/Hz at 10kHz offset with an associated +17dBm output.

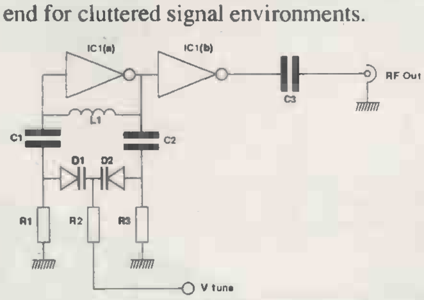
L_1 (nH)	VC_1 (pF)	o/p (MHz)
68	6	143.1
68	1.5	159.4
68	–	166.4
39	6	180.9
39	1.5	190.7
39	–	197.9



Oscillator for 2m band

An *LC* voltage-controlled oscillator designed to cover the 2m amateur band, can be formed from AC gates, when used with a synthesiser IC such as the National Semiconductor *LMX1501A*. High output level of the oscillator makes it well suited to driving a level 17 double balanced diode mixer. This, with a high intermodulation performance front-end amplifier, such as the *MAV11* from Mini Circuits, could form a high immunity receiver front end for cluttered signal environments.

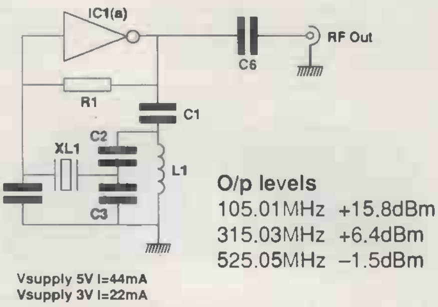




L_1	68nH 32CS smt
IC_1	*74AC04*
$R_{1\text{-}3}$	18kΩ
$C_{1,2}$	100pF ceramic
C_3	10nF ceramic
$D_{1,2}$	BB405B varactor

Crystal oscillator

This is a fifth-overtone crystal oscillator based on the 74AC04. It runs near series resonance and provides a stable output at high level, rich in harmonics. Typically, this would be used to form the basis of a low power vhf/uhf transmitter or, with filtering, as a vhf/uhf local oscillator for a receiver. Addition of a varactor diode, coupled via an appropriate capacitor, across C_3, using a resistor to bias it, allows a degree of tuning.

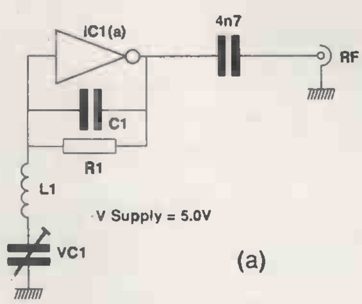


O/p levels
105.01MHz +15.8dBm
315.03MHz +6.4dBm
525.05MHz –1.5dBm

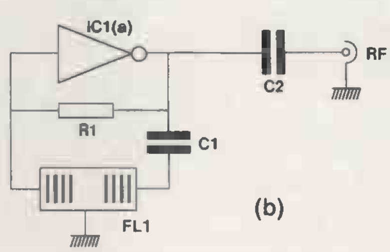
IC_1	*74AC04*
XL_1	105MHz 5th overtone HC18U
L_1	135nH MC105 variable
C_1	5.6pF ceramic
$C_{2,3}$	39pF ceramic
$C_{1,5}$	22pF ceramic

And at uhf

To complete this collection, (a) and (b) here show two oscillators designed to operate in the uhf band. In (a), C_1 provides feedback from output to input and, due to its low value, suppresses vhf oscillation, with R_1 biasing the gate into its linear mode. Inductor L_1 and the variable capacitor provide a variable phase shift to control the oscillator frequency. In (b), R_1 again places the gate in its linear mode but the feedback is a combination of C_1 and a 418MHz band surface-acoustic-wave resonator device, as used in key fob transmitters for car alarms ■



(a)



(b)

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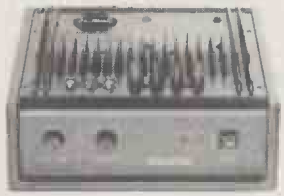
ASM100 ACTIVE SUBWOOFER MODULE



This attractive module consists of a low pass filter and power amplifier ready for you to mount in a suitable sub-woofer cabinet. The combined unit can then be combined with any new or existing hi fi or home cinema speaker system to add in the real bass punch missing from most setups.
The ASM 100 module comes as a ready-to-mount unit on a solid diecast aluminium frame/heatsink. Input signal can be at line or speaker level for easy system integration. There are three separate stereo inputs at line level and the unit will use any signal presented or mix all inputs to add bass to any signal. The speaker level inputs are used by simply wiring the unit in parallel with the existing speakers to provide them with strong bass support. Crossover frequency can be selected to 50, 100 or 200Hz and the bass level can be adjusted by a front panel control. The 'Green' power supply switches the unit to standby if no signal is present. Drawings are included free for the compact 418 x 380 x 303mm cabinet.
With its powerful 125 watt output and versatile filtering the ASM 100 is the ideal universal active driver module for all subwoofer requirements.
ASM 100 Module, complete with IEC mains lead, instructions and ASM - W20 cabinet drawings. Pt. No. V7000. . . . . £185.29
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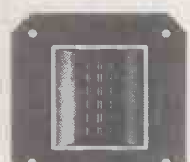

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CIRCLE NO. 141 ON REPLY CARD

New thoughts on demodulation

Edward Forster investigates the performance of Archie Pettigrew's award-winning amplitude-locked loop demodulation technique in both AM and FM receivers.

The amplitude-locked loop, or ALL, was not described as an automatic-gain system*, but it clearly is a distinct form of one. Generally, agc systems use gain-controlled amplifiers, i.e. multipliers, with a logarithmic or semi-log law to obtain large dynamic range. The dynamic range of an ALL with linear multiplier is described as 26dB.

Automatic gain control is rarely used to entirely suppress the amplitude modulation, but this is only a matter of bandwidth. It is true that the ALL outputs the reciprocal of envelope amplitude together with a fully compressed envelope signal within its operating range. But how useful this is remains to be seen.

Demodulating AM

The ALL is used here to provide a constant envelope signal to the demodulator which is of the square law carrier recovery type[1] using a phase locked loop, or pll. This might be unexceptional were it not for the claims made for this circuit. This is certainly not an advance in the art nor is it an optimum system. The ALL is said to provide special features which cannot be met by a limiter.

At threshold levels, I suggest that a soft limiter having a gain of 26dB put in place of the ALL would yield identical results. This is because at the end of its range, the ALL also has a constant gain of 26dB and it would be impossible to distinguish between the two. At high carrier levels it also makes no difference which is used.

The subsequent pll shown in the circuit as the carrier recovery device is not an optimum type. This is a common mistake. It raises the question of what the point of the system is in the first place. The problem of AM full carrier reception in conditions of multipath interference and doppler shifts – such as found on the hf broadcasting bands – was successfully solved in the *Liniplex F1/2* receiver made by Phase Track Limited throughout the eighties. This used a synchronous pll AM demodulator[2] at intermediate frequency in a superheterodyne receiver.

Figure 1 shows the pll carrier recovery system of that receiver which is a type II system, ie, it contains two perfect integrators these being an active integrator and the voltage controlled oscillator (vco). In servo parlance this is known as a proportional plus integral feedback loop. Although this is well known some of its characteristics as applied to this problem are apparently not well known.

Figure **1b** shows that the active filter can be redrawn as the equivalent sum of the proportional 'P' component and the integral 'I' component. This allows you to see more clearly what happens. **Figure 2** is the idealised response to a step offset of the vco. The 'P' component has a fast response but it eventually returns to zero. The 'I' component response is to gradually ramp towards the final control voltage needed.

When the response subsides, there is zero static error in the system. The loop may be opened without any effect. The same thing results if the input carrier also disappears for some time during a fade. The loop remains essentially locked and can provide the necessary carrier for effective synchronous demodulation of sidebands to continue undisturbed. When the carrier returns there is no re-locking as the loop never lost lock.

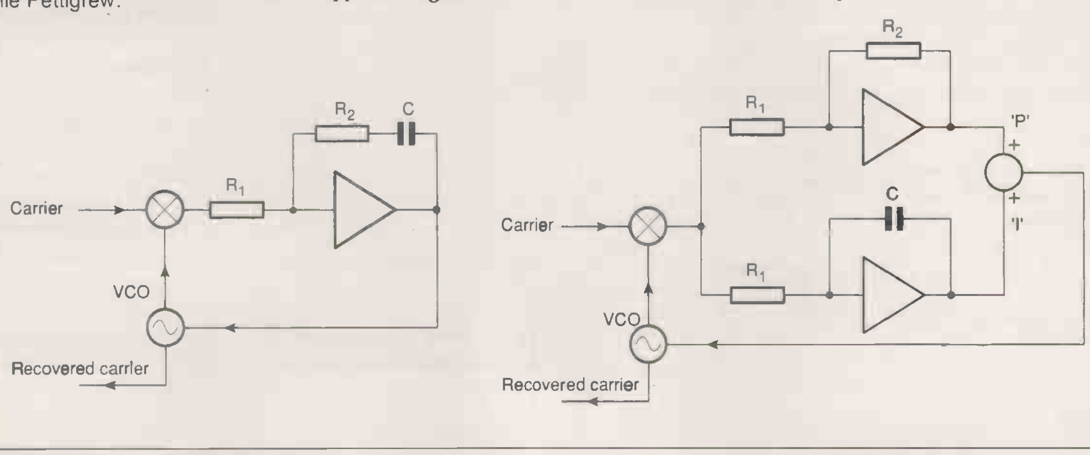
Another feature of the type II pll is that it offers the freedom to optimise the loop bandwidth without any restriction other than that the loop should follow any doppler shifts and vco drift. In the type I loop, setting the bandwidth correctly can result in the hold-in range of the pll being too small for practical use.

It is also necessary to have as small a loop bandwidth as possible. This is to prevent the control signal from frequency modulating the vco within the modulation band as this produces distortion.

Many such pll AM demodulators have appeared in up-market broadcast receivers. But because of this distortion, their audio quality was indistinguishable from the conventional envelope demodulator.

*June 1996 issue, page 466, Demodulation – a nerw approach by Archie Pettigrew.

Fig. 1. Carrier recovery by type II PLL; b) equivalent to a).



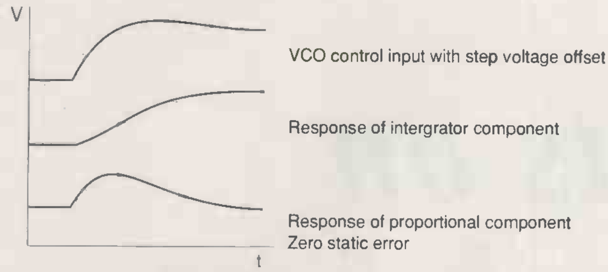


Fig. 2. Dynamics of type II PLL.

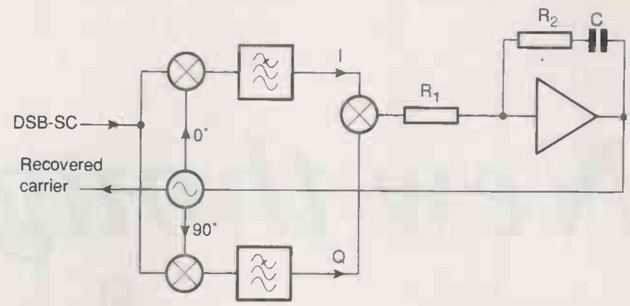


Fig. 3. Costas Loop with type II PLL.

The Costas loop

However, for the future, another old system brought up to date is preferred; this is the Costas loop[3–5], **Fig. 3**. It is suitable for AM full carrier or double sideband, or dsb, suppressed carrier reception. It relies directly on sideband information in the I, in-phase, and Q, quadrature channels which when multiplied together give an error signal.

The feedback error signal is intermittent in sound transmission and a special pll is required. Again the type II loop serves the purpose as its, in principle, infinite memory capability allows the loop to stay in lock during modulation pauses. This time instead of acting from direct carrier phase information, it is the sidebands alone from which the virtual carrier phase is derived.

The great opportunity of the I/Q Costas loop is in I/Q direct conversion receivers where much of the former intermediate frequency processing can be equivalently replaced by on-chip audio processing whether analogue or digital. Multi-conversion superhets can be replaced by direct conversion receivers with equivalent performance but at a far cheaper cost and lower power consumption.

Although the synchronous receiver produces optimum results and also allows for electricity saving dsb broadcast transmission, a simpler non-synchronous technique[6] has been devised for the AM I/Q receiver. The superheterodyne is fast becoming obsolete.

Demodulation for FM

The hyperbole accompanying Pettigrew's FM demodulation circuit has in many ways obscured any real understanding of how it works. But, by separating the functions and using a simple test signal, its effectiveness can be clarified.

Figure 4 shows an unmodulated carrier of unit magnitude in the presence of an offset carrier of amplitude *k*. It is clear that both amplitude and phase modulation are produced. When *k* is small, say below 0.1, the difference frequency modulations are nearly pure sinusoids in phase quadrature. With this information you can examine how the circuit performs with relative ease.

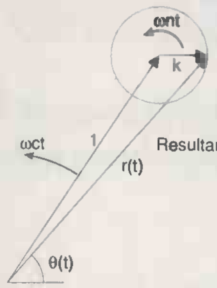


Fig. 4. Unmodulated carrier ωc rad/sec plus interfering carrier ωn rad/sec.

Figure 5 shows the simplified system. The ALL is assumed perfect as is the pll fm demodulator, which differentiates perfectly the phase modulation at its input. In being differentiated, the phase modulation is shifted by 90° to appear at the output of the fm demodulator, let us say for simplicity, as cos *a*.

Output from the ALL for small percentage amplitude modulation is also a cosine in-phase, say cos *a* again. The final processing is the puzzle. As shown, there can never be cancellation however the amplitudes are manipulated. Therefore, at small values of carrier interference the system cannot work.

For large levels of interfering carrier it is necessary to use computer simulation. This is, in fact, not too difficult. Using numerical differentiation it was possible to simulate the large signal case with less than 2k of Basic.

Results are as follows:

k	Improvement over pll o/p in dB
0.1	0
0.5	1
0.7	3
0.8	6
0.9	18
0.95	0

The improvement obtained is the result of some highly non-linear interactions but the significant improvement occurs within 3dB of the threshold, $k=1$, within a 2.2dB overall range from $k=0.7$ to $k=0.9$. Where the peak improvement occurs is a matter of adjustment but the above results are probably typical.

Outputs of both the amplitude and phase-locked loops under these circumstances are pulses, which are not necessarily well matched. This indicates that the ALL pulse is being used more as a gating or sampling pulse. You might therefore suppose that the AM related pulse could be generated elsewhere. Synchronous demodulation of the envelope, without ALL or limiter, could be devised to enable a pulse generator in this small range of *k*.

That aside, the pll frequency demodulator described by Pettigrew is fed from a constant carrier even at threshold. Presumably, it is considered that the best results will be obtained by simulating a limiter. But it is known that a limiter is detrimental to threshold extension in phase locked loops.

Schilling[7] has noted that type II loops produce better threshold performance by virtue of the extra integrator. It is also shown[8] that above threshold, a limiter is of no value and that near threshold it is positively damaging.

This is because, as the resultant carrier instantaneously falls to a low amplitude at the maximum rate of change of phase, the loop gain also falls to a low value. Consequently the loop does not track the rapid phase change and does not reproduce a sharp spike at its output. Maintaining full carrier level in all circumstances prevents this beneficial effect. Again we come back to the pll design. Is it a type I or type II?

If a type II pll were used for comparison in a receiver with slow agc but no limiter then any benefits may not look so great. ■

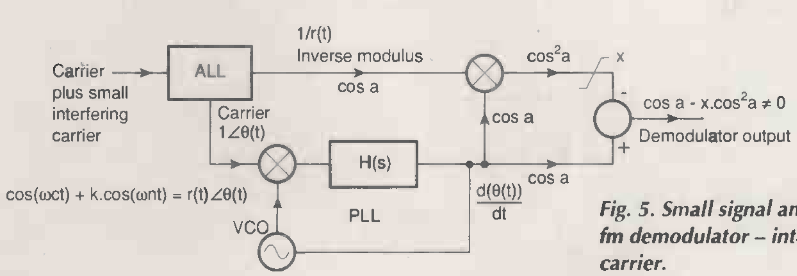


Fig. 5. Small signal analysis of fm demodulator – interfering carrier.

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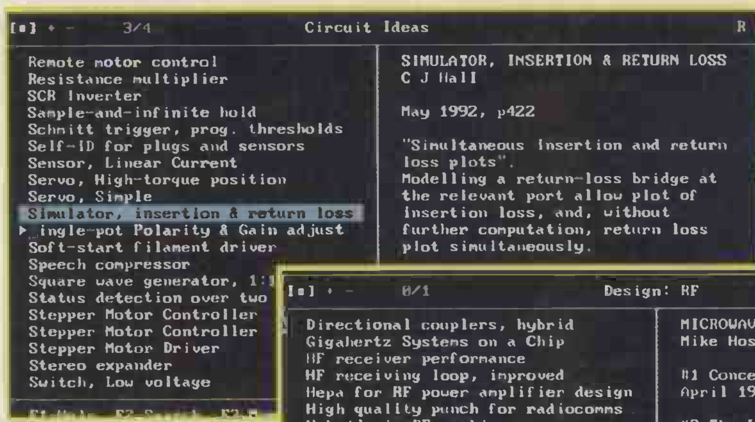

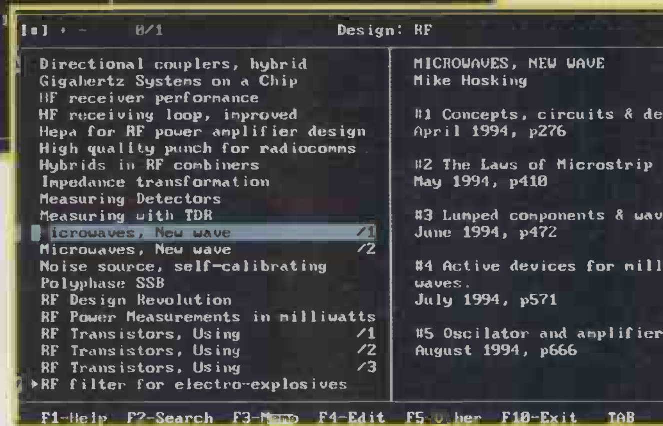

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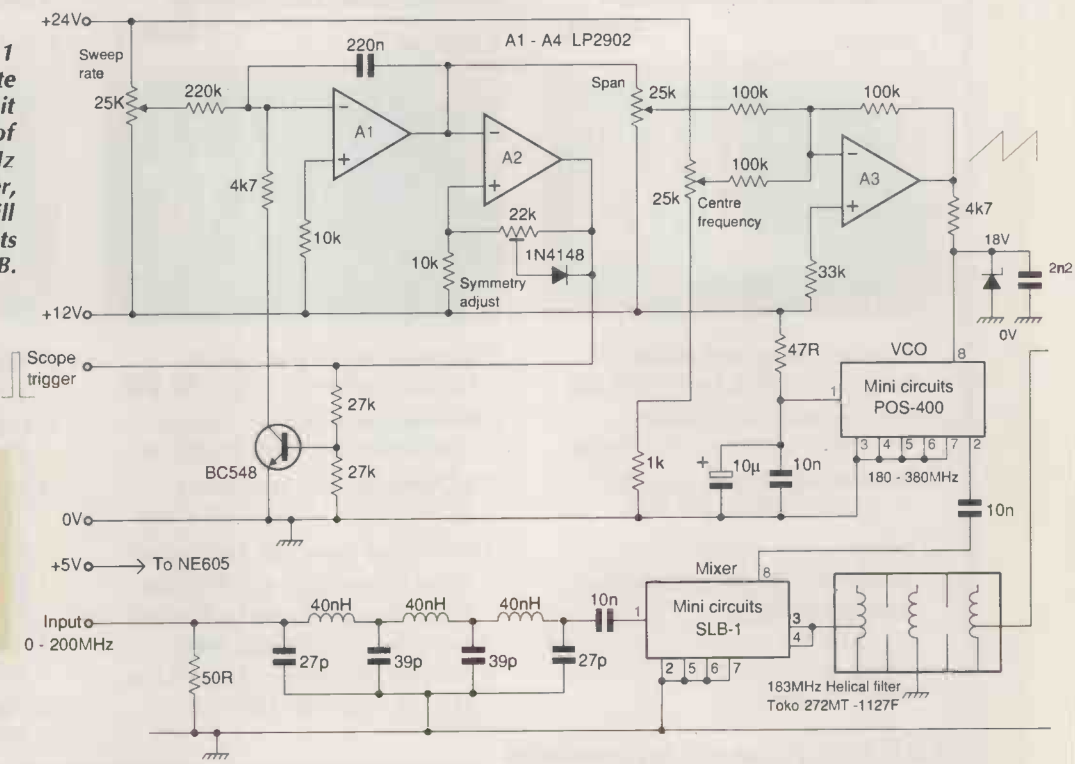
200MHz spectrum analyser displays to –75dB

Used with an ordinary oscilloscope, this circuit forms a spectrum analyser for the 0-200MHz range of frequencies. To simplify examination of the wanted frequency, span and centre frequency controls are arranged to make signals in the middle of the trace stay there as span decreases.

Amplifers A_1 and A_2 produce a sawtooth waveform, symmetrical about the 12V rail, which is amplified in A_3 with control of amplitude for span and offset for centre frequency. The discharge goes to the oscilloscope as a timebase trigger.

