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Tek 496 (9KHz-1.8GHz)	£2500

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Keithley 486/487 Picoammeter (+volt.source)	£1350/£1850
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Bias unit 3220 and 3225L Cal.Coil available if required.	(P.O.A)
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W&G PFJ 8 Error and Jitter Test Set	£6500
W&G SPM 30 and SPM 31 + PS30 Level Meter + Level Oscillators	(P.O.A)
Yokogawa WT110 Digital Power Meter (single phase)	£1250
Yokogawa 2534 Digital Power Meter (single phase)	£1250
Yokogawa 2533 Digital Power Meter (three phase)	£1250

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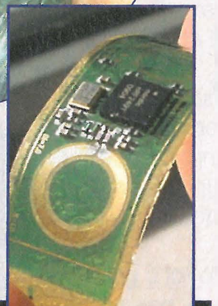


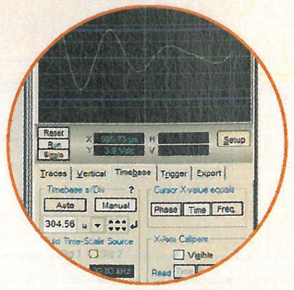
Top: Atlantis Redux appears in a new guise – p43

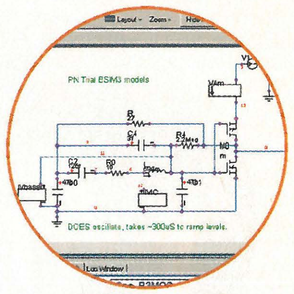
Right: Hi-tech band-aid – p5

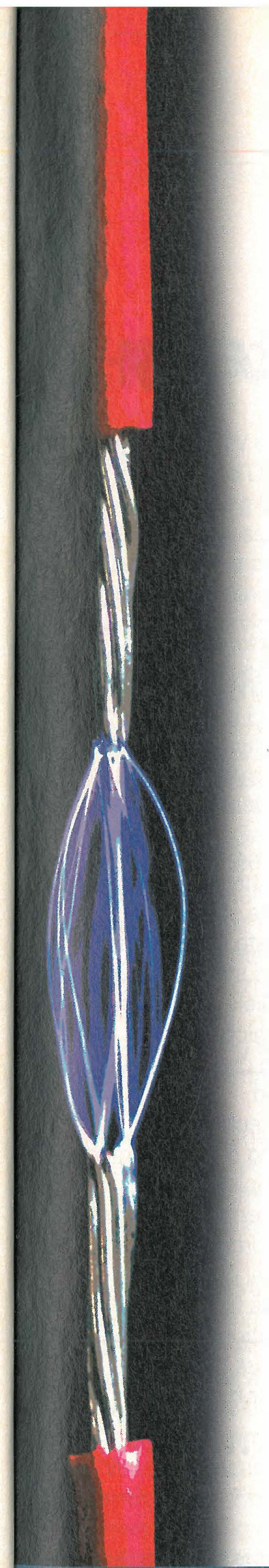
Below: Euro1080's HDTV studio – p5

Hi-tech bird-watching – p43

Front cover image is an element of the Atlantis Redux game







Old mag, new times

Many of you would probably be disappointed to read that Phil Reed has moved on to pastures new and is now an editor in the broadcasting field. However, I hope that this will give us the chance to know each other better and also change and evolve Electronics World.

The electronics market is still tough and this is reflecting on the remaining publications covering the electronics industry, including our magazine.

Despite the tough conditions, however, we remain positive about the future of this business and want to turn Electronics World into a far more interesting and informative magazine that will be appreciated much more widely.

We are adding a lot of new sections for which we might need your help.

For our *Tried and Tested* section, we would like to invite everybody who has just started using or sampling a new product, either hardware or software, to share the experience with the rest of us. We need your opinion on how well this product performs, what are the little niggling problems that you see with it, what engineers should look out for whilst using it and hints of usage if any.

We are also inviting our readers to contribute toward the new *Book Review* section. We are happy to supply technical books if you are interested in reviewing them, after which you can keep the book. No doubt many of you are already reading engineering or science books and have comments on their comprehensiveness, readability, accuracy and applicability.

A simple 'high' or 'low' assessment for its success: 'read it' or 'don't' at the end of the comment – or a rating, would give the rest of us a good idea if that particular book is a must or should be avoided.

Another reader contribution would be a *Top Tips* column that you can supply to us, whenever you have something to advise on. For example, you could give us your Top Ten Tips on Being an Engineer, or Top Tips to Engineering Students, or How to Deal with the Sales/Marketing Department, or How to Negotiate a Higher Salary, or Top Ten Tips from the Automotive Engineer on How to Drive Your Car Properly and so on. The list is endless; so let your imagination run free.

Traditionally, Electronics World has been receiving technical feature contributions from our readers – please continue to do so. In any case, we would like to continue hearing from you. Please send us your comments on how you would like to see your favourite magazine evolve and become even better.

Svetlana Josifovska
Editor

The winner of Electronics World's recent reader survey is John Worthington of Bolton, Lancashire, who wins a bottle of champagne.

We would like to thank all of the participants for their feedback, which will help us to improve and fine-tune the content of the publication to best suit our readers' needs and interests.

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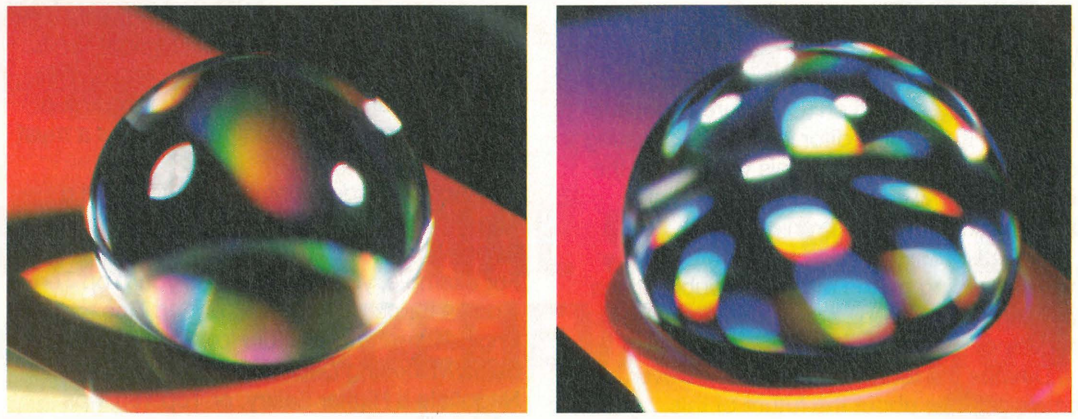
Nanograss to fuel a new battery



Left: Water forms a nearly perfect ball, suspended on the tip of tiny nanograss blades

Right: By electrically charging the surface, liquid can be driven through the nanograss, causing the ball to spread

The humble battery is getting a major capability boost thanks to a joint co-operation between Lucent Technologies and a US nanotechnology firm, mPhase.

Late in 2004, the two firms created a prototype battery based on Bell Labs's creation and manipulation of nanograss structures. The demonstration proves that it is possible to fabricate nanotechnology-based batteries that can store and generate electric current. Such batteries are promised to be lighter but with a longer life and better storage capacity than existing technologies.

"In general, improvements in battery technology have come very slowly in comparison to accelerating development cycles such as Moore's Law in semiconductors," said Dave Bishop, vice president of nanotechnology research at Bell Labs and president of the New Jersey Nanotechnology Consortium.

"We believe nanotech, specifically nanograss technology, will allow us to make a significant leap forward in battery capabilities."

mPhase will commercialise the nanobattery under license from Lucent, with a commercial model expected as soon as March 2005.

"The theory behind the nanobattery is now proven in practical terms and we are delighted to proceed with development of prototypes to meet initial customer requirements," said Ronald Durando, CEO of mPhase Technologies.

Potential initial applications include consumer electronics, defence, industrial and healthcare.

Nanograss is a specially engineered silicon surface that resembles blades of grass, only nanometers in size. In early 2004, Bell Labs discovered that liquid droplets of electrolyte stay in a dormant state atop these microscopic structures until an electric field is applied to them, by which method they can be precisely manipulated.