Driven by the sawtooth, the Mini Circuits *POS-400* voltage-controlled oscillator provides a liner voltage/frequency output over the

Fig. 1 Complete circuit diagram of the 200MHz analyser, which will display inputs at -75dB.



TTI PROGRAMMABLE BENCH MULTIMETER WINNER

Window detector has high input-impedance

Hysteresis at both upper and lower trip points and a high input impedance are the advantages of this detector, which uses only a dual comparator and a transistor.

There is little to say about the circuit shown but to give some formulae for trip points and hysteresis.

Lower trip point:

$$\frac{T_1}{E_p}=\frac{R_3}{R_1+R_2+R_3}.$$

Lower trip point hysteresis

$$\frac{H_1}{E_p}=\frac{R_3(R_1+R_2)}{R_5(R_1+R_2+R_3)}.$$

Upper trip point:

$$\frac{T_2}{E_p}=\frac{R_2+R_3}{R_1+R_2+R_3}.$$

Upper trip point hysteresis:

$$\frac{H_2}{E_p}=\frac{R_1}{R_4}\cdot\frac{R_2+R_3}{R_1+R_2+R_3}.$$

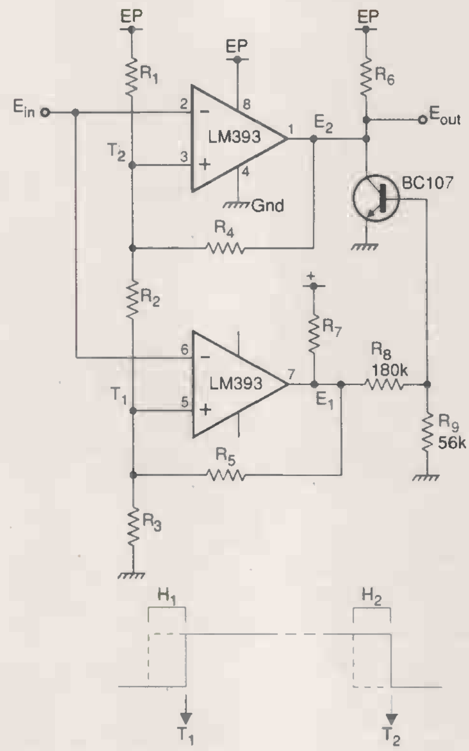
It is usually required that the hysteresis of both points should be equal, so:

$$R_4=R_5\frac{R_1}{R_3}\cdot\frac{R_2+R_3}{R_1+R_2}.$$

If the hysteresis of the lower trip point is zero or negative, it may be that the circuit will oscillate.

$$R_5\leq R_4\frac{R_1+R_2}{R_1}+R_2.$$

W Dijkstra
Waalre
The Netherlands



Window detector has designable hysteresis at upper and lower trip points and, unusually, high input impedance.

180-380MHz range and drives the *SLB-1* double-balanced mixer directly, signal input to the mixer coming via the low-past filter.

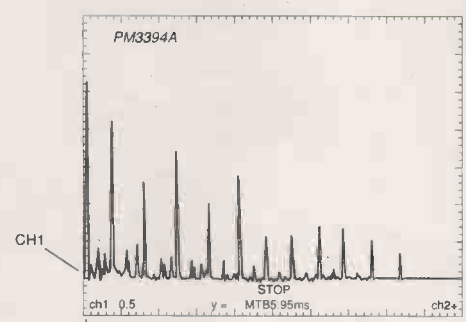
After filtering by the Toko *272MT-1127F*, mixer output is impedance matched to the *NE605*. This device converts down to a standard if of 10.7MHz, the local oscillator being a SAW type. A voltage proportional to the log. of the internally amplified 10.7MHz if appears at pin 7 of the *NE605* and is buffered in A_4 to be used as the oscilloscope input.

Symmetry of response is maintained by the *CFSK* ceramic filters, which also determine the bandwidth.

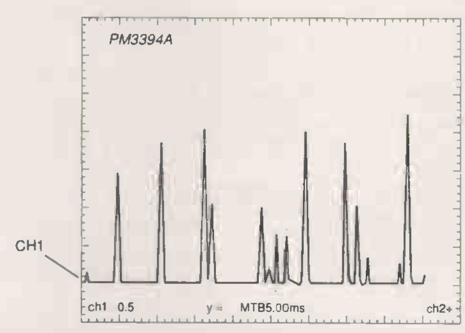
A limitation is the fairly slow response of the output of the *NE605*. It is usable, but reduces the amplitude of the display at faster sweep rates. It may be that the *ME625*, which is pin-compatible and faster, would improve matters.

Glyn Roberts
Walsall

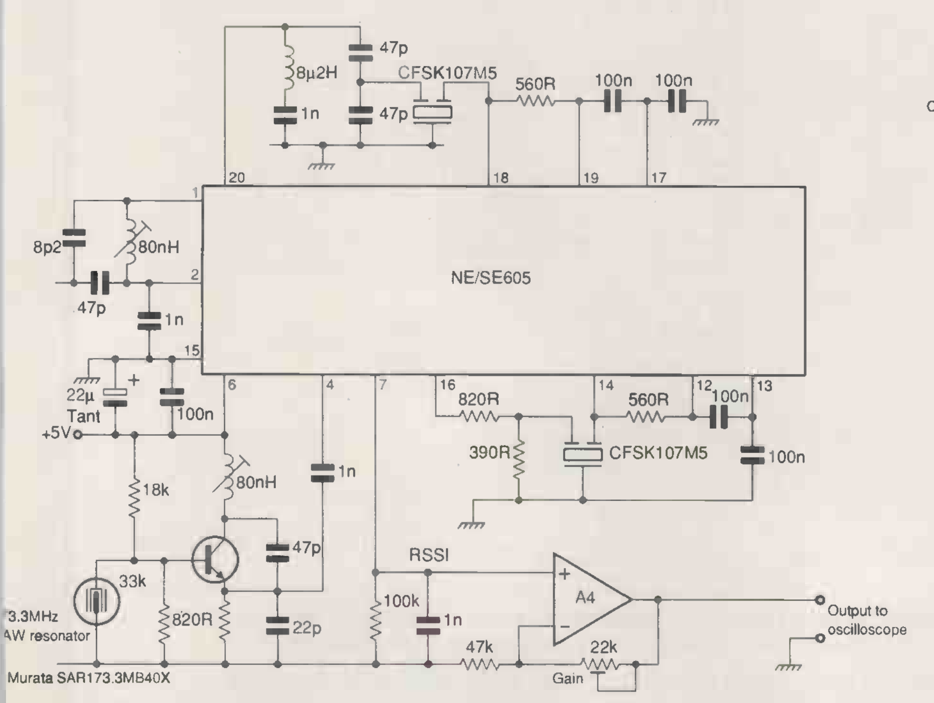
Spectrum of the local fm broadcast band, 88 to 108MHz, top, and 20MHz square wave, demonstrating sweep linerarity, bottom.



Y/Div: 500mV Timebase: 5.95ms Trace: ch1
Trigger: 10:30 Time: 07:47 Date: 16-03-1992



Y/Div: 500mV Timebase: 5.00ms Trace: ch1
Trigger: 10:35 Time: 07:56 Date: 16-03-1992



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HP Sweep Oscillators type 8690 A & B + plug-ins from 10Mc/s to 18GHz also 18-40GHz. P.O.R..
HP Network Analyzer type 8407A + 8412A + 8501A – 100Kc/s – 110Mc/s – £500 – £1000.
HP Amplifier type 8447A – 1-400Mc/s £200 – HP8447A Dual – £300.
HP Frequency Counter type 5340A – 18GHz £1000 – rear output £800.
HP 8410 – A – B – C Network Analyzer 110Mc/s to 12GHz or 18GHz – plus most other units and displays used in this set-up – 8411a – 8412 – 8413 – 8414 – 8418 – 8740 – 8741 – 8742 – 8743 – 8746 – 8650. From £1000.
Racal/Dana 9301A – 9302 RF Millivoltmeter – 1.5-2GHz – £250-£400.
Racal/Dana Modulation Meter type 9009 – 8Mc/s – 1.5GHz – £250.
Marconi RCL Bridge type TF2700 – £150.
Marconi/Saunders Signal Sources type – 6058B – 6070A – 6055A – 6059A – 6057A – 6056 – £250-£350. 400Mc/s to 18GHz.
Marconi TF1245 Circuit Magnification meter + 1246 & 1247 Oscillators – £100-£300.
Marconi microwave 6600A sweep osc., mainframe with 6650 PI – 18-26.5GHz or 6651 PI – 26.5-40GHz – £1000 or PI only £600. MF only £250.
Marconi distortion meter type TF2331 – £150. TF2331A – £200.
Tektronix Plug-Ins 7A13 – 7A14 – 7A18 – 7A24 – 7A26 – 7A11 – 7M11 – 7S11 – 7D10 – 7S12 – S1 – S2 – S6 – S52 – PG506 – SC504 – SG502 – SG503 – SG504 – DC503 –DC508 – DD501 – WR501 – DM501A – FG501A – TG501 – PG502 – DC505A – FG504 – 7B80 + 85–7B92A
Gould J3B test oscillator + manual – £150.
Tektronix Mainframes – 7603 – 7623A – 7613 – 7704A – 7844 – 7904 – TM501 – TM503 – TM506 – 7904A – 7834 – 7623 – 7633.
Marconi 6155A Signal Source – 1 to 2GHz – LED readout – £400.
Barr & Stroud Variable filter EF3 0.1Hz – 100kc/s + high pass + low pass – £150.
Marconi TF2163S attenuator – 1GHz. £200.
Farnell power unit H60/50 – £400 tested. H60/25 – £250.
Racal/Dana 9300 RMS voltmeter – £250.
HP 8750A storage normalizer – £400 with lead + S.A or N,A Interface.
Marconi TF2330 – or TF2330A wave analysers – £100-£150.
Tektronix – 7S14 – 7T11 – 7S11 – 7S12 – S1 – S2 – S39 – S47 – S51 – S52 – S53 – 7M11.
Marconi mod meters type TF2304 – £250.
HP 5065A rubidrum vapour FX standard – £1.5k.
Systron Donner counter type 6054B – 20Mc/s – 24GHz – LED readout – £1k.
Racal/Dana 9083 signal source – two tone – £250.
Systron Donner – signal generator 1702 – synthesized to 1GHz – AM/FM – £600.
Tektronix TM515 mainframe + TM5006 mainframe – £450 – £850.
Farnall electronic load type RB1030-35 – £350.
Racal/Dana counters – 9904 – 9905 – 9906 – 9915 – 9916 – 9917 – 9921 – 50Mc/s – 3GHz – £100-£450 – all fitted with FX standards.
HP4815A RF vector impedance meter c/w probe – £500-£600.
Marconi TF2092 noise receiver. A, B or C plus filters – £100-£350.
Marconi TF2091 noise generator. A, B or C plus filters – £100-£350.
Marconi 2017 S/G 10Khz – 1024MHz.
HP180TR, HP182T mainframes £300-£500.
Philips panoramic receiver type PM7900 – 1 to 20GHz – £400.
Marconi 6700A sweep oscillator + 18GHz PI's available.
HP8505A network ANZ + 8503A S parameter test set + 8501A normalizer – £4k.
HP8505 network ANZ 8505 + 8501A + 8503A.
Racal/Dana VLF frequency standard equipment. Tracer receiver type 900A + difference meter type 527E + rubidium standard type 9475 – £2750.
HP signal generators type 626 – 628 – frequency 10GHz – 21GHz.
HP 432A – 435A or B – 436A – power meters + powerheads – Mc/s – 40GHz – £200-£1000.
Bradley oscilloscope calibrator type 192 – £600.
HP8614A signal generator 800Mc/s – 2.4GHz, new colour £400.
HP8616A signal gen 1.8GHz – 4.5GHz, new colour £400.
HP 3325A syn function gen 20Mc/s – £1500.
HP 3336A or B syn level generator – £500-£600.
HP 3586B or C selective level meter – £750-£1000.
HP 3575A gain phase meter 1Hz – 13Mc/s – £400.
HP 8683D S/G microwave 2.3 – 13GHz – opt 001 – 003 – £4.5k.
HP 8660 A-B-C syn S/G. AM + FM + 10Kc/s to 110Mc/s PI – 1Mc/s to 1300Mc/s – 1Mc/s to 2600Mc/s – £500-£2000.
HP 8640B S/G AM-FM 512Mc/s or 1024Mc/s. Opt 001 or 002 or 003 – £800-£1250.
HP 86222BX Sweep PI – 01 – 2.4GHz + ATT – £1750.
HP 8629A Sweep PI – 2 – 18GHz – £1000.
HP 86290B Sweep PI – 2 – 18GHz – £1250.
HP 86 Series PI's in stock – splitband from 10Mc/s – 18.6GHz – £250-£1k.
HP 8620C Mainframe – £250. IEEE – £500.
HP 8615A Programmable signal source – 1MHz – 50Mc/s – opt 002 – £1k.
HP 8601A Sweep generator .1 – 110Mc/s – £300.
HP 3488A HP – IB switch control unit – £500 + control modules various – £175 each.
HP 8160A 50Mc/s programmable pulse generator – £1000.
HP 853A MF ANZ – £1.5k.
HP 8349A Microwave Amp 2 – 20GHz Solid state – £1500
HP 3585A Analyser 20Hz – 40Mc/s – £4k.
HP 8569B Analyser .01 – 22GHz – £5k.
HP 3580A Analyser 5Hz – 50kHz – £1k.
HP 1980B Oscilloscope measurement system – £600.
HP 3455A Digital voltmeter – £500.
HP 3437A System voltmeter – £300.
HP 3581C Selective voltmeter – £250.
HP 5370A Universal time interval counter – £450.
HP 5335A Universal counter – 200Mc/s – £500.
HP 5328A Universal counter – 500Mc/s – £250.
HP 6034A System power supply – 0 – 60V – 0 – 10 amps – £500.
HP 5150A Thermal printer – £250.
HP 1645A Data error analyser – £150.
HP 4437A Attenuator – £150.
HP 3717A 70Mc/s modulator – £400.
HP 3710A – 3715A – 3716A – 3702B – 3703B – 3705A – 3711A – 3791B – 3712A – 3793B microwave link analyser – P.O.R.
HP 3730A+B RF down converter – P.O.R.
HP 3552A Transmission test set – £400.
HP 3763A Error detector – £500.
HP 3764A Digital transmission analyser – £600.
HP 3770A Amp delay distortion analyser – £400.
HP 3780A Pattern generator detector – £400.
HP 3781A Pattern generator – £400.
HP 3781B Pattern generator (bell) – £300.
HP 3782A Error detector – £400.
HP 3782B Error detector (bell) – £300.
HP 3785A Jitter generator + receiver – £750-£1k.
HP 8006A Word generator – £100-£150.
HP 8016A Word generator – £250.
HP 8170A Logic pattern generator – £500.
HP 59401A Bus system analyser – £350.
HP 59500A Multiprogrammer HP – IB – £300.
Philips PM5390 RF syn – 0.1 – 1GHz – AM + FM – £1000.
S.A. Spectral Dynamics SD345 spectrascope 111 – LF ANZ – £1500.
Tektronix R7912 Transient waveform digitizer – programmable – £400.
Tektronix TR503 + TM503 tracking generator 0.1 – 1.8GHz – £1k – or TR502.
Tektronix 576 Curve tracer + adaptors – £900.
Tektronix 577 Curve tracer + adaptors – £900.
Tektronix 1502/1503 TDR cable test set – £1000.
Tektronix AM503 Current probe + TM501 m/frame – £1000.
Tektronix SC501 – SC502 – SC503 – SC504 oscilloscopes – £75-£350.
Tektronix 465 – 465B – 475 – 2213A – 2215 – 2225 – 2235 – 2245 – 2246 – £250-£1000.
Kikusui 100Mc/s Oscilloscope COS6100M – £350.
Nicolet 3091 LF oscilloscope – £400.
Racal 1991 – 1992 – 1988 – 1300Mc/s counters – £500-£900.
Fluke 80K-40 High voltage probe in case – BN – £100.
Racal Recorders – Store 4 – 4D – 7 – 14 channels in stock – £250 – £500.
Racal Store Horse Recorder & control – £400-£750 Tested.
EIP 545 microwave18GHz counter – £1200.
Fluke 510A AC ref standard – 400Hz – £200.
Fluke 355A DC voltage standard – £300.
Wiltron 610D Sweep Generator + 6124C PI – 4 – 8GHz – £400.
Wiltron 610D Sweep Generator + 61084D PI – 1Mc/s – 1500Mc/s – £500.
Time Electronics 9814 Voltage calibrator – £750.
Time Electronics 9811 Programmable resistance – £600.
Time Electronics 2004 D.C. voltage standard – £1000.
HP 8699B Sweep PI YIG oscillator .01 – 4GHz – £300. 8690B MF – £250. Both £500.
Schlumberger 1250 Frequency response ANZ – £1500.
Dummy Loads & power att up to 2.5 kilowatts FX up to 18GHz – microwave parts new and ex equipt – relays – attenuators – switches – waveguides – Yigs – SMA–APC7 plugs – adaptors.
B&K Items in stock – ask for list.
W&G Items in stock – ask for list.
Power Supplies Heavy duty + bench in stock – Farnell – HP – Weir – Thurlby – Racal etc. Ask for list.

ITEMS BOUGHT FROM HM GOVERNMENT BEING SURPLUS. PRICE IS EX WORKS. SAE FOR ENQUIRIES. PHONE FOR APPOINTMENT OR FOR DEMONSTRATION OF ANY ITEMS, AVAILABILITY OR PRICE CHANGE. VAT AND CARRIAGE EXTRA

ITEMS MARKED TESTED HAVE 30 DAY WARRANTY. WANTED: TEST EQUIPMENT–VALVES–PLUGS AND SOCKETS–SYNCROS–TRANSMITTING AND RECEIVING EQUIPMENT ETC.

Johns Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel. No: (01274) 684007. Fax: 651160

CIRCLE NO. 143 ON REPLY CARD

Simple, latching audio/visual alarm

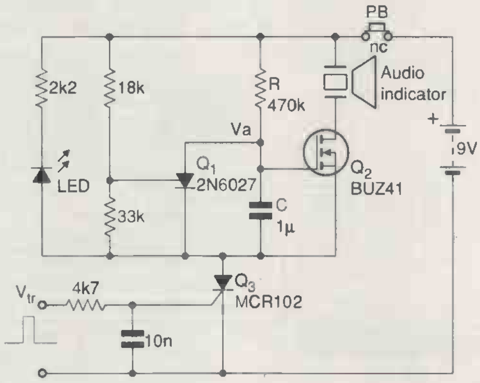
A pulse of greater than 1V amplitude applied to this alarm circuit illuminates a led and activates a piezoelectric sounder.

On the arrival of a pulse, the scr Tr_3 triggers, lighting the led which, with the 2.2kΩ resistor passes the scr's holding current once it has triggered.

Programmable unijunction Tr_1 and its associated components form a relaxation oscillator, enabled when Tr_3 triggers, driving the mosfet and the sounder at a frequency and duty cycle dependent on the *RC* time constant and the gate voltage of Tr_1.

Pressing the normally closed switch resets the alarm.

R. McGillivray
Ontario, Canada



Simple alarm circuit for both visual and audible output.

Video switch transmits up to 1km on a twisted pair

£100 WINNER

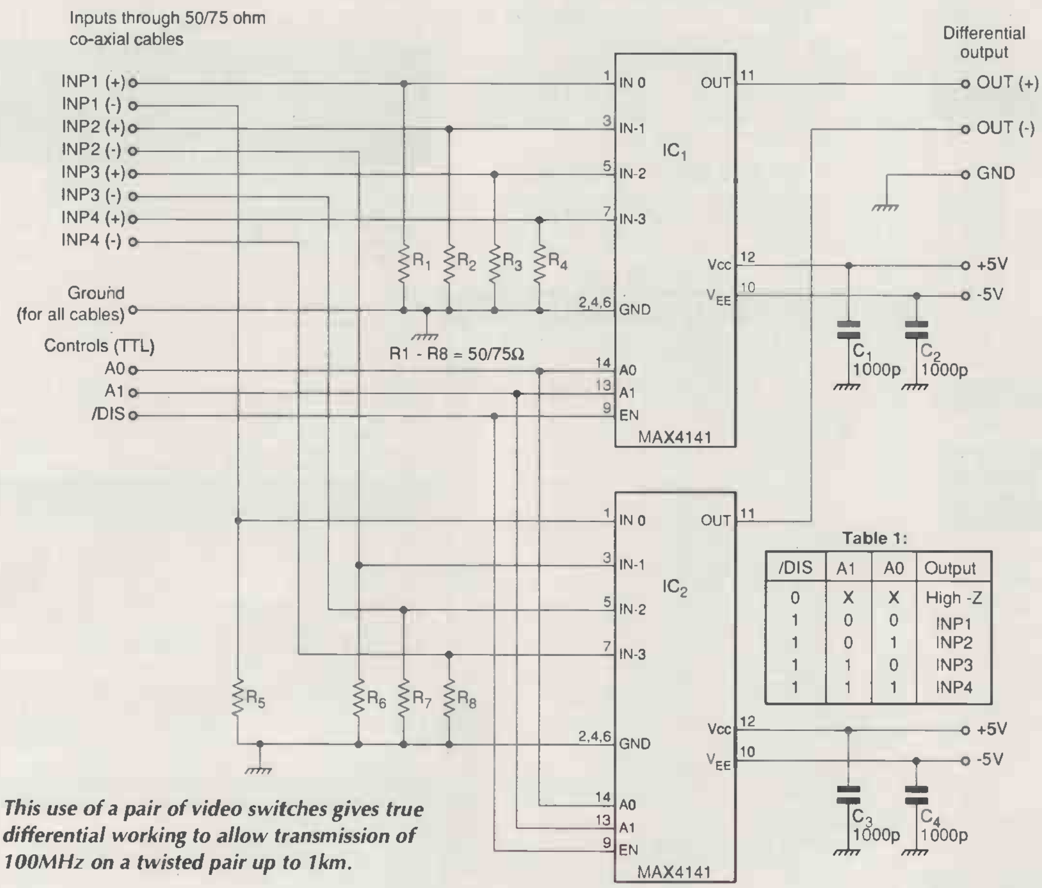


Table 1:

/DIS	A1	A0	Output
0	X	X	High -Z
1	0	0	INP1
1	0	1	INP2
1	1	0	INP3
1	1	1	INP4

This use of a pair of video switches gives true differential working to allow transmission of 100MHz on a twisted pair up to 1km.