The new technique of manipulating fluids has many potential applications, including thermal cooling of integrated circuits for computers, novel photonic components for optical communications and miniature, low-cost "lab-on-a-chip" sensor modules.

……

IoN calls for optical partners

The UK-based Institute of Nanotechnology (IoN) is looking for partners from industry and academia to jointly develop projects involving novel optical materials.

"We are seeking technology to modify the visual/optical properties of both hydrophilic and hydrophobic surfaces," said a call from the IoN to the industry. "The technology should ideally be deliverable from a surfactant-containing aqueous medium and should be able to generate optical effects perceivable by the human eye."

Routes to modifying the optical properties of surfaces to deliver effects such as shine, brightness, light-diffusing finish and others include materials that modify the basic optical properties of surfaces, such as absorption, transmission, reflection, refraction and scattering among others; materials that impart luminescence, such as fluorescence, phosphorescence, chemiluminescence and bioluminescence; and materials that exhibit structural colour effects, for example, imparting optical effects due to microscopic surface arrangements (pearlescence, iridescence and so on).

The IoN is involved in micro and nanotechnology research that might be translated into real applications.

If interested, contact Andy Garland, head of Information at the IoN at andy@nano.org.uk .

Japanese firm Showa Denko (SDK) has developed a blue light-emitting diode (LED) based on gallium nitride (GaN) that offers what it claims is the highest level of brightness on the market. The new 12mW LED has a flip-chip structure and offers the additional advantages of low forward voltage and low electricity consumption.

SDK is now constructing a plant in Chiba to produce around 30 million of these devices per month.

HDTV finds a way to Europe

Makers of TV sets, set-top boxes and DVD players can start looking forward to a lucrative business in Europe as TV operators commit to launch high definition television (HDTV) services next year.

One such channel, Antwerp-based Euro1080, already has a successful HDTV service, transmitted over the Astra satellite since January 2004. German pay-TV provider Premiere and the French TPS satellite service hope to transmit HDTV as of 2005. The UK-based BSkyB intends to launch its HD service in 2006, with the BBC's intending to produce all of its programming in HD by 2010.

According to market analysts IMS Research, such services will significantly expand the market for HDTV sets and the accompanying recording equipment. The firm forecasts that some eight million HDTVs will be sold in Europe in 2009, accounting for almost 17% of all TV sets sold in the region.

Euro1080 regularly transmits sporting events in HDTV

"We are forecasting that the number of European homes receiving digital TV will grow from around 47 million today to 108 million in 2009," said Ian Weightman, senior VP at IMS Research. "In 2009, we predict that almost 14 million of these digital TV households will be receiving broadcast HD programming, which would represent around 7% of all European homes with a TV."

Such activities look certain to cement HDTV's future in Europe, despite a slow start. "Until recently, the future for European HD looked bleak. The removal of EU funding had effectively killed the EU-95 initiative and most of the cable operators were simply trying to survive rather than plan advanced television services. However, things have changed markedly in recent months, spurred by the successful launch of the first pan-European HD channel, Euro1080's HD1," added Weightman.

The display format for Euro1080's HDTV service is 1920 pixels x 1080 lines at 50Hz interlaced format – also known as 1080i, hence the name Euro1080.

The SES-Astra satellite provider uplinks the signal for DTH reception. The signal can be picked up on a 60cm antenna and an HD set-top box (STB).

Electronics makers like Pioneer, Panasonic, Thomson, Sony, Samsung and others already offer a range of HDTV sets and STBs.

Cable operators can also get hold of the satellite signal as a transport stream. The 18Mbps HD signal is multiplexed with other services to occupy 40Mbps in a single 7MHz channel, modulated with the QAM 256 scheme.