This four-channel, differential input/output video switch was built for a computer-controlled security system, in which one of the 100MHz video signals had to be selected and tramsmitted 1km to control room.

Using two *MAX4141* cross-point video switches confers the benefits of differential working; ±5V input and twisted-cable transmission. Terminating resistors of 50Ω or 75Ω, depending on the type of cable in use, should be used at the inputs to avoid reflections, and the cable receiving end must be properly terminated.

Gain response is flat at 0.98 from zero to 100MHz.

Shyam Sunder
Kalpakkam
India

Surplus always wanted for cash!

THE *ORIGINAL* SURPLUS WONDERLAND!

THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

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LOW COST PC's -

SPECIAL BUY 'AT 286' 40Mb HD + 3Mb Ram

LIMITED QUANTITY only of these 12Mhz HI GRADE 286 systems Made in the USA to an industrial specification, the system was designed for *total reliability*. The compact case houses the motherboard, PSU and EGA video card with single 5¼" 1.2 Mb floppy disk drive & **Integral 40Mb hard disk drive** to the front. Real time clock with battery backup is provided as standard. Supplied in good used condition complete with **enhanced keyboard, 640k + 2Mb RAM, DOS 4.01** and **90 DAY Full Guarantee**. *Ready to Run!*
Order as **HIGRADE 286** ***ONLY £129.00*** (E)

Optional Fitted extras: VGA graphics card	£29.00
1.4Mb 3½" floppy disk drive (instead of 1.2 Mb)	£19.95
Wordperfect 6.0 for Dos - when 3½" FDD option ordered	£22.50
NE2000 Ethernet (thick, thin or twisted) network card	£29.00

LOW COST 486DX-33 SYSTEM

Limited quantity of this 2nd user, supurb small size desktop unit. Fully featured with standard simm connectors 30 & 72 pin. Supplied with keyboard, 4 Mb of RAM, SVGA monitor output, 256k cache and integral 120 Mb IDE drive with single 1.44 Mb 3.5" floppy disk drive. Fully tested and guaranteed. *Fully expandable*
Many other options avaiable - call for details. Only **£399.00** (E)

FLOPPY DISK DRIVES 3½" - 8"

5¼" or 3½" from only £18.95 !

Massive purchases of standard 5¼" and 3½" drives enables us to present prime product at industry beating low prices! All units (unless stated) are *BRAND NEW* or removed from often brand new equipment and are fully tested, aligned and shipped to you with a 90 day guarantee and operate from standard voltages and are of standard size. All are IBM-PC compatible (if 3½" supported on your PC).

3½" **Panasonic** JU363/4 720K or equivalent RFE	£24.95(B)
3½" **Mitsubishi** MF355C-L. 1.4 Meg. Laptops only	£25.95(B)
3½" **Mitsubishi** MF355C-D. 1.4 Meg. Non laptop	£18.95(B)
5¼" **Teac** FD-55GFR 1.2 Meg (for IBM pc's) RFE	£18.95(B)
5¼" **Teac** FD-55F-03-U 720K 40/80 (for BBC's etc) RFE	£29.95(B)
5¼" **BRAND NEW Mitsubishi** MF501B 360K	£22.95(B)
Table top case with integral PSU for HH 5¼" Flopp or HD	£29.95(B)
8" **Shugart** 800/801 8" SS refurbished & tested	£195.00(E)
8" **Shugart** 810 8" SS HH *Brand New*	£195.00(E)
8" **Shugart** 851 8" double sided refurbished & tested	£250.00(E)
Mitsubishi M2894-63 8" double sided *NEW*	£275.00(E)
Mitsubishi M2896-63-02U 8" DS slimline *NEW*	£285.00(E)
Dual 8" cased drives with integral power supply 2 Mb	£499.00(E)

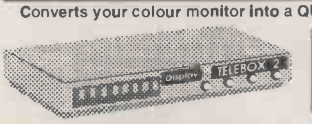
HARD DISK DRIVES

End of line purchase scoop! *Brand new* **NEC D2246** 8" 85 Mbyte drive with **industry standard SMD interface**, replaces Fujitsu equivalent model. Full manual. Only £299.00 or 2 for £525.00 (E)

3½" **FUJI** FK-309-26 20mb MFM I/F RFE	£59.95(C)
3½" **CONNER** CP3024 20 mb IDE I/F (or equiv)RFE	£59.95(C)
3½" **CONNER** CP3044 40mb IDE I/F (or equiv.)RFE	£69.00(C)
3½" **RODIME** RO3057S 45mb SCSI I/F (Mac & Acorn)	£69.00(C)
3½" **WESTERN DIGITAL** 850mb IDE I/F *Brand New*	£185.00(C)
5¼" **MINISCRIBE** 3425 20mb MFM I/F (or equiv.) RFE	£49.95(C)
5¼" **SEAGATE** ST-238R 30 mb RLL I/F Refurb	£69.95(C)
5¼" **CDC** 94205-51 40mb HH MFM I/F RFE tested	£69.95(C)
5¼" **HP** 9754B 850 Mb SCSI RFE tested	£89.00(C)
5¼" **HP** C3010 2 Gbyte SCSI *differential* RFE tested	£195.00(C)
8" **FUJITSU** M2322K 160Mb SMD I/F RFE tested	£195.00(C)
Hard disc controllers for MFM , IDE, SCSI, RLL etc. from	£16.95

THE AMAZING TELEBOX

Converts your colour monitor into a QUALITY COLOUR TV!!



TV SOUND & VIDEO TUNER *CABLE COMPATIBLE**

The **TELEBOX** is an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors made by makers such as **MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD** etc. The composite video output will also plug directly into most video recorders, allowing reception of **TV channels not normally receivable on most television receivers*** (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' UHF colour television channels. **TELEBOX MB** covers virtually all television frequencies VHF and UHF **including the HYPERBAND as used by most cable TV operators**. A composite video output is located on the rear panel for direct connection to most makes of monitor or **desktop computer** video systems. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard.

TELEBOX ST for composite video input type monitors	£36.95
TELEBOX STL as ST but fitted with integral speaker	£39.50
TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6 mHz sound specification.
*For cable / hyperband reception Telebox MB should be connected to a cable type service. Shipping code on all Teleboxe's is (B)

DC POWER SUPPLIES

Virtually every type of power supply you can imagine. Over 10,000 Power Supplies Ex Stock Call for info / list.

IC's -TRANSISTORS - DIODES

OBSOLETE - SHORT SUPPLY - BULK

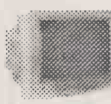
6,000,000 items EX STOCK

For *MAJOR* SAVINGS - CALL FOR SEMICONDUCTOR HOTLIST

VIDEO MONITOR SPECIALS

One of the highest specification monitors you will *ever* see - At this price - Don't miss it!!

Mitsubishi FA3415ETKL 14" SVGA **Multisync** colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including **IBM PC's** in CGA, EGA, VGA & SVGA modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE**. Many features: Etched faceplate, text switching and **LOW RADIATION MPR** specification. Fully guaranteed, supplied in EXCELLENT little used condition.



Tilt & Swivel Base £4.75
VGA cable for IBM PC included.
External cables for other types of computers CALL
Only £119 (E) Order as MITS-SVGA

As New - Used on film set for 1 week only!!
15" 0.28 SVGA 1024 x 768 res. colour monitors.
Swivel & tilt etc. Full 90 day guarantee. £145.00 (E)

Just In - Microvitec 20" VGA (800 x 600 res.) colour monitors. Good SH condition - from £299 - CALL for info

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with both **RGB** and standard **composite 15.625 Khz video inputs** via **SCART socket** and separate phono jacks. Integral audio power amp and **speaker for all audio visual uses.** Will connect direct to **Amiga and Atari BBC computers. Ideal for all video monitoring / security** applications **with direct connection to most colour cameras**. High quality with many features such as front concealed flap controls, **VCR** correction button etc. Good used condition - fully tested - guaranteed
Dimensions: W14" x H12¾" x 15½" D. **Only £95** (E)

PHILIPS HCS31 Ultra compact 9" colour video monitor with standard composite **15.625 Khz video** input via **SCART socket**. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive square black plastic case measuring W10" x H10" x 13½" D. 240 V AC mains powered. **Only £79.00** (D)

KME 10" 15M10009 high definition colour monitors with 0.28" dot pitch. Superb clarity and modern styling. Operates from any 15.625 khz sync RGB video source, with RGB analog and composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 13½" x 12" x 11". Good used condition. **Only £125** (E)

20" 22" and 26" AV SPECIALS

Superbly made UK manufacture. PIL all solid state colour monitors, complete with composite video & *optional* sound input. Attractive teak style case. Perfect for Schools, Shops, Disco, Clubs, etc.In EXCELLENT little used condition with full 90 day guarantee.

20"....£135 22"....£155 26"....£185 (F)

SPECIAL INTEREST ITEMS

MITS. FA3445ETKL 14" Industrial spec SVGA monitors	£245
2kW to 400 kW - 400 Hz 3 phase power sources - ex stock	£POA
IBM 8230 Type 1, Token ring base unit driver	£950
IBM 53F5501 Token Ring ICS 20 port lobe modules	£750
IBM MAU Token ring distribution panel 8228-23-5050N	£95
AIM 501 Low distortion Oscillator 9Hz to 330Khz, IEEE	£550
Trend DSA 274 Data Analyser with G703(2M) 64 i/o	£POA
Marconi 6310 Programmable 2 to 22 GHz sweep generator	£6500
HP1650B Logic Analyser	£3750
HP3781A Pattern generator & HP3782A Error Detector	£POA
HP APOLLO RX700 system units	£950
HP6621A Dual Programmable GPIB PSU 0-7 V 160 watts	£1800
HP3081A Industrila workstation c/w Barcode swipe reader	£175
HP6264 Rack mount variable 0-20V @ 20A metered PSU	£675
HP54121A DC to 22 GHz four channel test set	£POA
HP7580A A1 8 pen HPGL high speed drum plotter	£1850
EG+G Brookdeal 95035C Precision lock in amp	£650
View Eng. Mod 1200 computerised inspection system	£POA
Ling Dynamics 2kW programmable vibration test system	£POA
Computer controlled 1056 x 560 mm X Y table & controller	£1425
Keithley 590 CV capacitor / voltage analyser	£POA
Racal ICR40 dual 40 channel voice recorder system	£3750
Fiskers 45KVA 3 ph On Line UPS - New batts Dec.1995	£9500
ICI R5030UV34 Cleanline ultrasonic cleaning system	£POA
Mann Tally MT645 High speed line printer	£2200
Intel SBC 486/133SE Multibus 486 system. 8Mb Ram	£1200
Zeta 3220-05 A0 4 pen HPGL *fast* drum plotters	£1150
Nikon HFX-11 (Ephiphot) exposure control unit	£1450
Motorola VME Bus Boards & Components List. SAE / CALL	£POA
Trio 0-18 vdc linear, metered 30 amp bench PSU. New	£550
Fujitsu M3041R 600 LPM band printer	£1950
Fujitsu M3041D 600 LPM printer with network interface	£1250
Perkin Elmer 2998 Infrared spectrophotometer	£POA
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3750
Andrews LARGE 3.1 m Satellite Dish + mount (For Voyager!)	£950
Sekonic SD 150H 18 channel digital Hybrid chart recorder	£1995
TAYLOR HOBSON Tallysurf amplifier / recorder	£750
System Video 1152 PAL waveform monitor	£485
Test Lab - 2 mtr square quietised acoustic test cabinets	£300
Kenwood 9601 PAL Vectorscope - NEW	£650

Please call for further details on the above items

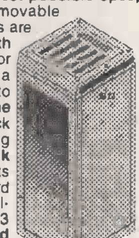
19" RACK CABINETS

Superb quality 6 foot 40U
Virtually New, Ultra Smart
Less than Half Price!

Top quality 19" rack cabinets made in UK by **Optima Enclosures Ltd.** Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and louvered removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the **most versatile** we have ever sold. Racks may be stacked side by side and therefore require only two side panels to stand singly or in multiple bays. Overall dimensions are: 77½" H x 32½" D x 22" W. Order as:

OPT Rack 1 Complete with removable side panels.	**£335.00** (G)
OPT Rack 2 Rack, Less side panels	**£225.00** (G)

32U - High Quality - All steel RakCab



Made by Eurocraft Enclosures Ltd to the highest possible spec, rack features **all steel construction** with removable side, front and back doors. Front and back doors are **hinged for easy access and all are lockable** with five secure 5 lever barrel locks. The front door is constructed of double walled steel with a **'designer style'** smoked acrylic front panel to enable status indicators to be seen through the panel, yet remain unobtrusive. Internally the rack **features fully slotted reinforced vertical fixing members to take the heaviest of 19" rack equipment.** The two movable vertical fixing struts (extras available) are pre punched for standard **'cage nuts'**. A **mains distribution panel** internally mounted to the bottom rear, provides 8 x IEC 3 pin Euro sockets and 1 x 13 amp 3 pin **switched utility socket**. Overall ventilation is provided by fully louvered back door and double skinned top section with top and side louvres. The top panel may be removed for fitting of **integral fans** to the sub plate etc. Other features include: fitted castors and floor levelers, prepunched utility panel at lower rear for cable / connector access etc. Supplied in **excellent**, slightly used condition with keys. Colour **Royal blue**. External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23¾" W)

Sold at LESS than a third of makers price !!

A superb buy at only £195.00 (G)

***Over 1000 racks** - 19" 22" & 24" wide*
3 to 44 U high. Available from stock !!
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CIRCLE NO. 144 ON REPLY CARD

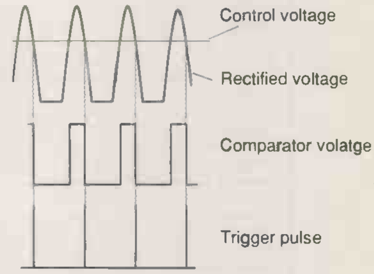
Linear, 90°-180° scr trigger

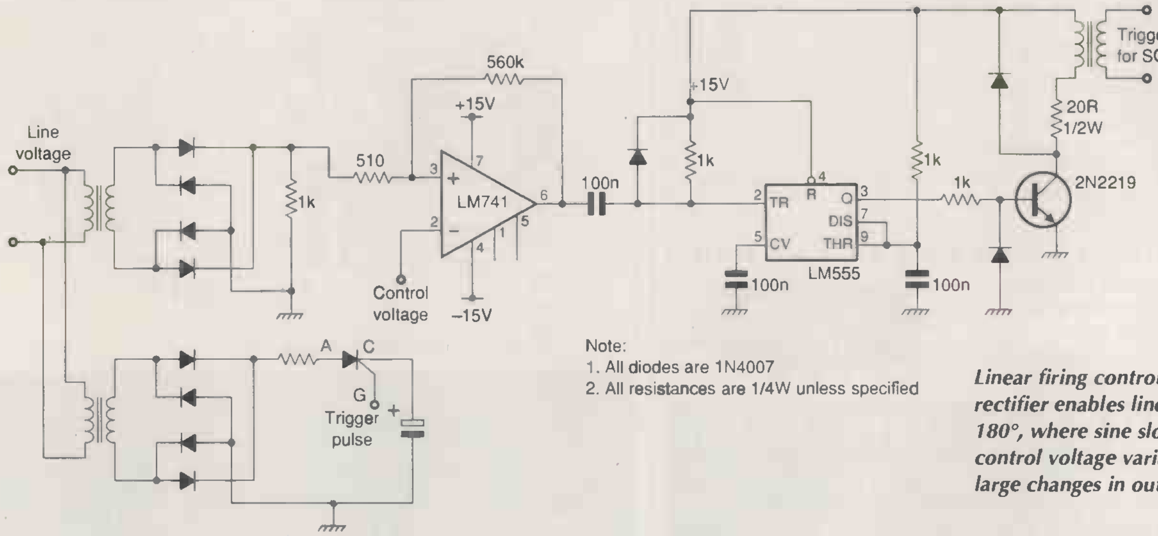
When 90°-180° scr firing control is needed in an scr-controlled power supply and a simple capacitor filter is in use, this arrangement reduces non-linearity of control characteristic near 180°, where the slope of the sine wave is steep.

A comparator 741 compares the rectified output of the bridge with the control voltage, its output falling edge triggering a *555*-based monostable to trigger the scr. Firing angle now varies bwteen 90° and 180° for a control voltage varying from the peak of the full-wave rectified ac to zero.

Output voltage on the capacitor is now stable to within about 0.05%, even at a firing angle near 180°.

M Revathi, Ved Prakash and R Yogesh
Cat-Indore
India





Linear firing control for scr. Full-wave rectifier enables linear control even near 180°, where sine slope is steep and small control voltage variations normally give large changes in output.

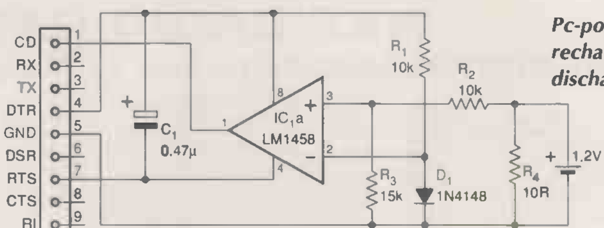
Pc tests rechargeable battery capacity

This little circuit and some software, plus the pc, constitute a tester for rechargeable batteries.

The circuit shown takes its power from the pc's serial port, the voltages being set up in software. Diode D1 holds the inverting input of the op-amp to 0.6V so that a voltage over 1V from the battery, divided by $R_{2,3}$, takes the op-amp output high.

Resistor R_4 discharges the battery at 100mA, the op-amp output going low when the battery voltage falls below 1V. The C program measures the time during which the voltage is greater than 1V and, as soon as it falls below this figure, calculates the battery capacity and displays it on screen.

Yongping Xia
Torrance
California
USA

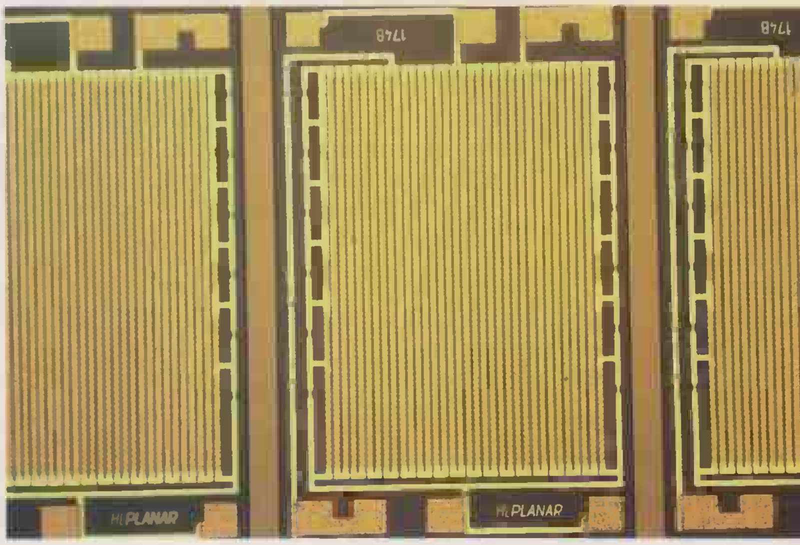


Pc-powered battery tester for rechargeables. Program measures discharge time and calculates capacity.

Listing for checking cells on the pc

```
#include <stdio.h>
#include <dos.h>
#include <time.h>
#include <conio.h>
#define DISCHARGE_CURRENT  0.12
#define MCR           4
#define MSR           6
struct time t;
time_t start_time, read_time;
int i, base_add1=0x3f8, base_add2=0x2f8;
double bat_time;
void set_port(void)
{
 outportb(base_add1+MCR, 0x01:
delay(1000);
}
int read_port(void)
{
int data;
data=(inportb(base_add1+MSR)&0x80)/128;
return (data);
}
void dis data(void)
{
long run_time, run_hour, run_min, run_sec,j;
read_time=time(NULL);
run_time=(long)difftime(read_time,
                    start_time);
run_hour=run_time/3600;
run_min=(run_time-run_hour*3600)/60;
run_sec=run_time-run_hour*3600-
                    run_min*60;
bat_time=DISCHRRGE_CURRENT*(float)
                    run_time/3.6;
gotoxy(2, 1);
printf("Battery has %.2fmAH", bat_time);
gettime(&t);
gotoxy(1,24);
if (run_hour<10)
   printf ( "0" );
printf("%d:", run_hour);
if (run_min<10)
   printf("0");
printf("%d:", run_min);
if (run_sec<10)
   printf("0");
printf("%d", run_sec);
}
void main(void)
{
   int read_data;
   clrscr();
   set_port();
   start_time=time(NULL);
   gotoxy(60,24);
   printf ("Hit any key to  quit");
   bat_time=0;
    do{
     read_data= (read_port ());
     dis_data();
     delay(1000);
    } while(!kbhit() && read_data!=0);
   if (read_data==0)
  {

   gotoxy(1,24);
   printf("Test is done");
   getch();
  }
}
```



Applying magnetoresistance

With circuits examples including a sensor for the Earth's magnetic field and an overcurrent switch for protecting igbts, Neil Chadderton demonstrates the

Fig. 1. Above, magnetoresistive magnetic field sensor chip photograph.