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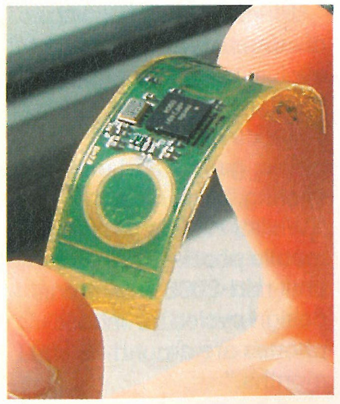


Band-aid goes hi-tech

A 'smart sticking plaster' capable of taking ECG or EEG readings from patients on the move is being developed by researchers at IMEC.

Part of the Belgian research outfit's Human++ programme, the smart plaster is 35x12mm and just 2mm thick. It contains a rechargeable battery, sensors, signal processing and a wireless link.

Taking electrocardiogram (ECG) or electroencephalogram (EEG) readings without the encumbrance of mains powered equipment removes the need for patients to remain in hospital. This reduces cost, time and stress for all involved.

Children should be taught video games in schools as it helps them to develop, recommends a research group from London University. Pupils should be encouraged to play, learn about games and even create their own as it is a "valid form of expression much like drawing and writing", said the research team. Caroline Pelletier, who is part of this team, said that computer games are a legitimate cultural form that deserves a critical analysis.

Ω

More employers in the manufacturing sector were recruiting than laying off staff over the final three months of 2004, says Manpower, the UK's workforce management company. Around 21% of manufacturing employers were looking to take on more staff over this period, compared to an average of all UK business sectors of +18%. This figure is the highest in Europe and represents a year-on-year increase of 14%.

Ω

US firm Atmel has received a £1.2m grant from the Scottish government to continue to grow its semiconductor activities in East Kilbride, Lanarkshire. Scotland's Enterprise Minister Jim Wallace discussed with senior Atmel executives the planned expansion of Atmel's facility and jobs in Scotland. Atmel has been developing and testing mainly smartcard chips in its East Kilbride plant, since it purchased it in 1999.

Ω

EU's proposals to ban the use of lead in electronic equipment is likely to worsen the industry's growing problem of maintaining expensive, long-lifespan equipment when some of their components become obsolete, says the Component Obsolescence Group (COG). "We already have problems for an increasing number of industry sectors that rely on equipment lasting for ten, 20 or even 40 years. This could be anything from an expensive medical device, to a train, an aircraft or equipment in a power plant," said Michael Trenchard, COG's chief executive.

Clock-less design goes mainstream

Synchronous ICs – the dominant design style in the chip industry – are set to be challenged by UK processor firm ARM.

The embedded processor specialist is to produce its first commercial asynchronous, or clock-less, MPU.

The concept of asynchronous hardware is certainly not new, with most of the design fundamentals dating back decades. However, the technique has not been picked up by chip designers except in a few cases.

Intel, for example, used a clock-free design inside the arithmetic unit of its Pentium processors.

Philips has produced several circuits for low power products such as pagers.

Indeed it is the latter, Philips, where ARM has gone for the technology needed to produce an asynchronous microprocessor.

Philips recently formed a business unit – Handshake Solutions – to market its technology. It has worked on asynchronous logic for ten years or more, originally calling its compiler technology Tangram.

Most asynchronous designs, like Philips's technology, are based around the idea of micropipes described by one of Sun's chief engineers, Ivan Sutherland. A circuit, such as an adder, only does work when it is presented with data to work on. Handshake signals tell upstream and downstream circuits when the block is ready or finished.

There are three main advantages touted for clock-less ICs. Intel exploited the first – speed – in its use of the technology. Unlike a clocked circuit, which guesses the fastest speed it can run at, a clock-less design runs at the fastest speed it can.

Philips made most use of the second and third main properties of the circuits – low power and reduced electromagnetic emissions.

Global clock networks in modern IC designs are huge, consuming significant amounts of power. Removing these saves significant amounts – perhaps as much as a third of the chip's power budget.