Layout of a typical magnetoresistive chip is shown in **Fig. 1**, and is for example the chip used in the *ZMY20* sensor. Thin film stripes are a characteristic feature of a magnetoresistive chip. These stripes are made by photolithography and consist of permalloy, $Ni_{18}Fe_{19}$ – a magnetic material evaporated on an oxidised silicon wafer. The electrical resistivity of the stripes is changed by a magnetic field H_y due to the magnetoresistive effect. The field H_y causes a rotation of the magnetisation in the stripe, **Fig. 2**. Resistivity R of a permalloy stripe depends on the angle between the directions of electric current, I, and magnetisation M:

$$R=Ro_0+\Delta R_0\cos 2\alpha.$$

where ΔR_0 describes the strength of the magnetoresistive effect.

The maximum relative change of resistivity $\Delta R_0/R$ is approximately 2 to 3% for permalloy. The relationship between an external field H_y and angle α is determined by the geometrical dimensions of the stripe and the magnetic anisotropy of permalloy. This is taken into account by introducing a field H_0 that represents the demagnetising and anisotropic field. One obtains,

$$\sin^2\alpha=\frac{H_y^2}{H_0^2} \quad \text{for } H\le H_0$$

$$\sin^2\alpha=1 \quad \text{for } H\ge H_0$$

The characteristic of a magnetoresistive stripe as a field sensor is:

$$R=R_0+\Delta R_0\left(1-\frac{H_y^2}{H_0^2}\right) \quad \text{for } H\le H_0.$$

A linear characteristic of the magnetoresistive sensor is required to measure a small magnetic field. The linear behaviour of the magnetoresistive sensor is achieved by using a 'Barber-pole' geometry. The stripes in Fig. 1 are covered with aluminium bars having an inclination of 45° to the stripe axis. Aluminum has a low resistivity compared to permalloy. Therefore the Barber poles cause a change of the current direction. The angle between current and magnetisation is shifted by 45°, **Fig. 3**. The relationship between resistance and magnetic field is now,

$$R=R_0+\frac{\Delta R_0}{2}\pm\Delta R_0\left(\frac{H_y}{H_0}\right)\sqrt{1-\frac{H_y^2}{H_0^2}}$$

A linear characteristic of the sensor is given around $H_y^2/H_0^2=0$. The sign in this equation is determined by the inclination of the Barber poles, ±45°, to the stripe axis. The characteristic of a sensor with and without Barber poles is presented in **Fig. 4**.

The stripes of the magnetoresistive chip are arranged as a meandering pattern. They form a Wheatstone bridge which is

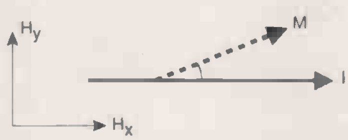


Fig. 2. Magnetoresistive effect depends on the angle between the direction of electric current I and magnetisation M. A rotation of the magnetisation in a permalloy stripe takes place when a magnetic field in the y direction is applied. Without an external field the magnetisation is along the x direction due the shape of the stripe.

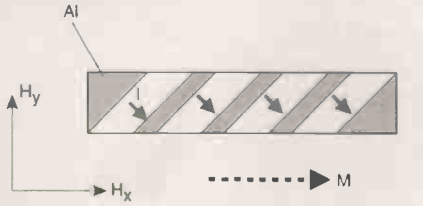


Fig. 3. Covering the stripe with 'barber poles' consisting of aluminium changes the direction of the current. This does not influence the direction of magnetisation.

shown schematically in **Fig. 5**. The applied voltage is V_b. Each half bridge consists of two resistors with different Barber-pole orientations. Voltage between the resistors of a half bridge changes upon application of a magnetic field.

The resistance of one resistor increases, while the other resistor has a lower resistance due to the differing field characteristic. Adding a second half bridge with an opposite arrangement of Barber poles provides a Wheatstone bridge.

Voltage difference V_0 is the output signal of the sensor. Each half bridge is trimmed to $V_b/2$ with an additional resistor in order to get an output voltage close to zero when no external field is applied. The trimming structures of the resistors in Fig. 1 mark off the meander stripes on the left and right side of the chips.

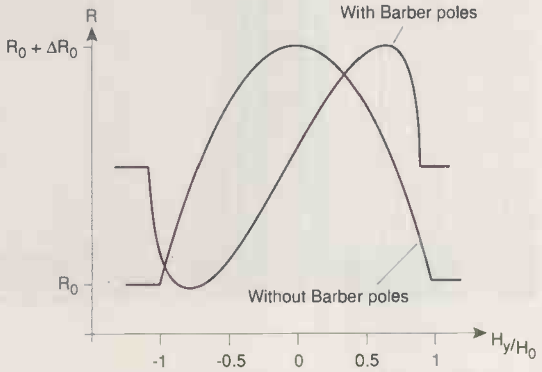


Fig. 4. Characteristics of magnetoresistive sensors. The barber-pole structure enables a linear behaviour of the sensor for a small magnetic field.

Operating conditions and parameters

The shape of the stripe and the anisotropy of permalloy only define an axis along the x-direction for the magnetisation without external field H_y. This means that in this state the stripe can have areas with a different direction of magnetisation (magnetic domains) and the sensor does not work in a stable way. A safe operation of the sensor is achieved by applying an auxiliary field H_x. This field defines the direction

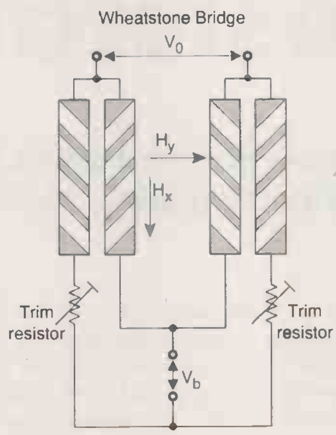


Fig. 5. Wheatstone bridge of a magnetoresistive sensor with barber-pole structure. The bridge is balanced by laser trimming.

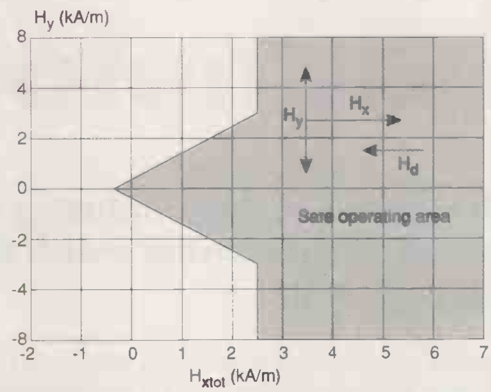


Fig. 6. Safe operating area of ZMY20/ZMZ20 magnetoresistive sensors. $H_{x(tot)}$ is H_x+H_d, ambient temperature is -25°C and H_d is the disturbing field.

Appendix B. Extract from the ZMY20/30, ZMZ20/30 magnetoresistive sensor data sheet. Most of these characteristics assume an ambient temperature of 25° and H_y of 3kA/m.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Test conditions
Bridge resistance	R_{br}					
ZMY20/ZMZ20		1.2	1.7	2.2	kΩ	
ZMY30/ZMZ30		2.0	3.0	4.0		
Output voltage range	V_o/V_B					
ZMY20/ZMZ20		16	18	22	mV/V	
ZMY30/ZMZ30		12	16	20		
Open-circuit sensitivity	S	3.2	4.0	4.8	(mV/V)/	No disturbing
ZMY20/ZMZ20		2.0	3.0	4.0	(kA/m)	field, H_d, allowed
ZMY30/ZMZ30						
Hysteresis of output	V_{OH}/V_B			50	μV/V	Hy≤2kA/m
Offset	V_{off}/V_B	−1.0		+1.0	mV/V	
Operating frequency	f_{max}	0		1	MHz	
Temp. coeff. of offset	TCV_{off}	−3		+3	(μV/V)/K	T_{amb} −25...+125°C
Temp. coeff. of bridge resistance	TCR_{br}		0.3		%/K	T_{amb} −25...+125°C
Temp. coeff.of open circuit sensitivity V_B=5V	TCS_V		−0.4		%/K	T_{amb} −25...+125°C
Temp. coeff. of open circuit sensitivity I_B=3mA	TCS_I		−0.1		%/K	T_{amb} −25...+125°C

of the magnetisation. The range of H_y for safe sensor operation is determined by the strength of the auxiliary field. The safe operating area of the sensor is demonstrated in **Fig. 6**.

Field $H_{x(tot)}=H_y+H_d$ determines the allowed field values for H_y, where H_d is an external disturbing field in the x-direction.

There is no limitation for H_y in the case of $H_{x(tot)} \geq 2.6$kA/m. A small permanent magnet is sufficient to create the auxiliary field. Where *ZMZ 20/30* or *ZMY 20/30* devices are used, the magnet can be glued on the sensor package. Another option is the *ZMY20M* which provides a very compact sensor including an integrated magnet, and is available in surface mount packaging.

The operating data sheet parameters of the Wheatstone bridge are referred to an input voltage V_b=1V, due to the linear relationship between input and output voltage in this region.

The sensitivity S [mV/V/kA/m] of the magnetoresistive sensor is defined as the slope of the output voltage versus external field for -1kA/m$\leq H_y \leq$1kA/m. This parameter depends on the geometry of the permalloy meander and the auxiliary field. The latter is demonstrated in **Fig. 7** for H_x=3kA/m and H_x=6kA/m. Note the small operating area in the case of H_y=0kA/m. A high sensitivity of the sensor leads to a small operating area for H_y.

The Wheatstone bridge is balanced without the application of an external field of $H_y \leq 0.1$kA/m.

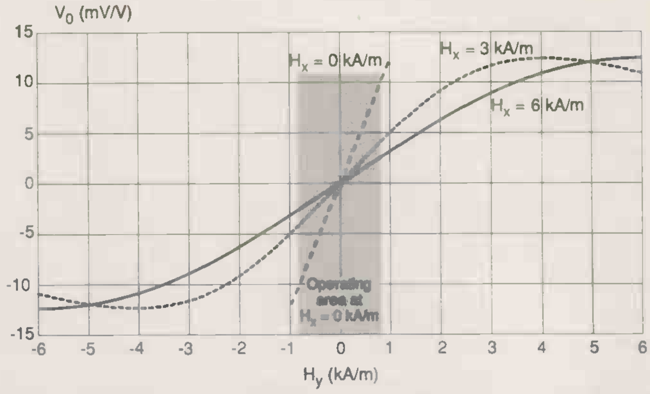


Fig. 7. Sensor output characteristic of ZMY20/ZMZ20. Sensitivity of the sensor can be controlled by applying auxiliary field H_x. This auxiliary field is necessary for sensor operation in a large field range, $V_o=f(H_y)$; H_x-parameter; V_b=const; T_{amb} –25°C.

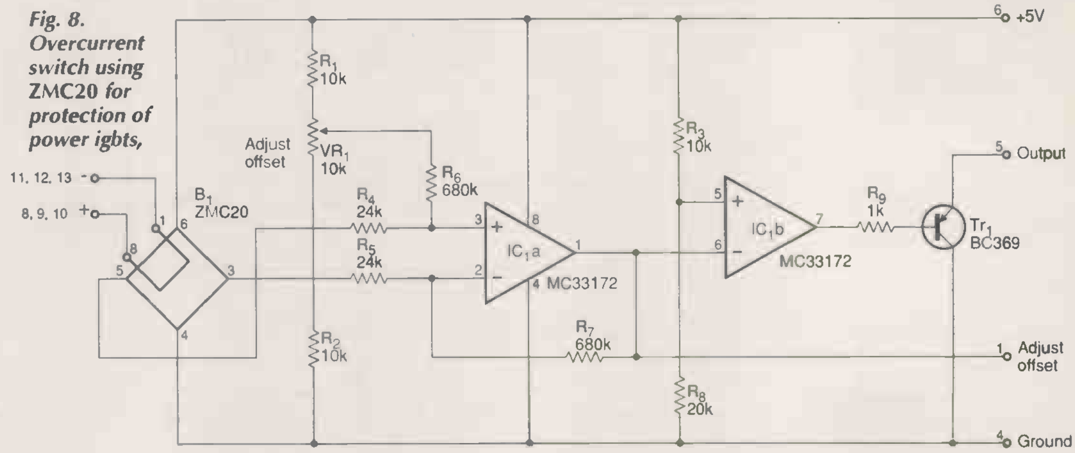


Fig. 8. Overcurrent switch using ZMC20 for protection of power igbts,

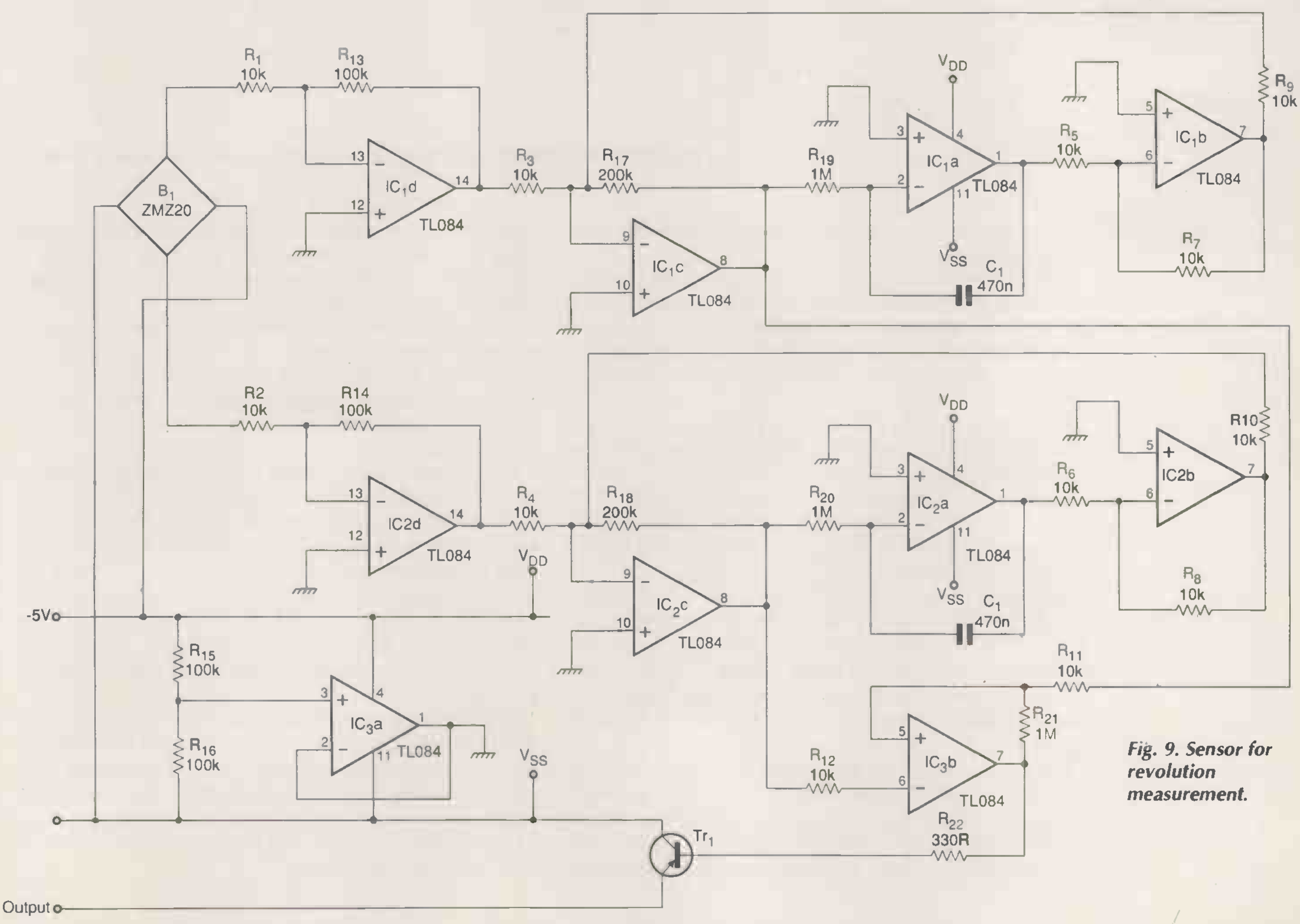


Fig. 9. Sensor for revolution measurement.

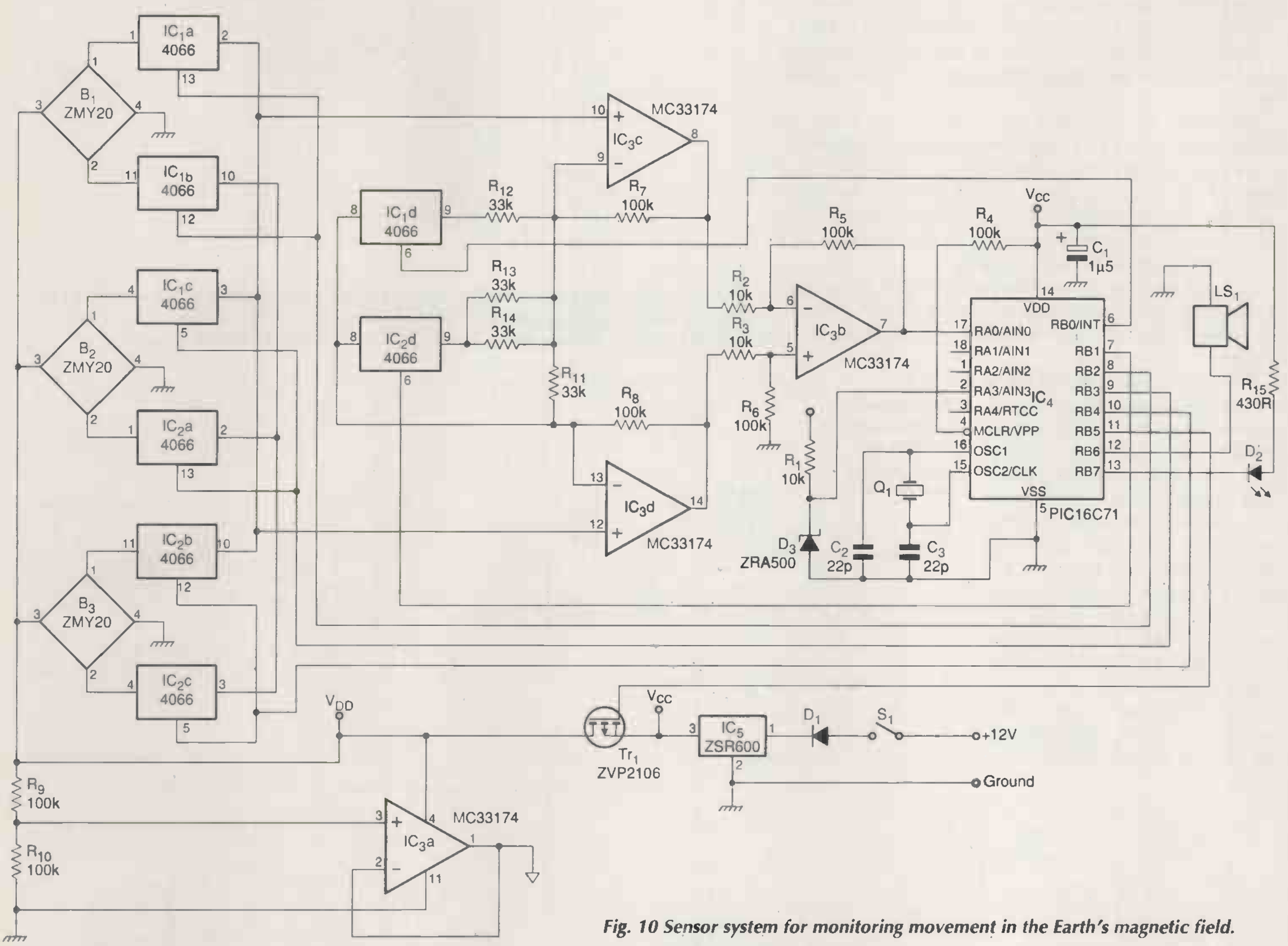


Fig. 10 Sensor system for monitoring movement in the Earth's magnetic field.

In this case, output voltage of the sensor is close to zero at room temperature.

Deviation of the output voltage from zero is called the offset voltage V_{off}/V_b [mV/V]. The offset is caused by small geometric variations of the bridge which occur during the photolithographic process. The offset of the bridge is adjusted by laser trimming. The voltage output of each half bridge is $V_b/2$.

Bridge resistance R_{br} [%/K] of the magnetoresistive sensor depends linearly on temperature. The temperature coefficient of bridge resistance TCR_{br} [%/K] is positive. This is typical for metals. The temperature coefficient of sensitivity, TCS [%/K] of the sensor is negative for V_b=const (TCS_V), because the strength of the magnetoresistive effect becomes smaller with increasing temperature.

In the case of I_B=const (TCS_I), when the sensor is powered by a constant current supply, the temperature dependence of the sensitivity is reduced due to the linear relationship between input and output voltage. A higher bridge resistance caused by a rise in temperature leads to an increased applied voltage, partly compensating the change of sensitivity.