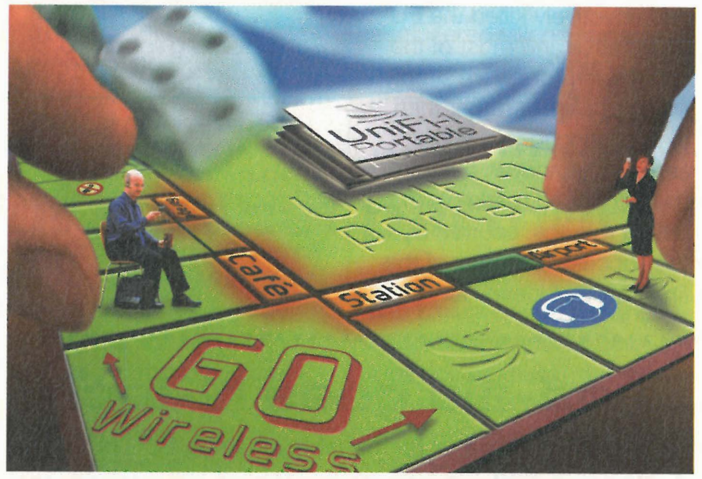
Again, because there are no clocks, there are reduced current spikes as there are not the thousands of registers all clocking concurrently, leading to lower EMI.

ARM's processor is due to be ready for licensing next year, and will run the popular ARM7 instruction set along with the 16-bit Thumb instructions and DSP extensions.

However, it is not the first time that the ARM architecture has appeared in asynchronous form. Professor Steve Furber of Manchester University, one of the designers of the ARM architecture, used it as the basis for the Amulet series of clock-less micros.

CSR zooms in on Wi-Fi

CSR, the Cambridge-based Bluetooth modules provider, has diversified its portfolio with the launch of Wi-Fi (IEEE 802.11a/b/g) devices. The company has applied its Bluetooth expertise to deliver a single-chip product family – One.11 – and the first devices in that family – the UniFi 1. They are targeted at embedded, battery-powered applications such as mobile phones, PDAs and digital cameras. Wi-Fi will enable them to share files a lot faster and to stream video.



James Collier, CSRs technical director and co-founder, said that the Wi-Fi modules typically used in the computer industry are not suitable for embedded applications due to their dimensions, the power they consume and the use of software Media Access Controller (MAC), which requires higher host-processor power. CSR, in turn, has created a 11mm x 9.5mm chip (implemented in 0.13µm CMOS process) that consumes 300mW when streaming 54Mbps over 10m, has a hardware MAC, and on-chip two antennas and four receivers to get better capacity of the communications link and good signal reliability.

"We've designed this to emit 60dB less than what's available in computers. It's a whole new architecture, built on our Bluetooth experience," said Collier.

UniFi-1 is priced at less than $8. The firm believes that in several years' time, its Wi-Fi portfolio could account for 40% of its business, which until now has focused solely on Bluetooth.

"Bluetooth is not going to disappear; we'll continue to evolve it. The killer application for Bluetooth today is voice calls, tomorrow it'll be music, games and picture sharing," said Collier. "[Whilst] Wi-Fi's [take-up in mobile phones] will be slow until mid-2006 and, then, design cycles for mobile phones are around 18 months."

State-of-art display created in Bristol

Hewlett-Packard (HP) Laboratories in Bristol, UK, has developed a prototype display that is bistable, colour, all-plastic and made without expensive vacuum deposition or photo-lithography.

The 3x4cm (128x96xRGB) device uses no active matrix and can display 125 colours, making it suitable for graphics and text display in "electronic books and magazines and digital posters and photographs," said HP. "The technologies used to create the prototype are at an early stage, but are designed to scale to paper-like resolutions over large areas so that future products could affordably deliver full-colour, print quality from a low-cost printed display."

An as yet undisclosed technique, which HP is calling 'imprinting', is used to create features within the display. "All of the patterning in the prototype has been carried out by a printing-like processes," said HP manager of display research, Adrian Geisow. "The details of the processes are still being developed, and we expect it will take a few more years of further applied research to properly develop and assess their commercial potential."

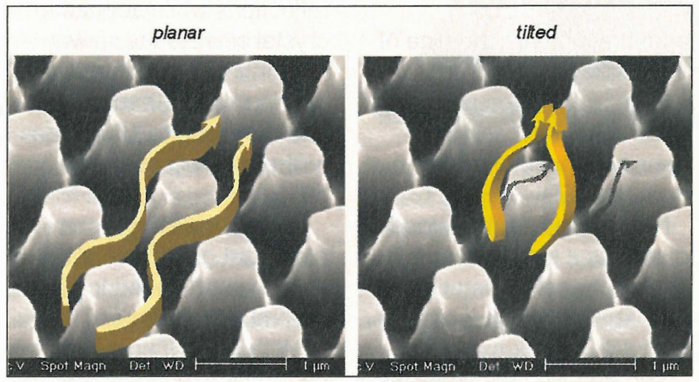
For example, the tiny glass beads used to separate the two glass sheets in a normal LCD are replaced by walls imprinted in a hexagonal pattern across the inner surface of one of the two plastic substrates.

The liquid crystal is stabilised in one of two states by micron-sized imprinted pillars (see photo). These encourage liquid crystal chains to align homeotropically (up the pillars) or horizontally in the plane of the display, but not in between. The two stable states have different effects on the polarisation of light passing through and represent on and off states.

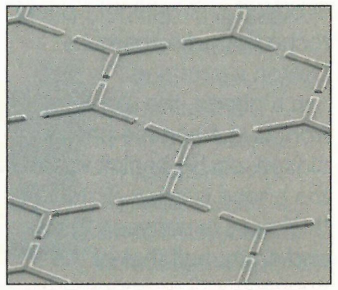
Grey is obtained by having different pillar patterns in different parts of each pixel, allowing some part or all of each pixel to be switched by applying different voltages momentarily to an X-Y matrix of electrodes.

Colour comes from red, green or blue filters over every third pixel.

Left: HP's prototype colour display is bistable, needing no power to maintain an image



Below left: Plastic pillars create conditions to hold the surrounding liquid crystals either vertically or horizontally,



Below: A technique HP calls 'imprinting' is used to deposit hexagonal spacers as well as microscopic pillars

Although the display is colour, it is not fast. "The development is targeted at applications other than video displays such as TVs and computer monitors," said HP.

Vacuum-deposited X-Y conductors, like the indium-tin oxide used in most LCDs, are avoided. Instead, HP uses polymer conductors in which 5µm metal wires are imprinted to keep resistance down. These are deposited along with the colour filters, said HP.

Although not deliberately flexible, finished displays can be bend to some extent, making them robust during manufacture and use, said Geisow.

Automotive LEDs are on

In a move which suggest the power LED market is poised to become mainstream, Philips Electronics has signed a deal with Californian LED maker Lumileds Lighting to develop and market LED-based modules for vehicle use.

"Solid-state lighting will represent a significant portion of the future automotive market and Philips Automotive Lighting and Lumileds will set the pace in that market," said Hans de Jong, CEO of automotive lighting at Philips.

Lumileds is part-owned by Philips and a joint venture with Agilent – a firm which also has a separate medium-power (under 150mW) LED business with established automotive products.

Other firms in the race are Germany's Osram, Japan's Nichia and Cree of the US.

Double-sided display simplifies phone design

Japanese firm Omron has developed an LCD that can be viewed in the dark from both sides, but is lit from only one side.

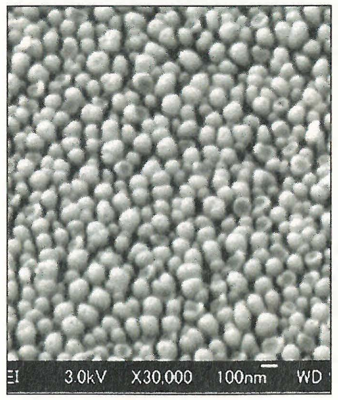
It is aimed at clamshell phones, which normally have two back-to-back LCD-backlight combinations, and is based on frontlight optical technology disclosed by Omron a year ago.

In a phone, the display front is lit when the phone is closed, and is backlit when the phone is open. Total thickness is between 2mm and 4mm, half that of the conventional arrangement, said the firm.

Key to the whole assembly is and edge-lit light guide, which has 100nm nanoprisms embossed on the side facing the display and 3µm micro-prismatic pits in the side away from the display.

With the light guide fed from the corner or edge by one or more LEDs, the microprisms are the key to frontlight behaviour.