The Wheatstone bridge cannot fully compensate the temperature dependence of the resistors. The temperature coefficient of offset voltage TCV_{off} [µV/V/K] is due to local changes of resistivity in the permalloy thin film and photolithographic variations. This characteristic of the magnetoresistive sensor limits the measurement of small magnetic fields in a wide temperature range, especially in the case of static fields. Two sensors can be selected having a comparable temperature coefficient.

Offset drift is partly eliminated by using the difference of the output voltages of both sensors. Another elegant way to avoid offset drift is to invert the direction of the auxiliary field, thus inverting the output voltage of the sensor. This can be done by small coils providing an auxiliary field that can change its direction.

Hysteresis of output voltage $V_{off(H)}/V_b$ [mV/V] describes the accuracy of the magnetoresistive sensor. The magnetisation of the permalloy stripe is not completely homogeneous. There are small areas of the meander, especially at the corners of the stripes, where the magnetisation is pinned and does not correctly follow the external field. The hysteresis is measured in a magnetic field loop, where H_y goes from –3kA/m to 3kA/m and back to 0kA/m (H_x=3kA/m). $V_{off(H)}/V_b$ denotes the shift of the offset voltage caused by this loop.

The maximum range of output voltage $\Delta V_0/V_b$ [mV/V] is defined as the difference of output voltage for α=0° and α=90°, where α denotes the angle between current and magnetisation of the magnetoresistive stripe. This means that $\Delta V_0/V_b$ represents the strength of the magnetoresistive effect. This parameter decreases with temperature and determines the sensitivity of the sensor.

Applications

Some examples of applications for magnetoresistive sensors are presented in the panel.

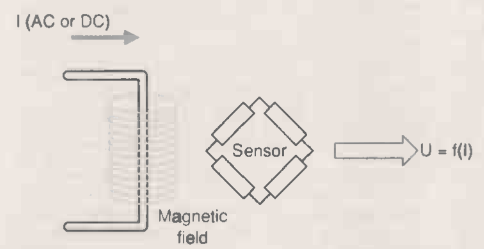
Figure 8 shows a *ZMC20* current sensor being used as a basis for an overcurrent trip switch used to protect power igbts within a motor driver system. The circuit reacts within 3μs to prevent latch-up related failure under transient/pulse conditions, and was built within a module measuring 35×20×25mm. An external 10kΩ preset potentiometer is required for offset adjustment. Supply voltage is +5V ±10% at 10mA; output is via an open-collector transistor rated at 1A, 20V; operating temperature range is 0 to80°C.

Figure 9 provides a method for revolution measurement by reacting to a modulated magnetic field due to a rotating cog. The circuit gives a signal whose frequency is proportional to the rotational velocity of the cog, and a high level output for no rotation.

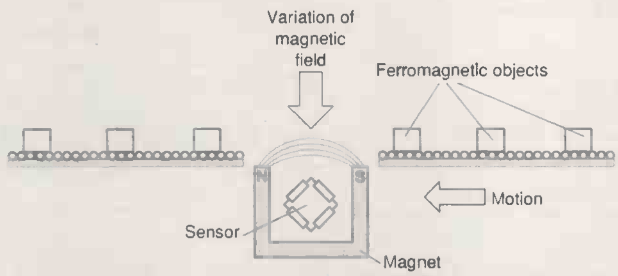
Figure 10 shows an application circuit for three-dimensional magnetic field observation. When the unit is enabled, it calibrates itself to the existing magnetic field of the earth, and then generates a warning signal if it is moved. The system employs three *ZMY20* sensors – one for each dimension – and a c-mos e-prom microcontroller with an a-to-d converter. Similar circuits have been designed for automotive immobiliser/alarm systems that monitor the position of the vehicle by sensing the magnetic field of a movable permanent magnet. This magnet is necessary to shield the sensor from disturbing fields (generated by supply lines, car alternators, etc.) Supporting software for these systems is available on request. ■

Magnetic sensors discussed in this article are available from 2001 Electronics Components Ltd, Stevenage Business Park, Pin Green, Stevenage ST1 4SU, tel. 01438 742001, fax 742002.

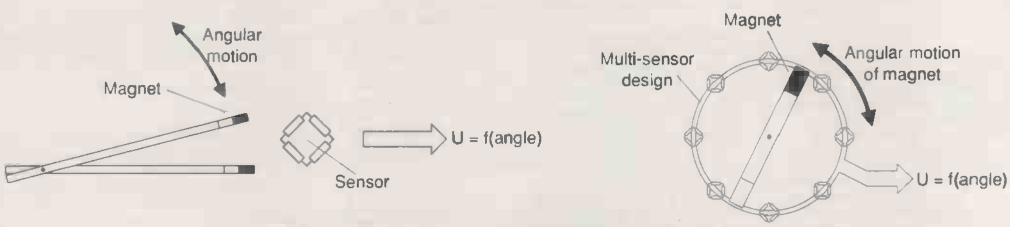
Application outlines for the magnetoresistive sensor.



Measurement of Current – ac or dc

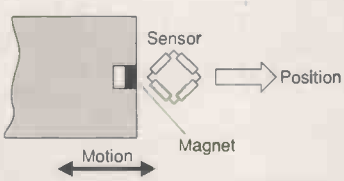


Detection of ferromagnetic objects

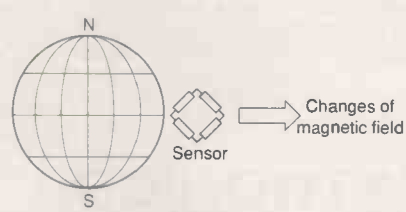


Measurement of angular position

Measurement of rotation velocity



Position sensing



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Close-tolerance lasers. NEL's *DFB* lasers are for use in the safe detection of toxic and flammable gases. For this purpose, the emitted wavelengths must be accurate to within ±1nm, and these are. BFI IBEXSA Electronics Ltd. Tel., 01622 882467; fax, 01622 882469.

Linear integrated circuits

Isolation amplifier. An isolation amplifier from Analog Devices, the *AD215* features 1.5kV rms isolation voltage, 120kHz bandwidth and –80dB thd. There is an uncommitted op-amp for input buffering or amplification, which drives low-impedances and has offset trim. The 115V dc power supply is on-chip and can provide 110mA for various front ends or transducers. Analog Devices Ltd. Tel., 01932 266000; fax, 01932 247401.

Memory chips

Folding rams. Framms are foldable, rigid-assembly memory modules, which means that you can fold them in two to maximise memory density or, to put it another way, to cram more in. *ED14G3232F* and *ED14G3632F* are 32Mb-by-32 and 32Mb-by-36 types respectively, both drams meeting the 72-pin simm standard. They are direct replacements for existing modules. EDI (UK). Tel., 01276 472637; fax, 01276 473748.

Microprocessors and controllers

New *Z8* microcontroller. The *Z8* family is not yet for the chop, for Zilog has introduced new members, the *Z86C02/E02/L02*, which are 8-bit devices having 512byte of rom and 61byte of ram. Operating frequency is 8MHz and the supply is 3-5.5V for the *C02*, 4.5-5.5V for the *E02* and 1-3.9V for the L version. There are 14 i/o lines and five vectored prioritised interrupts from five different sources, 14 digital inputs at cmos level and a fast instruction pointer. Options include a software-enabled permanent watchdog timer and an oscillator taking *RC* timing, a crystal or ceramic resonator, *LC* tuning or external drive. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Television components

Catv amplifiers. For cable television, Motorola has two hybrid amplifiers for 750MHz, the *MHW7272/7292*, working from 24V and giving power gains of 27dB and 29dB, broadband noise figure of 6.5dB and good stability. Motorola. Fax, 01354 688248.

PC/104 expansion. Industrial expansion modules from Arcom for machinery and automation applications provide combinations of digital and serial i/o and have either built-in signal conditioning or an interface to the standard Signal-Conditioning System. The *AIM104* range is used with Arcom's *PC/104* processor boards or any compatible host. There are four digital functions with combinations of 16 opto-isolated inputs and outputs or relay outputs, a 32-channel bit-programmable i/o and a model having four programmable comms channels. All come with a free driver library with its C source code. Arcom Control Systems Ltd. Tel., 01223 411200; fax, 01223 410457.

Communications controllers. Mitsubishi's *M37733/4/5* are 16-bit microcontrollers meant for DECT and portable communications and featuring direct output external bus signalling and a 32kHz dual clock. These devices are based on the *7700* series core and have a cpu and bus interface. The *37734* runs at 25MHz to give 160ns cycle time, incorporates 103 basic instructions and has 60Kbyte of rom and 1048byte of ram. Power supply is 2.7-5.5V. *M37733/5* are compatible and also have three serial i/o and a 10-bit a-to-d converter. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Micro with CAN module. An 8-bit microcontroller in Siemens' *C500* family, the new *C515C* is 80C515A-compatible and also has an SPI interface and an on-chip version 2.0B controller area network module, which will run the extended CAN protocol with 29-bit identifiers. Maximum clock rate of the *C515C* is 10MHz and instruction cycle time 600ns; it has 64Kbyte of rom, 2.5Kbyte of ram, three 16-bit counters, a 4-channel capture-and-compare unit for pwm generation and full duplex serial interface. Emi/rfi performance is better than in earlier *C500* family members. Siemens plc. Tel., 01344 396313; fax, 01344 396721.

8-bit flash PICs. Microchip has a new family of 8-bit *PIC* microcontrollers which have flash program memory and eeprom data memory. *PIC16F84/83* are the first and provide 1024 by 14 and 512 by 14 program memory respectively, with 64byte of eeprom. Both use 35 single-word, 400ns instructions, work from a 2-6V rail and take a 10MHz clock. There are also 13 i/o pins with individual direction control, an 8-bit timer/counter with a pre-scaler, 15 hardware registers, an 8-level-deep stack and led drive. All *PICs* have the support of a development system and other development tools. Arizona Microchip Technology Ltd. Tel., 01628 851077; fax, 01628 850259.

Mixed-signal ICs

Deserialiser. Maxim has the *MAX3680*, a bipolar chip which contains input and output buffers, a shift register and a parallel output

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register. Its function in life is to convert a 622Mb/s, serial, 8-bit-wide input to 77Mb/s parallel output. Power needed is 265mW from 3.3V, and there is a ttl-sync. input for data realignment and framing as part of the interface to the real world. Maxim Integrated Products UK Ltd. Tel., 01734 303388; fax, 01734 305511.

Optical devices

Quad optoisolators. *ISQ204* optoisolators by Isocom consist of four low-power devices in the one package, each offering isolation resistance of $5{\times}10^6\Omega$ and peak differential voltage between input and output of 7.5kV. Drive current needed is 0.5mA for full output, at which level current transfer ratio is 50%, rising to 100% at 1mA. Output saturation voltage is 0.4V. Isocom Components Ltd. Tel., 01429 863609; fax, 01429 863581

PASSIVE

Passive components

High-value resistors. Philips' *VR37* and *VR68* series of high-value, high-voltage metal-glaze resistors now have UL 1676 approval; they now meet all relevant standards, including VDE 0860 and BS 415. Temperature coefficients are under 200ppm. Values subject to the approval are 510kΩ-11MΩ, the full range being 100kΩ-220MΩ over the two ranges. Philips Components. Tel., 00 31 40 722790; fax, 00 31 40 724547.

Power meter. Covering from 10MHz to 26GHz, the Krytar *9000A* low-cost power meter digitally displays power between –30dBm and 20dBm, three detectors are designed for broad coverage laboratory and limited coverage field work and there is a type N detector for portable, battery-powered applications. Tony Chapman Electronics Ltd. Tel., 01992 578231; fax, 01992 576139.

Data line chokes. Surface-mounted, four-element chokes for the protection of data on lines in noisy environments are introduced by Siemens, giving up to 90% saving in space over leaded types. These chokes are primarily for the So basic access and S^{2}m multiplex interface of an ISDN system, but will find application in other areas as well, such as CAN buses in vehicles. Inductances in the range vary from 4 by 470μH to 4 by 4.7mH. A variety of characteristics is available for the different applications. Siemens plc. Tel., 01344 396313; fax, 01344 396721.

Audio products

Single-chip surround-sound codec. The first single-chip surround-sound codec to support Dolby Digital Surround (AC-3) and Dolby Pro Logic is available from Crystal Semiconductor. *CS4226* contains 95dB stereo a-to-d converters, six d-to-a converters, each with its volume control (which only varies volume at zero-crossings to minimise clicks) a mono a-to-d converter and a Sony/Philips digital interface format receiver, the chip replacing up to nine earlier ics. The S/PDIF receiver supports stereo pcm data and compressed 5.1 channel AC-3 and MPEG audio. Crystal Semiconductor Corporation. Tel., (USA) 001 512 442 7555; fax, 001 512 445 7581.

Connectors and cabling

Microwave connectors. Transradio has a range of coaxial terminations for commercial microwave equipment in SMA and N forms. Both types cover 0-3GHz, have resistance and impedance of 50Ω ±5%, are rated at 1W and exhibit a voltage standing wave ratio of between 1.08 and 1.2 over the frequency range. The type N has a peak power rating of 500W for 1μs and the smaller SMA 100W for 1μs. Transradio Ltd. Tel., 0181-997 8880; fax, 0181-997 0116.

Cabling wall sockets. *HideOut* multimedia wall outlets by AMP are a convenient method of hiding and protecting connections to mixed-media cabling in networks and telephone systems. The face plate is flat and almost flush with the wall and the cables enter the bottom edge, so being protected from furniture. The sockets use exiting AMO inserts for ST and SC fibre connections and Cat. 3 and 5 unshielded and shielded twisted-pair cables. They take four copper and two fibre cables or four fibre connections. AMP. Tel., 0181-9542356; fax, 0181-954 7467.

Displays

High-contrast lcd. Using a black mask, Densitron has increased the contrast of transmissive lcds to 100:1 in displays with bright led or fluorescent backlighting. The first available provides a total of 20 digits and 12 graphics symbols for use in consumer equipment, displays with red and green backlighting, allowing viewing in all lighting conditions from a distance of 5m. Results are similar to those from a vacuum fluorescent display, but with a lifetime of 50,000 hours. Densitron Perdix. Tel., 01959 700100; fax, 01959 700300.

13-in colour lcd. NEC's *NL128102AC20-07* 13in colour lcd is meant principally for cad and desktop workstations, providing a high-brightness display to a resolution of 1280 by 1024. It is an active-matrix type working from rgb input, with built-in backlight and inverter and giving a good viewing angle. Vertical screen expansion (multiscan) allows images of different resolutions to fill the display area. Sunrise Electronics Ltd. Tel., 01908 263999; fax, 01908 263003.

Filters

If filter for DECT telephones. An if surface-wave filter from Siemens takes up 30% less surface area than the QCC10 case; the *B4539* measures 9.1 by 4.8 by 1.8mm. Insertion loss is about 8dB and group delay 250ns; adjacent-channel rejection 32dB, 52dB and 54dB for first, second and third. Although designed for use in the Siemens *PMB 2420* DECT chip set, the output is 150Ω, making the device suitable – without an impedance network – for the National Semiconductor set. Siemens plc. Tel., 01344 396313; fax, 01344 396721.

Inter-board connectors. Siemens' surface-mounted board-to-board connectors use no pins or sockets but, instead, spring-loaded contacts on one board that mate with contact pads etched and plated on the other. The result is no need for through-board holes and a space between boards of between 2.5 and 3.2mm. Connectors come in 6-way and 30-way form and provide a 20mΩ contact resistance and 0.5A current-carrying capacity. Siemens plc. Tel., 01344 396313; fax, 01344 396721.

Hardware

Tailored boxes. Bafbox can now deliver small numbers of custom-designed plastic enclosures by mail order at volume prices. The company has developed cad/cam software to allow customers to specify the size and shape of box and where holes should be, so eliminating expensive machining of standard cases. If the holes are then found to need moving, it can be done at no "significant" cost difference. Rfi/emi shielding can be supplied, as can screen printing and various paint finishes. Prototypes in a few days, production in five weeks. Bafbox Ltd. Tel., 01280 705777; fax, 01280 706320.

Test and measurement

Handheld multimeters. Tektronix has a series of multimeters that are small and tough and have a 40,000-count display. The *DMM800* meters possess a dual display for taking two simultaneous readings, with an analogue type of indication, and measure true rms values in addition to the full range of voltage, current, resistance, diode test, frequency and capacitance. Type *DMM870* also

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offers a 1ms peak hold, dB and dBm readings and has a backlit display. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

High-voltage oscilloscope amp. Gould's *DP9010* is a differential amplifier for floating, high-voltage measurement on a grounded oscilloscope. Its bandwidth is 0-80MHz and the differential inputs are balanced to 1MΩ; standard probes are suitable. Input voltage range with direct input is ±30V and, with suitable probes, extends to 20kV; cmrr with direct input is 70dB at 1MHz. Gould Instrument Systems Ltd. Tel., 0181-500 1000; fax, 0181-501 0116.

Interfaces

Keypad, driver/micro interface. Rohm's *BU9768K* interface controller ic contains all keypad and lcd driver functions in the one device, operating on a three-wire bus back to the microprocessor, which is relieved of much of the routine and can therefore be of lower performance. It handles keypad scanning without attention from the processor, which downloads data to the *BU9768K* through a serial link, the interface controller doing the rest. The *BU9768K* draws 200μA active, 30μA on standby. Flint Distribution. Tel., 01530 510333; fax, 01530 510275.

Vibration sensors. Used with a zener barrier, the *MTN/1101* vibration sensors by Monitran are certified by BASEEFA as intrinsically safe for use in all hazardous areas and gas groups, being rated to EEx ia IIC T6. These piezoelectric devices with internal electronics give an ac output of 100mV/g and can be processed in a DIN-rail-mounted unit to give a 4-20mA current-loop signal. They are made in stainless steel and sealed, a choice of attachments for mounting being available. Monitran Ltd. Tel., 01494 816569; fax, 01494 812256.

Literature

Programmable analogue. Imp, of San Jose, offers the *Electrically programmable Analog Circuit Design Handbook*, which describes these epac devices that are the analogue equivalent of field-programmable gate array. It also provides application notes and development tool details, with a collection of seminar reprints. Imp also offers Animal Magic, which is Windows-based design software for analogue and mixed-signal epacs. Tel., 001 408 434 1467; fax, 001 408 434 0335. E-mail http://www.impweb.com

Drams on cd. A cd-rom from NEC provides all details on all NEC drams and srams, including 64Mb devices. There is also information on applications, reliability and quality. The cd runs under Windows, is menu-driven and has copy-and-paste facilities, with text search and printing to speed things up. NEC Electronics (UK) Ltd. Tel., 01908 691133; fax, 01908 670290.

Harris. Harris Semiconductor offers a new brochure, *Semiconductor Solutions for Multimedia, Video and Imaging*, the solutions being op-amps and buffers, data converters, standards converters and various other video ics for these areas. There is also a section on dsps. Harris Semiconductor UK. Tel., 01276 686886; fax, 01276 682323.

Thermal analysis on the Web. Flomerics has a World Wide Web site on http:/www.flomerics.com, on which the company describes its Flotherm thermal analysis software, together with case studies from some of the bigger companies who have used it. Also described is *DELPHI* which is a collection of thermal models for electronic components and hardware to assist engineers in system design. The site contains *Electronic Cooling*, a magazine published by Flomerics. Flomerics Ltd. Tel., 0181-941 8810; fax, 0181-941 8730.

Materials

Anti-static plastic compound. TBA ECP is shortly to announce some new static-dissipating plastic compound that can be moulded and made in many colours, as opposed to earlier types which have also been in any colour as long as it was black. Some of them were coloured, but only because they were laced with additives which did not last. This new material is injection moulded ABS alloy with a resistivity of around $10^9\Omega$/square, with the appropriate static decay characteristic. The company offers a moulding service. TBA Industrial Products Ltd. Tel., 01706 47718; fax, 01706 46170.

Cleaning fluids. Since the more ferocious solvents formerly used to clean electronic assemblies are now banned under the Montreal Protocol, new ones are now appearing. Loctite, for example, has *Loctite 7070* and *Loctite 7063*, both alternatives to 1,1,1,Trichlorethane. *7070* is for open tanks and brush use, drying in around two minutes and pervading the air with a scent of lemons, while *7063* dries in 15 seconds and is very good at cutting through oil; it has to be used in closed tanks and doesn't smell of lemons, so far as we know. Both types come in air-rechargeable aerosols, pump sprays, cans and drums. Loctite UK Ltd. Tel., 01707 821000; fax, 01707 821200.

Heat-shrink tubing. Methode offers *ShrinkMate* (why do so many people insert a capital half-way through a name?), which is heat-shrink tubing based on polymer thick-film silver ink technology to give efficient connections and eliminate emc problems on signal and power lines. The material is easily applied using a heat gun or oven and is meant for use on spliced cables or connectors,

Keylock switches. EAO offers a new range of multiposition keylock switches to the *04 Series* of push-buttons. Bezels are round or square and the switches come in a variety of forms from three-position, 60° throw, to 12-position, 30° throw, with up to 16 contacts. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Digital wattmeter. Yokogawa's *WT130* is a three-phase wattmeter with three input modules for independent measurement on each phase. Bandwidth is 0-50kHz to allow measurement on pwm variable-speed drives. High-speed measurement is followed by calculation of effective power, apparent power, reactive power, power factor and phase individually and for the three phase system. The instrument carries out 32-bit FFTs using a rectangular window and analyses harmonic content of voltage, current and power waveforms by amplitude and by phase to the fundamental. The *WT130* has an RS 232 interface. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002.

where it gives a circumferential seal round the cable shielding and the base of nearly every connector type, also obviating the need to solder braided cable shielding. Shielding rating of a connector so treated is 40-82dB over the 30-1000MHz range. Methode Electronics Europe Ltd. Tel., 01389 732123; fax, 01389 732777.

Printers and controllers

Fast thermal printer. Star Micronics *TMP-200* is a high-speed device for oems; it provides easy access to the head with a view to simple maintenance. It prints at eight dots/mm, at up to 1.5in/s and there are options of auto cutter and interface boards. Paper feed is from the rear or bottom. Roxburgh Electronics Ltd. Tel., 01724 281770; fax, 01724 281650.

Production equipment

Ultrasonic cleaning. Since some of the cleaning agents previously in use are now prohibited, new types of ultrasonic cleaners are needed to give the same results with new, flammable solvents. Caresonic has new equipment for this purpose which enable these vicious-sounding solvents to be used harmlessly by providing interlocking lids, purging and venting, and automatic timing. Solvent is contained under the tank, is pumped in for use and then pumped out again before the lid can be opened. Heat is not needed. Care Ultrasonics Ltd. Tel., 0151-356 4013; fax, 0151-356 4037.

Vacuum cleaner. Among life's minor irritations are items of equipment that have been computer-designed to be virtually impossible to clean, such as keyboards and cameras. Jessop, in an effort to ease the stress, have introduced the *Mini Vacuum* battery-powered cleaner kit, which also blows, possibly through various nozzles and brushes. It has a dust bag and an array of cloths, sprays, tissues and cotton buds to further the process. It cost £9.99 from Jessop photographic shops. Jessop Group Ltd. Tel., 0116-232 0033; fax, 0116-232 0066.

Man-machine interface design. National Instruments announces *BridgeVIEW*, which is a graphics package for process and manufacturing application. Using techniques taken from the company's *LabVIEW*, it provides real-time process monitoring, trending, on-line configuration and programmable logic controller connectivity. It has a gui and the G development language for data acquisition and analysis, man-machine interfacing and supervisory application. National Instruments UK. Tel., 01635 572400; fax, 01635 523154.

Power supplies

60W dc-to-dc. Emi/rfi-shielded on all sides of an aluminium case, Amplicon's *RW Series* of 50-60W dc-to-dc converters are current-mode types giving an efficiency of 83% from 10-72V input. There are 48V models for telecomms use with case to positive, 24V ones for process control and 12V versions for use in vehicles. Single, dual and triple versions combine 5V, ±12V and ±15V in various ways and the units have a remote on/off control.They switch at 300kHz, are isolated to 500V dc and are short-circuit protected, with autostart. Temperature coefficient is ±0.02%/°C, stability ±0.05%, ripple and noise 1% pk-pk and transient response 500µs. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

Integrated power supply. Working without external components, National's *LM2825* is said to be six times more reliable than a psu module, provides a power density of 35W/in^3 and meets Class B of CISPR 22 for radiated emissions. It handles inputs up to 40V and gives output of 1A from 3.3V and 5V at 80% efficiency and is protected against overcurrent, shorts and high temperatures. Avnet Access. Tel., 01462 480888; fax, 10262 488567.

Low-voltage Schottkys. New Schottky diodes from Philips are for use in 3V and 3.3V switch-mode power supplies and have a 0.33V forward drop at rated forward current. Low capacitance and no stored charge in nickel silicide junctions make them suitable for high-frequency use. *PBYR1025CT* is a single diode rated at 20A and *PBYR1525CT/2025CT* dual types rated at 15A and 20A respectively, all withstanding 25V reverse. Philips Semiconductors (Eindhoven). Tel., 00 31 40 2722091; fax, 00 31 40 2724825.

New Klippon range. Weidmuller Klippon has a new range of psus, including switched-mode types and dc-to-dc converters meeting a large number of standards and CE marked. All the s-m types have short-circuit, thermal, overvoltage and inrush protection, universal ac and dc inputs and variety of housings, including a 1A unit in an EG case, claimed to be the smallest available. Weidmuller (Klippon Products) Ltd. Tel., 01795 580999; fax, 01732 844444.

Minute 40W supply. XP's *NLP40* is claimed to be the smallest emc-compliant 40W supply available, measuring 4.25 by 2.5 by 1.25in and meeting low-voltage Directives and EN55022 for conducted noise. The company ascribes its power density of 3W/in^3 to a new type of switch-mode operation and a fixed switching frequency, together with a patented integrated boost flyback topology. Input is universal and nine models cover outputs of 5V single to 5V with ±15V triple. XP plc. Tel., 01734 845515; fax, 01734 843423.

Radio communications products

Broadband amplifiers. Advanced Control Components Inc. announces a range of ultra-broad-band and octave band amplifiers for mobile communications between 10MHz and 4000MHz. *ACAM 8928* and *7932* both give 1W and are meant for use in level test or integration into test systems. Frequency ranges are 10-2500MHz and 100-4000MHz, both including the cellular, SMR and PCN/PCS bands. Gain of the *7928* is 36dB±0.75dB, while the compact 7932 has a 24dB±1dB gain. There are also three 10-octave amplifiers in rack-mount form covering 100-500MHz, 500-1000MHz and 1000-2000MHz. Anglia Microwaves Ltd. Tel., 01277 630000; fax, 01277 631111.

Protection devices

Shielded windows. Emc shielding for display panels and other transparent areas is available from TBA ECP. Conductive coatings based on indium tin oxide are applied to glass or plastic such as polycarbonate and acrylic and give conductivity down to 10Ω/square and up to 90.5% transparency. Tooling exists to coat complex shapes and coatings can extend up to 350 by 320mm. The company also makes windows using fine wire meshes or metal oxide interlayers in laminated glass or plastic. TBA Industrial Products Ltd. Tel., 01706 47718; fax, 01706 46170.

Switches and relays

Miniature relay. A miniature, hermetically sealed relay from Finder, the Series 30, meets BT47 and BT51 specifications and is suitable for most telecomms applications. It is rated at 250V ac for resistive loads and comes with 20mW (BT47) or 40mW coil voltages of between 5V and 48V dc. Two changeover contacts are silver/gold-plated and power handling is 125VA; maximum switching frequency is 600cycles/h. AX Electronic Component Distribution. Tel., 01403 240055; fax, 01403 255657.

Reed relay. CP Clare's *MVS Series* of reed relays use the company's *MH4* bounce-free, mercury-wetted reed switch and have a life of up to 10^{10} operations at low to intermediate levels. Contact resistance is stable at ±5mΩ from the 100mΩ rated figure, maximum switching voltage 1kV and switching current 2A (carry current 3A). Several of the devices in the range are fitted with diodes as an option and one has an electrostatic shield. Clare UK Sales. Tel., 01823 352541; fax, 01823 352797.

Semiconductor relays. Matsushita would like to point out that its *PhotoMos* relays do not suffer from most of the disadvantages found in electromechanical ones or even thyristor or transistor types, while providing true relay switching. You can get versions to switch very low currents or up to more than 4A, with multiple contact arrangements of the n.o. or n.c. type. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

W95 keyboard. A new version of Cherry's keyboard. the *Model 3000*, works with Windows 95 and gives a better choice of "feel". It has 104 or 105 keys, two or three of them for Windows use, and the F and J keys are dished for touch typists, the 5 key on the numeric pad having a dimple for the same reason. A dil switch copes with PC, AT, XT or PS/2 modes of operation. The keyboard meets all relevant standards. Cherry Electrical Products Ltd. Tel., 01582 763100; fax, 01582 768883.

Bipolar Hall switch. Allegro offers the *3134* low-hysteresis, bipolar Hall-effect switch for automotive and industrial use. It has a novel Schmitt trigger built in which compensates for temperature changes to maintain trigger and release points. Further compensation is provided by magnetic switch points that become more sensitive with temperature. Also on-chip are a voltage regulator, a quadratic Hall generator, temperature compensation, an amplifier and a buffered open-collector output stage. Allegro MicroSystems Inc. Tel., 01932 253355; fax, 01932 246622.

High-current relay. Matsushita's *LK* relay is designed to handle inrush currents up to 100A, with a barrier between coil and contacts to improve creepage, to give a 6mm clearance and to provide noise immunity. It measures 24 by 25 by 11mm, is rated at 5A, 277V ac and will withstand 10kV surges. Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599.

Snap switches. Cherry has two new switches in its *Snap Switch* range. The *D48* high-power microswitch operates at up to 150°C, has a current rating of 21A at 240V, long life and silver contacts, while the *D3* type has a contact gap of over 3mm to take high inrush currents; this one switches continuous loads of 16A at 380V, with short-period overloads. Cherry Electrical Products Ltd. Tel., 01582 763100; fax, 01582 768883.

Sealed switches. C&K offers a range of sealed toggle, rocker and push-button switches, which are available with both through-hole and surface-mountings to withstand flow-solder, vapour phase and infrared reflow operations. All have ultrasonically sealed bodies, O-ring bushes and epoxy sealed terminals. Roxburgh Electronics Ltd. Tel., 01724 281770; fax, 01724 281650.

Transducers and sensors

Optical encoder. *HS Series* optical shaft encoders by Control Transducers are of low cost and are meant for use on machinery for feedback and positioning. The range covers resolutions from 96 to 2048 lines per revolution in 16 models. The encoders measure from 1in to 2in diameter with mounting plates and two ball bearings handle speeds up to 10,000rev/min. Components such as cable, line drivers, power supplies are available. Control Transducers. Tel., 01234 217704; fax, 01234 217083.

Audible alarms. *Kingstate* piezoceramic alarms operate from dc and provide the requisite racket while measuring only 13.8mm diameter, and even more racket from 42mm types. They come with flying leads or pins to standard formats, most of them being sealed for soldering and cleaning. Roxburgh Electronics Ltd. Tel., 01724 281770; fax, 01724 281650.

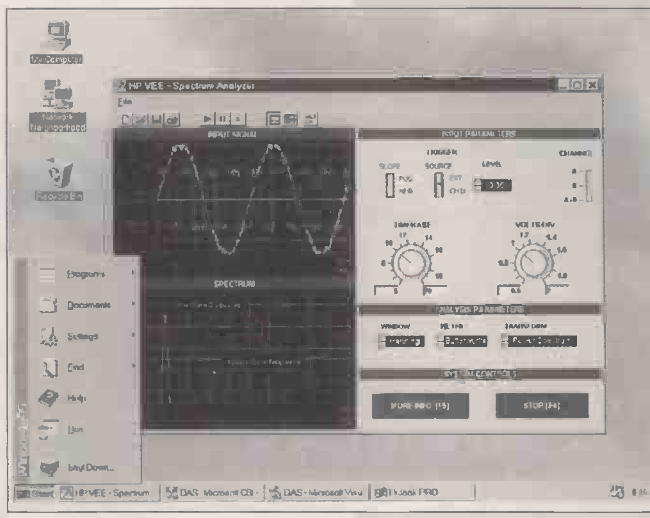
More audible alarms. Piezoceramic alarms from Fuji also make a very loud noise – 108dB at 1kHz – from 5V rms and are only 2mm thick and use less power while doing it than many others. Connection is by flying lead, through-hole or surface mounting. Distributed Micro Technology Ltd. Tel., 01276 33391; fax, 01276 36703.

Current measurement. JJ Systems announces a range of flexible transducers for contactless current measurement, which take the form of air-cored, toroidal winding, the Rogowski coil, which is placed around a conductor carrying from 1A to 1MA to give an accurate waveform reproduction for oscilloscope or dvm; the coil is completed by plug and socket. Frequency range is 0.1Hz-1MHz with an accuracy within 1%. Sensitivity is insensitive to the position of the coil. JJ Systems Ltd. Tel., 01256 895111; fax, 01256 896100.

COMPUTER

Development and evaluation

68HC11 development. MD Electronics introduces the *MC11*, which is a development or training aid based on Motorola's *69HC11* microcontroller. The kit can also be used as a low-cost controller. It is linked to a pc by way of a standard serial port, a monitor in read-only memory allowing programs to be developed and debugged or, for longer programs, developed on the host pc and downloaded. The 40-way input/output port is compatible with much equipment used in education. Further connectors allow access to the eight analogue-to-digital channels and permit system expansion. MD Electronics. Tel., 01926 850315.



Virtual instruments. The result of cooperation between ComputerBoards Inc. and Hewlett-Packard, *VIvalue* brings together a range of data acquisition boards (ISA or PCMCIA) for the pc at low cost, and H-P's *HP-VEE* software, the total package enabling the design and realisation of virtual instruments at much lower cost than has been common. The software allows the creation of programs graphically rather than by writing code and will run existing C, Basic, Pascal and Fortran programs; it supports hundreds of GPIB and VXI plug&play instruments, all drivers being supplied. Adept Scientific Micro Systems Ltd. Tel., 01462 480055; fax, 01462 480213.

Software

Maths library. Mathtools announces *Matcom v.2* maths library, a C++ matrix library having more than 300 maths functions, including basic unary and binary operations, indexing, signal processing, linear algebra and 2D and 3D graphics. Matrices are supported. E-mail info@mathtools.com; fax, 001 215 957 1719.

Image analysis. *Image-Pro Plus* from Media Cybernetics, which runs on all Windows variants and Mac 7, provides accurate image processing and analysis of monochrome, grey scale and 24-bit colour images. It has a range of counting, sizing, statistical and image-enhancement tools and is meant to be used in any area where an image can help one to understand a process, to make comparisons or to identify objects. Examples are: measuring areas, perimeters, roundness, population density; display measurements as histograms; calculate line areas; perform FFTs; read files from a camera, disk or cd. And a great deal more. DataCell. Tel., 01628 415415; fax, 01628 415400.

8xC186 C compiler. IAR Systems and Intel introduce a C compiler for the 8xC196 embedded microcontroller. ICC196 v.5.10 is dos-based and includes compiler, assembler, linker and library.The ANSI-compliant compiler supports all current 8xC196 controllers and is future-proof. Malloc and realloc are supported to confer flexibility in controlling processor heap size. Four memory models support code and data from 64Kb to 16Mb and bank switching to 8Mb is available. Efficiency gains from the use of mixed C and assembly language listings, in which each C line is followed by the equivalent assembly code, compiler errors being reported with line number, syntax and pointer to the error. IAR Systems Ltd. Tel., 0171-924 3334.

Graphing for *Mathcad 6.0*. The acquisition of the *Axum* graphics and analysis software by *Mathcad* publishers MathSoft now allows the integration of the two packages to provide drag-and-drop graphs, including 3-D surface mesh, linear and non-linear curve-fitting, automatic error bars and colour-filled contours, in *Mathcad* and any OLE 2-compliant application, to publication quality. Both *Mathcad Plus 6.0* and *Mathcad 6.0* standard edition now come with an *Axum* link and there is a patch disk for existing users. Adept Scientific Micro Systems Ltd. Tel., 01462 480055; fax, 01462 480213. ■

Designing reliable

In this second article*, Ray Fautley runs through the steps necessary to design a reliable half-wave rectifier psu.

Ray's first article, in the September issue, ran through design steps for a full-wave bridge rectifier.

In the conventional half-wave rectifier, alternating voltage is applied to diode *D*, where it is rectified and the output smoothed by the reservoir capacitor *C*. The fundamental frequency of the ripple voltage is the same as the supply frequency, **Fig. 1**.

The half-wave rectifier is mainly used for low-current supplies. This is because the dc load current flows through the mains transformer secondary winding. If this current is too high, it can produce saturation of the transformer core. This current thus lowers transformer efficiency.

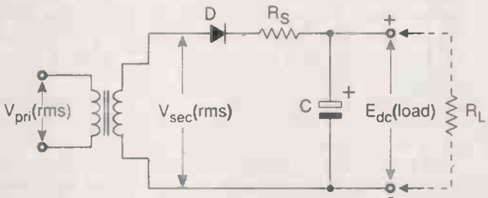


Fig. 1. The conventional half-wave rectifier is simple and useful in that it has a low component count. It is however inefficient, only suitable for low current loads and ripple is 50Hz, not 100Hz as is the case for full-wave rectifiers.

Table 1. Using the percentage ripple voltage to find value X.

V_r%	R_S/R_L% 0.1	0.3	1.0	3.0	5.0	10	30
0.1	1783	1748	1632	1602	1573	1502	1342
0.2	855	844	807	791	776	739	654
0.3	565	556	525	515	505	481	432
0.4	422	404	392	386	379	364	322
0.5	334	330	315	305	303	288	258
0.6	278	274	261	257	253	243	216
0.7	241	236	221	219	216	211	186
0.8	206	203	193	190	187	180	163
0.9	186	183	171	168	166	160	145
1.0	164	159	155	152	150	144	131
2.0	81	80	76	75	74	72	66
3.0	53	52	50	49	49	47	43
4.0	40	39	37	37	37	36	33
5.0	32	31	30	29	29	28	26
6.0	26	25	25	24	23	23	22
7.0	22	21	21	20	20	20	19
8.0	19	18	18	17	17	17	16
9.0	17	16	16	15	15	15	14
10	15	15	15	14	14	14	13
20	7.6	7.4	7.2	7.0	6.9	6.8	6.3
30	5.0	4.9	4.7	4.6	4.5	4.5	4.1
40	3.6	3.5	3.5	3.4	3.3	3.3	3.0
50	2.8	2.7	2.7	2.6	2.5	2.5	2.3
60	2.2	2.1	2.1	2.0	2.0	2.0	1.8
70	1.8	1.7	1.7	1.6	1.6	1.6	1.4
80	1.4	1.4	1.4	1.3	1.3	1.3	1.1
90	1.2	1.1	1.1	1.1	1.1	1.1	0.9
100	1.0	1.0	0.9	0.9	0.9	0.9	0.8

Design steps for a half-wave rectifier

1) Specify required dc output voltage at full load $E_{dc(load)}$ (V).
2) Specify required maximum load current $I_{dc(load)}$ (A)
3) Specify maximum ripple acceptable $V_{r(rms)}$ (V)
4) Specify the ac mains supply voltage $V_{pri(rms)}$ (V)
5) Specify the frequency of the ac mains supply f (Hz)
6) Determine the value of the equivalent load resistance R_L:
   $R_L=E_{dc}/I_{dc}$
   where E_{dc} is the design value of the dc output voltage. This is the voltage across the load $E_{dc(load)}$ added to the voltage drop across the rectifier diode:
   $E_{dc}=E_{dc(load)}+V_{rec}$
   and V_{rec} is the 0.9V drop across the rectifier diode.
   So:
   $$R_L = \frac{E_{dc(load)}+0.9}{I_{dc(load)}}$$
7) Determine the average current through the diode, I_o. As all the current must flow through the diode:
   $I_o=I_{dc(load)}$.
8) Determine a value for the source resistance of the supply, R_s. As only low current supplies are being considered the

rectifiers

resistance of the transformer windings will predominate. Thus: $R_s = R_{sec} + R_{pri}/N^2$ If the transformer winding resistances are not known, assume that R_s is about 5% of R_L. Then: $R_s = R_L \times 5/100$.

9) Calculate the ratio of R_s to R_L as a percentage: $R_s/R_L \times 100\% = 5\%$, as assumed in (8).

10) Determine percentage ripple voltage from the specified maximum ripple voltage and the dc output voltage: $V_r\% = V_{r(rms)}/E_{dc(load)} \times 100\%$

11) From **Table 1**, determine the value of X required to provide the percentage ripple voltage, $V_r\%$ in (10) above, for $R_s/R_L\%$ calculated in (9). If the figures for $V_r\%$ and $R_s/R_L\%$ are not exactly the same as those found in the table headings, then the required value for X must be interpolated as described in (11) for the bridge-rectifier design procedure (September issue).

12) Calculate the value of the reservoir capacitor C, required to provide the ripple voltage $V_{r(rms)}$ from:

$$C = \frac{X}{2\pi f \times R_L} \times 10^6 \mu F$$

13) Find the nearest standard value for the reservoir capacitor C, close to or preferably just above, the value calculated in (12). If the value is different from that in (12), call it C_1 and determine a new value for X (call it X_1) from: $X_1 = 2\pi f R_L C_1$, with C_1 in µF:

$$X_1 = \frac{2\pi f R_L C_1}{10^6}$$

14) From **Table 2**,determine the value of Y for X in (11), or X_1 in (13), and $R_s/R_L\%$ in (9).

15) Determine the transformer secondary voltage $V_{sec(rms)}$ required, from the value for Y in (14):

$$V_{sec(rms)} = \frac{E_{dc}}{\sqrt{2} \times Y}$$

Table 2. Using X and R_S/R_L, find the value of Y.

X	R_S/R_L% 0.05	0.1	0.5	1.0	2	4	6	8	10	12.5	15
0.1	0.31	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.29	0.28	0.27
0.2	0.32	0.32	0.32	0.31	0.31	0.31	0.30	0.30	0.29	0.28	0.27
0.3	0.32	0.32	0.32	0.31	0.31	0.31	0.30	0.30	0.30	0.29	0.28
0.4	0.32	0.32	0.32	0.32	0.32	0.32	0.31	0.31	0.30	0.30	0.29
0.5	0.33	0.33	0.33	0.33	0.33	0.32	0.31	0.31	0.30	0.30	0.29
0.6	0.34	0.34	0.34	0.34	0.33	0.33	0.32	0.32	0.31	0.30	0.30
0.7	0.35	0.35	0.35	0.34	0.34	0.34	0.33	0.33	0.32	0.31	0.31
0.8	0.36	0.36	0.36	0.35	0.35	0.35	0.34	0.33	0.32	0.31	0.31
0.9	0.37	0.37	0.37	0.36	0.36	0.36	0.35	0.34	0.34	0.33	0.32
1.0	0.38	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.35	0.34	0.33
1.5	0.44	0.44	0.44	0.43	0.43	0.42	0.41	0.40	0.39	0.38	0.37
2.0	0.49	0.49	0.48	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.41
2.5	0.54	0.54	0.53	0.53	0.52	0.50	0.49	0.48	0.47	0.46	0.44
3.0	0.57	0.57	0.57	0.56	0.56	0.55	0.54	0.53	0.51	0.49	0.47
4.0	0.63	0.63	0.62	0.61	0.60	0.59	0.58	0.57	0.55	0.53	0.50
5.0	0.68	0.68	0.67	0.66	0.65	0.63	0.62	0.59	0.57	0.55	0.52
6.0	0.71	0.71	0.70	0.70	0.69	0.67	0.64	0.61	0.59	0.56	0.53
7.0	0.74	0.74	0.73	0.73	0.71	0.69	0.66	0.62	0.60	0.57	0.54
8.0	0.77	0.77	0.76	0.75	0.75	0.70	0.67	0.63	0.60	0.57	0.54
9.0	0.79	0.79	0.78	0.77	0.76	0.71	0.68	0.64	0.61	0.58	0.55
10	0.80	0.80	0.79	0.78	0.77	0.72	0.69	0.65	0.61	0.59	0.55
15	0.86	0.85	0.84	0.82	0.80	0.74	0.70	0.67	0.63	0.59	0.56
20	0.89	0.88	0.87	0.85	0.82	0.76	0.71	0.68	0.64	0.60	0.57
25	0.91	0.90	0.89	0.86	0.83	0.77	0.71	0.68	0.64	0.60	0.57
30	0.92	0.91	0.90	0.88	0.84	0.78	0.72	0.68	0.65	0.60	0.57
40	0.94	0.92	0.91	0.89	0.84	0.78	0.72	0.69	0.65	0.61	0.57
50	0.95	0.93	0.92	0.89	0.84	0.78	0.72	0.69	0.65	0.61	0.57
60	0.96	0.94	0.93	0.90	0.85	0.78	0.73	0.69	0.65	0.61	0.57
70	0.97	0.95	0.93	0.90	0.85	0.78	0.73	0.69	0.65	0.61	0.57
80	0.97	0.95	0.93	0.90	0.85	0.78	0.73	0.69	0.65	0.61	0.57
90	0.98	0.96	0.94	0.90	0.85	0.78	0.73	0.69	0.65	0.61	0.57
100	0.98	0.96	0.94	0.90	0.85	0.78	0.73	0.69	0.65	0.61	0.58
200	0.99	0.97	0.94	0.91	0.85	0.79	0.73	0.69	0.65	0.61	0.58
300	0.99	0.97	0.95	0.91	0.86	0.79	0.73	0.69	0.65	0.61	0.58
1000	1.00	0.98	0.95	0.91	0.86	0.79	0.73	0.69	0.65	0.61	0.58

continued over...

where $E_{dc} = E_{dc(load)} + V_{rec}$,

$$= \frac{0.707 \times E_{dc}}{Y}$$

16) Determine the peak voltage, or peak inverse voltage, that the rectifier diode must withstand. For the half-wave rectifier, the peak inverse voltage varies with the degree of load. The worst case occurs when the load is zero or very

Table 2 continued – finding the value of Y.

X	R_s/R_L% 20	25	30	35	40	50	60	70	80	90	100
0.1	0.26	0.25	0.24	0.21	0.23	0.21	0.20	0.19	0.18	0.17	0.16
0.2	0.26	0.25	0.24	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16
0.3	0.27	0.26	0.25	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16
0.4	0.27	0.26	0.25	0.25	0.24	0.22	0.21	0.20	0.18	0.17	0.16
0.5	0.28	0.27	0.25	0.25	0.24	0.22	0.21	0.20	0.18	0.17	0.16
0.6	0.29	0.27	0.26	0.26	0.25	0.23	0.22	0.21	0.19	0.18	0.17
0.7	0.29	0.28	0.26	0.26	0.25	0.23	0.22	0.21	0.19	0.18	0.17
0.8	0.30	0.28	0.27	0.26	0.25	0.23	0.22	0.21	0.19	0.18	0.17
0.9	0.31	0.29	0.28	0.27	0.26	0.24	0.22	0.21	0.19	0.18	0.17
1.0	0.32	0.30	0.28	0.27	0.26	0.24	0.23	0.21	0.19	0.18	0.17
1.5	0.35	0.33	0.31	0.30	0.29	0.26	0.24	0.22	0.20	0.19	0.18
2.0	0.38	0.36	0.34	0.32	0.31	0.28	0.25	0.24	0.22	0.20	0.19
2.5	0.41	0.38	0.36	0.34	0.32	0.30	0.26	0.25	0.23	0.21	0.20
3.0	0.43	0.40	0.38	0.36	0.34	0.32	0.28	0.26	0.24	0.22	0.21
4.0	0.46	0.42	0.40	0.38	0.36	0.33	0.29	0.27	0.25	0.23	0.21
5.0	0.48	0.44	0.41	0.39	0.37	0.33	0.30	0.27	0.25	0.24	0.22
6.0	0.49	0.45	0.42	0.40	0.37	0.34	0.30	0.28	0.26	0.24	0.22
7.0	0.49	0.45	0.42	0.40	0.38	0.34	0.30	0.28	0.26	0.24	0.22
8.0	0.50	0.46	0.43	0.40	0.38	0.34	0.30	0.28	0.26	0.24	0.22
9.0	0.50	0.46	0.43	0.40	0.38	0.34	0.30	0.28	0.26	0.24	0.22
10	0.50	0.46	0.43	0.41	0.38	0.34	0.30	0.28	0.26	0.24	0.22
15	0.50	0.47	0.43	0.41	0.38	0.34	0.30	0.28	0.26	0.24	0.22
20	0.51	0.47	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
25	0.51	0.47	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
30	0.51	0.47	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
40	0.51	0.47	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
50	0.51	0.47	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
60	0.51	0.47	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
70	0.51	0.47	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
80	0.51	0.48	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
90	0.51	0.48	0.44	0.41	0.38	0.34	0.31	0.28	0.26	0.24	0.22
100	0.51	0.48	0.44	0.41	0.39	0.34	0.31	0.28	0.26	0.24	0.22
200	0.52	0.48	0.44	0.42	0.39	0.34	0.31	0.28	0.26	0.24	0.22
300	0.52	0.48	0.45	0.42	0.39	0.35	0.31	0.28	0.26	0.24	0.22
1000	0.52	0.48	0.45	0.42	0.39	0.35	0.31	0.29	0.26	0.24	0.22

low, when:
$PIV=2\times V_{sec(peak)}=2\sqrt{2}\times V_{sec(rms)}$
$=2.828V_{sec(rms)}$

17) Find Z from **Table 3** for X in (11), or for X_1 in (13), and for R_s/R_L% in (9), where $Z=I_{(rms)}/I_o$

18) From the value of Z found in (17), determine current through the rectifier diode: $I_{(rms)}=I_o\times Z$

19) Determine recurrent peak current $I_{(peak)}$ through the diode, from **Table 4** for X (or X_1) and for R_s/R_L% find W, which is $I_{(peak)}/I_o$. Thus find $I_{(peak)}=I_o\times W$.

20) Determine the initial switch-on current I_{on}. As C (or C_1) will be initially discharged, load on the rectifier diode will be nearly a short-circuit at the instant of switch-on, limited only by the source resistance R_s. Then:
$I_{on}=V_{sec(peak)}/R_s$ and
$V_{sec(peak)}=\sqrt{2}\times V_{sec(rms)}$
where $V_{sec(rms)}$ was found in (15). This very high current flows for only a very short time, but the rectifier diode must be capable of withstanding it. If a suitable device with such a high pulse current rating is not available, the source resistance R_s must be increased by adding an external resistor R_{ext} between the rectifier and reservoir capacitor C or C_1. The value of R_{ext} to limit the switch-on current to an acceptable lower value $I_{on(L)}$, is determined in (28).

21) Decide on a suitable rectifier diode type. The device must have ratings equal to, or greater than, the following: PIV or $2V_{sec(peak)}$, sometimes called V_{RRM}, see (16); initial switch-on current or I_{on}, sometimes I_{FSM}, see (20); average current or I_o, sometimes $I_{F(AV)}$, see (7).

22) Determine the rms ripple current $I_{c(rms)}$ flowing through the reservoir capacitor C (or C_1):

$$I_{c(rms)} = \sqrt{I_{rms}^2 - I_{dc(load)}^2}$$

23) Decide on the specification for the reservoir capacitor to be used. The capacitor must have ratings equal to, or greater than, the following: Capacitance C or C_1, see(12) or (13); dc working voltage $V_{sec(peak)}$, see (16); ripple current $I_{c(rms)}$, see (22).

24) Total transformer secondary current $I_{t(rms)}$ is the same as the current through the diode: $I_{t(rms)}=I_{(rms)}$

25) Transformer volt-amp, or VA, rating T_{VA} decides size of the transformer: $T_{VA}=V_{sec(rms)}\times I_{t(rms)}$

26) Transformer requirements:
volt-amp rating T_{VA} (25)
primary winding $V_{pri(rms)}$ (4)
secondary winding $V_{sec(rms)}$ (15)
secondary current $I_{t(rms)}$ (24)

27) When a suitable transformer has been chosen, measure resistance of both windings. If measured source resistance:

$$R_{s(m)} = R_{sec} + \frac{R_{pri}}{N^2} + R_{rec}$$

is less than R_s calculated in (8), then an external resistor of $R_{ext}=R_s-R_{s(m)}$ must be added, see (28), to limit I_{on} to the value found in (20).

28) If external resistor R_{ext} was found necessary in (20) or (27) to be fitted between the rectifier and the reservoir capacitor C or C_1 to limit the switch-on current to $I_{on(L)}$, its value will be:

$$R_{ext} = \frac{V_{sec(pk)}}{I_{on(L)}} - R_s$$

29) Power P_r dissipated in R_{ext} (if used) is given by: $P_r=(I_{t(rms)}^2)\times R_{ext}$. A suitable resistor should have a power rating of about twice the value of P_r for reliable operation.

30) If external resistor R_{ext} is used, regulation of the supply can be improved by adding a shorting-out device as recommended for the bridge rectifier circuit in Figs. 2 and 3 of my first article.

A worked example

Here is a worked example for a half-wave rectifier design to be used as a bias supply of 100V at 10mA.

1) $E_{dc(load)}=100V$
2) $I_{dc(load)}=10mA$
3) $V_{r(rms)}=1.0V_{rms}$
4) $V_{pri(rms)}=240V_{rms}$
5) $f=50Hz$
6) $R_L=E_{dc}/I_{dc(load)}$
where $E_{dc}=E_{dc(load)}+V_{rec}$
$=100+0.9=100.9V$
so $R_L=100.9/10\times10^{-3}=100.9\times10^3/10$
$=10{,}090\Omega$ or $10.09k\Omega$
7) $I_o=I_{dc(load)}=10mA$
8) $R_s=R_L\times5/100=10.09\times10^3\times5/100$
$=504.5\Omega$
9) $R_s\times100/R_L\%=504.5\times100/10.09\times10^3\%$
$=5\%$
10) $V_r\%=V_{r(rms)}\times100/E_{dc(load)}\%$

Table 3. Find value Z here to determine current through the rectifier.

X	R_S/R_L% 0.02	0.05	0.1	0.2	0.5	1.0	2	5	10	30	100
1	1.80	1.80	1.79	1.79	1.79	1.78	1.77	1.77	1.73	1.70	1.66
2	2.03	2.02	2.01	2.00	1.99	1.98	1.97	1.96	1.89	1.77	1.67
3	2.19	2.17	2.16	2.14	2.13	2.11	2.10	2.03	1.95	1.79	1.67
4	2.32	2.30	2.28	2.26	2.24	2.22	2.17	2.08	1.98	1.80	1.68
5	2.43	2.40	2.36	2.32	2.27	2.23	2.19	2.10	2.01	1.82	1.68
6	2.50	2.48	2.46	2.44	2.42	2.40	2.28	2.13	2.04	1.83	1.68
7	2.58	2.53	2.51	2.49	2.47	2.45	2.31	2.16	2.05	1.84	1.68
8	2.66	2.63	2.61	2.60	2.58	2.50	2.35	2.17	2.06	1.84	1.68
9	2.73	2.70	2.68	2.66	2.64	2.57	2.38	2.18	2.07	1.85	1.68
10	2.80	2.78	2.75	2.73	2.70	2.62	2.40	2.19	2.08	1.86	1.68
20	3.30	3.20	3.17	3.15	2.83	2.82	2.53	2.26	2.12	1.88	1.68
30	3.64	3.50	3.40	3.29	3.05	2.89	2.59	2.30	2.15	1.90	1.68
40	3.91	3.72	3.55	3.40	3.13	2.92	2.62	2.32	2.16	1.90	1.68
50	4.08	3.87	3.68	3.48	3.22	2.93	2.64	2.33	2.17	1.91	1.68
60	4.23	3.97	3.78	3.55	3.25	2.94	2.66	2.35	2.18	1.91	1.68
70	4.35	4.03	3.87	3.60	3.27	2.95	2.67	2.36	2.18	1.91	1.68
80	4.45	4.10	3.94	3.65	3.30	2.96	2.68	2.36	2.18	1.91	1.68
90	4.52	4.18	3.98	3.67	3.31	2.97	2.68	2.37	2.19	1.91	1.68
100	4.62	4.23	4.02	3.69	3.32	2.98	2.69	2.37	2.19	1.91	1.68
200	5.03	4.60	4.27	3.86	3.37	2.99	2.69	2.38	2.19	1.91	1.68
300	5.20	4.79	4.33	3.88	3.38	3.00	2.69	2.38	2.19	1.91	1.68
400	5.35	4.86	4.37	3.88	3.38	3.00	2.70	2.38	2.19	1.91	1.68
500	5.45	4.90	4.38	3.89	3.38	3.00	2.70	2.39	2.19	1.91	1.68
600	5.51	4.93	4.38	3.89	3.39	3.00	2.70	2.39	2.19	1.91	1.68
700	5.60	4.96	4.39	3.90	3.39	3.01	2.70	2.39	2.19	1.91	1.68
800	5.67	4.98	4.39	3.90	3.39	3.01	2.70	2.39	2.19	1.91	1.68
900	5.70	4.99	4.39	3.90	3.39	3.01	2.70	2.39	2.19	1.91	1.68
1000	5.75	5.00	4.39	3.90	3.39	3.01	2.70	2.39	2.19	1.91	1.68

Table 4. Value W is needed to find peak current.

X	R_S/R_L% 0.02	0.05	0.1	0.2	0.5	1.0	2	5	10	30	100
1	3.70	3.70	3.70	3.64	3.62	3.60	3.60	3.59	3.58	3.57	3.46
2	4.60	4.57	4.55	4.53	4.52	4.50	4.28	4.20	4.08	3.72	3.51
3	5.50	5.40	5.33	5.30	5.20	5.10	5.00	4.67	4.33	4.00	3.55
4	6.20	6.17	6.13	6.10	6.00	5.98	5.45	5.20	4.95	4.05	3.57
5	7.30	6.95	6.90	6.85	6.80	6.75	6.51	5.60	5.00	4.10	3.62
6	8.00	7.90	7.70	7.60	7.50	7.30	6.90	5.84	5.09	4.19	3.63
7	8.70	8.55	8.50	8.30	8.10	7.82	7.30	6.00	5.10	4.22	3.64
8	9.60	9.50	9.35	9.00	8.50	8.20	7.69	6.15	5.14	4.23	3.64
9	10.3	9.80	9.60	9.50	9.10	8.55	7.72	6.23	5.21	4.25	3.65
10	10.9	10.7	10.5	10.1	9.50	8.64	7.74	6.30	5.28	4.26	3.66
20	16.0	15.0	14.4	13.0	11.1	9.44	7.83	6.47	5.29	4.27	3.66
30	19.7	18.0	16.3	14.3	11.7	9.60	7.92	6.50	5.31	4.27	3.66
40	21.9	20.0	17.3	14.7	12.1	9.64	8.01	6.51	5.33	4.28	3.66
50	23.7	20.8	18.2	15.2	12.2	9.70	8.10	6.51	5.34	4.28	3.66
60	24.9	21.1	18.5	15.4	12.3	9.77	8.12	6.51	5.34	4.29	3.66
70	25.9	21.4	18.9	15.6	12.4	9.84	8.14	6.51	5.34	4.29	3.66
80	26.7	21.8	19.4	15.7	12.4	9.90	8.16	6.51	5.34	4.30	3.66
90	27.5	22.2	19.5	15.8	12.5	9.93	8.18	6.51	5.34	4.30	3.66
100	28.5	22.5	19.7	15.9	12.5	9.96	8.19	6.52	5.35	4.31	3.66
200	30.5	23.0	20.0	16.3	12.6	10.0	8.19	6.52	5.36	4.31	3.67
300	31.6	23.3	20.5	16.9	12.7	10.0	8.20	6.53	5.38	4.32	3.67
400	32.8	23.5	20.9	17.0	12.7	10.0	8.20	6.54	5.40	4.32	3.67
500	33.3	23.8	21.0	17.1	12.8	10.0	8.20	6.55	5.42	4.33	3.68
600	33.8	24.0	21.1	17.2	12.8	10.1	8.20	6.56	5.44	4.33	3.68
700	34.2	24.5	21.2	17.3	12.9	10.1	8.20	6.57	5.46	4.33	3.69
800	34.4	24.9	21.4	17.4	12.9	10.1	8.20	6.58	5.48	4.33	3.69
900	34.5	25.8	21.5	17.5	13.0	10.1	8.20	6.59	5.52	4.33	3.70
1000	34.7	27.0	21.6	17.6	13.0	10.1	8.20	6.60	5.56	4.33	3.70

$=1\times100/100\%=1.0\%$

11) Value of X for $V_r\%$ and for $R_s/R_L\%$ i.e. $V_r\%=1.0$ and $R_s/R_L\%=5.0$ from Table 1 is found to be 150.

12) $C=X/2\pi f\times R_L\times10^6\mu F$
$=150\times10^6/2\pi\times50\times10.09\times10^3\mu F$
$=47.3\mu F$

13) 47μF is a standard value for an electrolytic capacitor and would be a suitable choice.

14) The value of Y for X and for $R_s/R_L\%$ i.e. $X=150$ and $R_s/R_L\%=5.0$. from Table 2 is found to be 0.76

15) $V_{sec(rms)}=E_{dc}/\sqrt{2}\times Y=100.9/\sqrt{2}\times0.76$
$=93.9V$

16) $PIV=2.828V_{sec(rms)}=2.828\times93.9=266V$

17) The value of Z for X and for $R_s/R_L\%$ i.e. $X=150$ and $R_s/R_L\%=5.0$ from Table 3 is found to be 2.375

18) $I_{(rms)}=I_o\times Z$
i.e. $Z=2.375$ and $I_o=10mA$ (see (7))
$=10\times10^{-3}\times2.375=0.02375A$ or 23.75mA

19) The value of W for X and $R_s/R_L\%$ i.e. $X=150$ and $R_s/R_L\%=5.0$ from Table 4 is found to be 6.52 and so:
$I_{(peak)}=I_o\times W=10\times10^{-3}\times6.52$
$=0.0652A$ or 65.2mA.

20) $I_{on}=V_{sec(peak)}/R_s=\sqrt{2}\times V_{sec(rms)}/R_s$
$=\sqrt{2}\times93.9/504.5=0.263A$ or 263mA

21) Diode ratings required:
PIV (or V_{RRM})=266V
I_{on} (or I_{FSM})=263mA
I_o (or $I_{F(AV)}$=10mA

22)

$$I_{c(rms)}=\sqrt{I^2_{(rms)}-I^2_{dc(load)}}$$
$$=\sqrt{23.75^2-10^2}=\sqrt{564-100}$$
$$=\sqrt{464}=21.54$$

Both $I_{(rms)}$ and $I_{dc(load)}$ are in mA.

23) Reservoir capacitor ratings required:
$C=47\mu F$
$V_{sec(peak)}=V_{DC(wkg)}=\sqrt{2}\times V_{sec(rms)}$
$=\sqrt{2}\times93.9=132.7V$
$I_{c(rms)}=21.54mA$

24) $I_{t(rms)}=I_{(rms)}=23.75mA$

25) $T_{VA}=V_{sec(rms)}\times I_{t(rms)}$
$=93.5(23.75\times10^{-3})=2.22VA$

26) Mains transformer ratings required:
T_{VA} VA = 2.22VA
$V_{pri(rms)}$ primary winding = $240V_{rms}$
$V_{sec(rms)}$ secondary winding = 93.9V rms
$I_{t(rms)}$ secondary current = 23.75mA rms

In a subsequent article, Ray will describe the steps needed for designing full-wave centre-tapped rectifier circuits. The September issue contained the procedure for full-wave bridge rectifiers. ■

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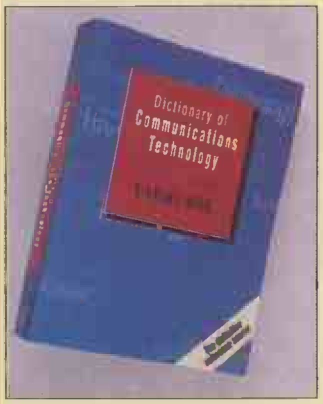

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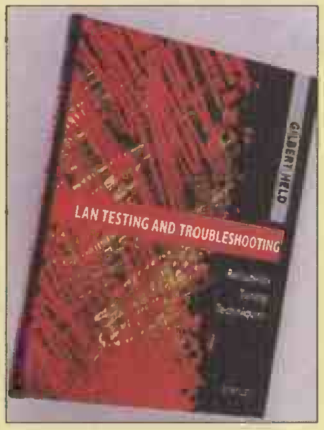

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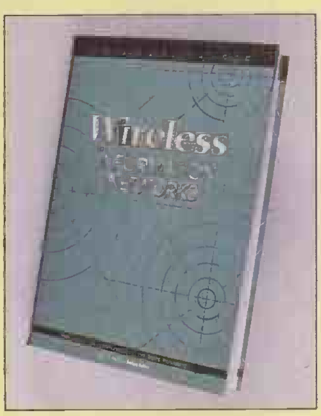

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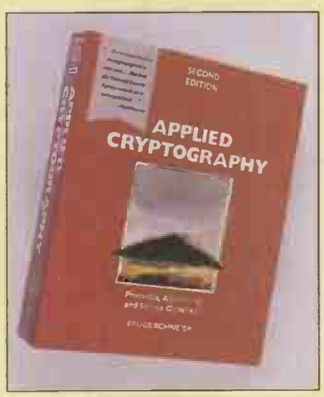

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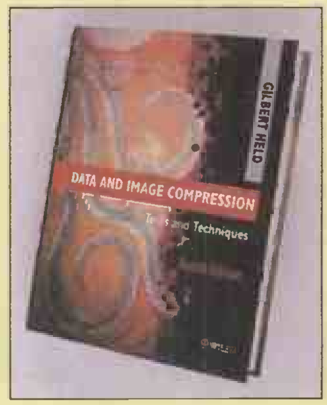

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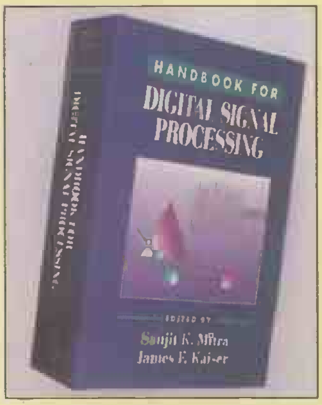

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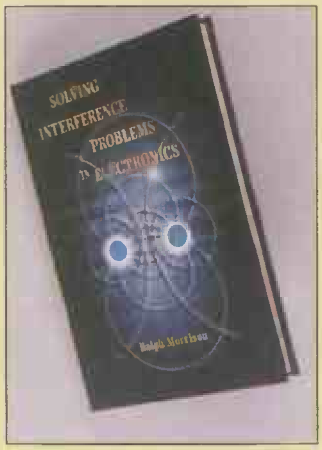

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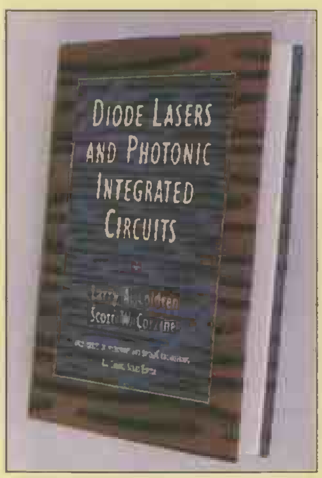

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LETTERS

Letters to "Electronics World"
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Music in Mind

In response to Ian Hickman's challenge in the October 1996 issue, as to why his gyroscope headphone system did not work on stereo, I offer the following thoughts.

Firstly, there is more to head movement than just delay shift. The acoustic signal reaching the ear is turned toward the sound source is increased in level at high frequencies, while the other ear receives less high frequency. This is due to the head attenuating the directional signal.

Secondly, and perhaps more importantly, is that classical recordings are made for reproduction on loudspeaker systems. In stereo, two techniques for obtaining the stereophonic effect exist: intensity differencing and time differencing. If the signal from the left speaker arrives at the ear earlier than the signal from the right speaker, the apparent source location is shifted to the left. For a source to be perceived to be entirely at the left or right, quite large time differences are needed.

In practice, it appears that stereo through time differences gives a more widespread – and often more pleasing – stereo sound on loudspeakers than does intensity stereo. Also, the omnidirectional microphones suitable for this technique are superior. As a result, most classical music recordings use time-difference stereo.

The microphones are spaced about a meter or so apart, giving spatial cues containing time differences of up to 3ms between the left and right speaker. As you can imagine, adding some 150μs extra delay to this difference to obtain an in-front localisation on head phones, as Ian did in his experiment, would not have a noticeable effect.

If this theory is right, there should be a solution. Try listening to a stereo recording with intensity differences solely. I think that recordings from Nimbus would demonstrate this. The clue is to look for recordings that are made using coincidental, or nearly coincidental, microphone techniques. Maybe a special artificial head-recording would do.

It would be interesting to see whether this theory gives any result.

Eelco Grimm
Editor
Pro-Audio Magazine

Congratulations to Ian Hickman for his attempts at correcting for head rotation with headphone listening. The use of the piezo-vibrating gyroscope is a worthwhile contribution.

However, the parameters under control are inadequate and I suggest are the reason why sound sources remain stubbornly localised within the head.

The secret of auralisation with headphones is the accuracy to which the required signals can be reconstructed at the entrance to the ear canal, to match those produced by a real-life source. It is well known that an external sound source will have two associated transfer functions between the source and each ear. These are called the head related transfer functions, or hrtfs.

Each point in space has a unique pair of hrtfs (one for each ear) with respect to head orientation. The transfer functions are influenced by the head shape, pinna geometry and, to a lesser extent, the effect of the torso. Even more frustrating is that each listener will have a unique set of transfer functions, although fortunately there is some degree of commonality between listeners, though head size can play a role too.

When the head rotates with respect to an external point source, the transfer functions change dynamically. Any system that is intended to recreate the correct ear signals must therefore include a knowledge of these filters and an ability to process them dynamically. Computing purely on a basis of amplitude and time differentials is insufficient to recreate accurate out-of-head spatialisation. This also implies that information that is encoded using normal stereo will not readily be amenable to such processing. Binaural sources obviously have an advantage, but when the head moves the signals are so interwoven that they cannot accurately be processed into their correct perspective, although better results should in theory be possible.

Mr Hickman, however, should not feel too disheartened. I have heard several systems claiming to do this with low-cost electronics, some using multiple drive unit headphones, and all have failed to impress. The only system (for me) so far to work using an orientation measurement was demonstrated to me by Dr Mike Hollier at British Telecom Research Laboratory.

The system used the 'Huron' manufactured by Lake, which is a digital filter costing £60,000 or so and capable of very long impulse responses that can be controlled dynamically. The system incorporates a set of hrtfs and a positional sensor is located on the headphones. Listening in real time to a person talking into a microphone, and rotating my head, an external image was perceived that was localised accurately within the room's frame of reference.

Note, however, that the Huron is a bit of overkill in this application. Its power is intended to incorporate the long impulse responses that are encountered when simulating a large acoustic environment where the aim is to be able to move around within an artificially created space. That is the acoustic wing of virtual reality.

So, any working system must use real-time dsp and include accurate hrtf data. It must also use appropriate headphones, preferably feeding directly into the ear canal as there can be significant errors introduced into the hrtfs due to the vague coupling between headphone and ear canal. Multiple drive units within headphones do not solve this particular problem. Sometimes a slight adjustment of the headphone can compromise the whole system by differentially changing the left- ear and right-ear hrtfs.

Prof Malcolm Omar Hawksford
Director
Centre for Audio Research & Engineering
University of Essex

Anti-gravity and the aether

In *EW* May 1996, p. 429, Dr. David Fisher advised you to "double-check the work of anyone who is known to believe in dowsing, ball lightning, 'free energy' and/or anti-gravity." He fears incitement of panic.

In *EW* August 1996, p. 590, when challenged by his prey, Anthony Hopwood, Dr. Fisher stated that in fact he was thinking of me, for my belief in this nonsense! See my article (*E&WW*, pp. 29-31, 1989).

I have not written anything on the subject of dowsing and am now wondering if Dr. Fisher has conveyed similar advice to the editor of the *Sunday Telegraph* who reported in the 1 September 1996 issue, a breakthrough in antigravity. The report concerns research at Tampere University of Technology in Finland and declares that objects on every floor of the laboratory that were positioned directly above the anti-gravity machine lost some weight when the machine on the lower floor was set spinning.

I believe that this is because the flywheel was developing spin-off owing to precessional motion in globules of aether, a weak version of thunderballs, which rose through the intervening floors. Why this causes a loss of weight is explained in my paper 'The Theory of Anti-Gravity' in Physics Essays, (Vol. 4, pp. 13-19; 1991).

Readers of *Electronics World* do not panic when there is noise in their radio reception; they just seek to understand the cause. However, maybe NASA might panic when faced with the dilemma of having anti-gravity space travel technology at the price of making radio communication incoherent.

Whether one induces that aether precession by magnets acting on superconductive flywheels or mechanically as in Laithwaite's faster-than-natural precession of an offset flywheel, those aetherial eddies have the power to reduce the weight of matter they occupy. They also affect the speed of light.

There is some evidence that they are produced by earthquakes because they seem to affect fm signals but not am signals. See 'Earthquake-Related EM Disturbances', *Quarterly Journal of the Royal Astronomical Society*, Vol. 28,535536 (1987).

Harold Aspden
Chilworth, Hampshire

Victoria listened in too

Tom Ivall's article on Marconi's patent of 1896 characterises the era by commenting: "Queen Victoria was still on the throne". But she was

far from being a passive observer of events. Two years later, in the summer of 1898, she was buying "wireless sets".

Edward Prince of Wales, convalescing after a knee injury, elected to spend some weeks aboard the Royal Yacht, which was moored two miles away in Cowes bay, discreetly out of sight of Osborne.

The 80-year old Queen-Empress determined to have some easy means of communication with him. Never one to overlook the latest technology, she commissioned Marconi to install wireless telegraphy apparatus. This was done, and a 100-foot aerial was erected in the grounds of Osborne; a similar affair with a somewhat smaller aerial was provided aboard the Royal Yacht.

The resulting traffic was irredeemably trivial, being mainly on the "when are you coming to dinner?" level, though some sea trials were also carried out.

But: "The Prince of Wales and other Royalties gave expression to Mr. Marconi of their high appreciation of his system... " (*Electrical Review*). The publicity was immensely useful to the infant Marconi Company.

This incident, and much more fascinating material too, may be found in W.P. Jolly's biography of Marconi (Constable, London, 1972).

Ashby Tabb
Taunton, Somerset

Thermal compensation: why bother?

Of course if the only circuits available for Class B complementary pair use were the standard ones such as those shown in Fig. 6 of Douglas Self's 'Night thoughts on crossover distortion', *EW* Nov. 1996, it would fully justify not just the article itself, but all his preceding articles.

As I have shown in 1982, (Class S, *Wireless World*, Sep. 1982) there another way.

Quite simply, using this legally protected circuit, crossover distortion is hard to measure and the circuit needs no setting up. It is tolerant of ageing and temperature effects. As a bonus it also has lower large signal distortion.

Why is this? Referring to page 793 of this magazine for October 1996, the output impedance of the voltage amplifier A_1 is very low, ideally zero. This forms a heavy attenuator when combined with the upper 22Ω resistor for any distortion generated by the push-pull power stage A_2 and its transistors.

This attenuation holds just as well for low value cross over voltages as for large value amplitudes. All A_2 and its components do is provide, ideally, the load current, leaving A_1 to provide very little current while seeing a high impedance load.

Because A_1 sees for most of the time this high impedance load and only for a few millivolts of excursion (in the crossover region) has to drive the real low impedance load, which it can easily do, the net result is an amplifier with excellent performance and a clear method of operation.

Finally, apologies for the trumpet blowing but it is partly the result of exasperation and partly the result of needing the publicity in order to obtain work.

Aubrey Sandman
London

Feedback feedback please

Having built two new power amps and then found out that in use their gain was about 12dB too much, I shuddered at the thought of all the work involved to redesign for the lower gain. I thought for the umpteenth time that there must be a simpler way, like using low gain linear stages with little or no overall negative feedback.

I was happy with the output stage, **Fig. 1**, which is a fet version of the Texas Instruments Texan amplifier and has been described in *EW+WW*, April and September 1990. It needed a bit of experimentation with R_1 to get equal positive and negative half cycles, open loop, but that is all it needs.

Applying negative feedback to give a gain of four, the stage has quite a reasonable performance, except that the output impedance is about 1Ω. Also, when loaded, the stage distorts because there is nothing to increase the drive. I tried all sorts of comparators to apply feedback only when there was a difference between output and input, but none worked effectively.

I was about to give in when I came across a reference to an error cancelling technique by Hawksford in the *Siliconix Mospower Applications Handbook* (Application 6.6.3). **Figure 2** gives the theory and **Fig. 3** the way I applied it. Having got the gains right, the results were astounding.

If the gain from P-R-Q to P is less than unity, Z_o will have some small value. If the gain is unity, Z_o will be close to zero. If the gain is slightly greater than unity, Z_o will have a negative resistance characteristic. The gain from P-S-Q-P must be the reciprocal of the closed-loop gain of the corrected amplifier.

During testing, it was found that a capacitive load of more than 22nF caused a high output at high frequency. This was a surprise as the output stage itself would happily drive a 10μF at 1kHz. More experimenting gave the feeling that this was not parasitic oscillation, but rather amplified and filtered noise. While loading the output with increasing values of capacitor, the output of A_1 became increasingly noisy until it burst into oscillation at about 2MHz. Putting a small capacitor across R_8 (A_1) stopped the oscillation but was not the best place as only the error signal was being filtered. The best solution was a 22pF across R_{12} (A_2) to filter signal and error. The amplifier now drives 10μF with no problem.

The only explanation I can give at the moment is that a capacitor across the output filters out high frequency noise at that point (22nF=3R6 at 2MHz). This would mean that the noise at S would not be cancelled in A_1 by noise from P and would be fed back as a signal. I am not entirely happy with that idea since there is not much noise at those points anyway. Resistor R_{15} is chosen to give required gain.

I would welcome your comments on this technique.

K H Ellis
Wolverhampton
England

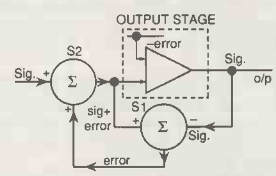


Fig. 2. Hawksford's error-cancelling technique. Output stage has –error signal added to it. Input signal has +error added to it and so cancels the error out. S_1 creates the error signal.

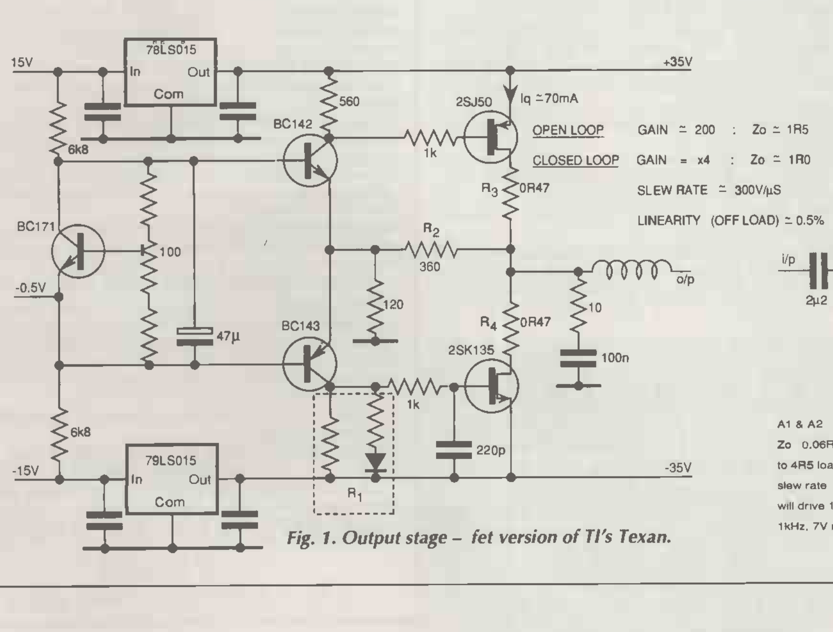
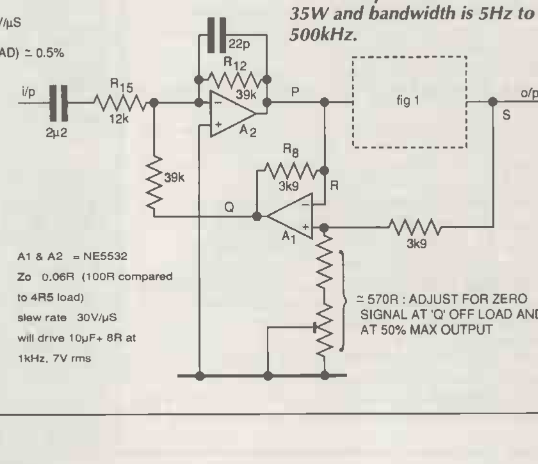


Fig. 1. Output stage – fet version of TI's Texan.

Fig. 3. Application of Hawksford's error-cancelling technique. Gain is 12, maximum power into 4.5Ω is 35W and bandwidth is 5Hz to 500kHz.



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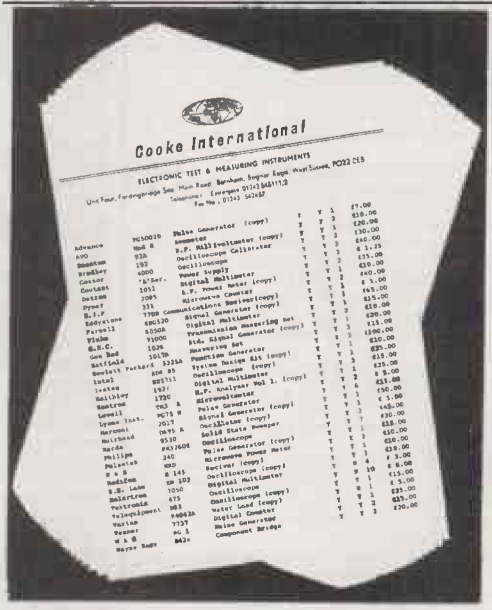

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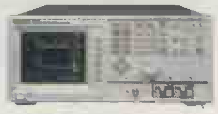

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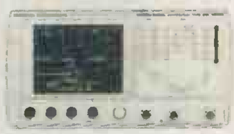

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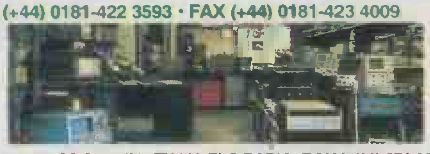

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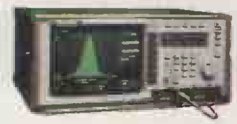
PHILIPS PM5167 1mHz-10MHz function generator	£275
RACAL-DANA 9300 milli-voltmeter	£400
RACAL-DANA 9301A true RMS RF milli-voltmeter	£350
SCHLUMBERGER 7081 precision voltmeter 8.5 digits	£2750
TEKTRONIX P6201 FET PROBE	£350
WANDEL & GOLTERMANN WM30 level tracer	£500
WANDEL & GOLTERMANN PJM-4S jitter meter for SONET & SDH	£5500
WAVETEK 23 synthesized function generator 0.01Hz-12MHz	£1250
WAVETEK 1067 opt 522 1-500MHz sweep generator	£500
WAYNE KERR 3220 20A bias unit (for 3245 inductance analyser)	£1250
TEKTRONIX AM503/P6303 current probe	£1500

HEWLETT PACKARD



1640B serial data generator	£500
3764A digital transmission analyser	£1500
3335A synthesizer/level generator	£2000
3235A switch/test unit	£1000
3324A synthesized function generator	£2000
33320G/33322G programmable attenuators 4GHz, with driver 11713A	£1000
As above but 18GHz set	£1500
3581C selective voltmeter	£1250
3779D primay multiplex analyser	£5000
37900D signalling test set with 2 x 37915A Interface cards	£5500
4140B pA/meter, DC voltage source	£4000
4272A multi-frequency lcr meter	£3500
435B microwave power meter, analogue	£400
5386A 3GHz frequency counter	£1500
54100A 1GHz digitizing oscilloscope, now inc 2 x 1GHz active probes	£2000
54502A digital oscilloscope 400MHz 400MSa/s	£2500
8007B pulse generator 100MHz	£950
8018A serial data generator	£1000
8082A pulse generator 250MHz	£2000
8111A pulse generator 20MHz	£1250
8146A optical tdr, with options 2/3/plug-in 81465SH (single-mode)	£8500
816A slotted line 1.8-18GHz with 809C & 447B probe	£500
8444A tracking generator with option 059	£1000
86222A/8620C 10MHz-2.4GHz sweep generator	£2000
87510A gain-phase analyser 100kHz-300MHz	£6500
8753A 3GHz vector network analyser	£7500
J2215A FDDI portable multimode test set	£1500
J2219A 486-based, colour option main-frame	£1000
J2219A/J2171A 486-based colour screne option network advisor	£3000

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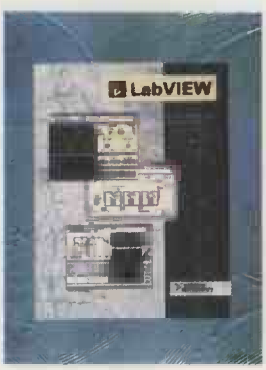

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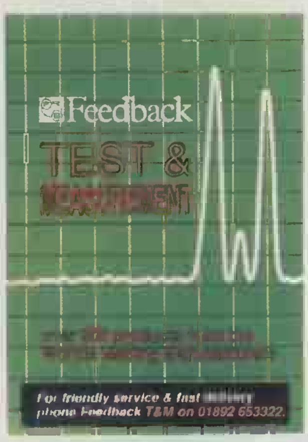

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