As it passes across the light guide, the microprisms turn it through 90 degrees and direct it onto the face of the display.



Nanoprisms up close

Even illumination is assured by increasing the density of prisms further from the LED.

New for the double-sided display is a small prism ahead of each prismatic pit (see above), which increases useful illumination by 30% compared with the year-old monoprism design, said Omron.

By adopting a transflective display and a frontlight, the image can be viewed front-lit through the lightguide, and backlit from the far side.

In front-lit mode, the display would be adversely affected by reflections of ambient light from the back of the lightguide, said Omron, or at least it would if the nanoprisms were not added. "When viewing an image on the front light side, there was a problem that it would become whitish due to the reflection of light from the light guide surface," said the firm. For complex reasons, the 100nm nanoprisms reduce contrast-reducing reflections while appearing crystal clear to the viewer. Omron's previous frontlight offering had 200nm prisms, and the move to 100nm has further cut reflections by 50%.

Overall, the single, complex, light guide has done away with the need for several optical films.

"With these [micro- and nanoprism] technologies, the diffusion and prism sheets [in standard displays] are no longer required for the backlight," said Omron. "Furthermore, as a frontlight, the improvement of the transparency allows less fuzzy and significantly higher contrast ratio of the display image on the sub-display."

The ITU and ANSI standards bodies accepted Agere Systems new standard proposals for enhanced telecommunications services. The proposals revolve around an Application Service Resiliency (ASR) mechanism as a fundamental requirement for next generation networks. ASR is the measurable attribute for maintaining application service continuity regardless of network failures. This is particularly of value in VoIP, streaming video, multimedia and e-commerce applications.

LinuxWorld has just announced the latest version of the LynxOS real-time operating system (RTOS) – LynxOS-178 aimed at military and avionics industries. It adds support for ARINC-653 APplication/EXecutive (APEX) interface to meet stringent safety and reliability standards for military and commercial avionics systems.

LunuxOS is a commercial off-the-shelf (COTS) operating system.

Sharp has supplied the Australian government with an electronic passport (e-passport) IC module for a trial programme that started late in 2004. This is a 512kB, 424kbps contactless IC module based on the ICAO (International Civil Aviation Organization) recommendations. It collects and processes passport data in less than one second. E-passports are growing in popularity as they are seen to be an effective method in fighting passport forgery.

'Perfect' lens not possible, after all

Negative refractive index materials will not lead to much-predicted 'perfect' lenses, admitted researchers at Purdue University and the Massachusetts Institute of Technology (MIT).

"It may be possible to build a better imaging system, but it could never be perfect," said Purdue professor Kevin Webb. "That's the bottom line."

Perfect lenses, suggested in 2000 by John Pendry of Imperial College London, could compensate for evanescent light – which accounts for some of the light lost from an image as it passes through a lens, said the team. Such lenses would be able to focus light better, allowing, for example, finer geometry chips to be etched.

One way proposed to make a perfect lens is to use negative index materials – which refract light the 'wrong' way – combined with normal optical materials.

The negative materials are possible and some examples have been made. In 2001 researchers at the University of California, San Diego, constructed a 3D matrix copper rings and wires that negatively refracted microwaves.

Sadly, the Purdue-MIT mathematical analysis shows negative refractive index is not a route to perfect focusing. "Through a rigorous mathematical analysis, however, we have been able to show that, while a negative refraction index could conceivably be used to build better imaging systems, a perfect lens is not possible," said Webb.

Matter to light data transfer

Physicists in the US claim to have transferred quantum information from two groups of atoms to a single photon.

It might sound esoteric, but it means data has been transferred from matter to light, so the achievement could pave the way to quantum communication networks.

"A really big issue in quantum information systems today is distributed quantum networks, and for that, you must be able to convert quantum bits of information based on matter into photons," said Assistant Professor Alex Kuzmich.

He and graduate student Dzmitry Matsukevich from the Georgia Institute of Technology encoded data as horizontal or vertical polarisation of the light.

Light was split and passed through two clouds of rubidium atoms, each with a different quantum state. Together they form a quantum bit, or qubit.

By recombining the light the qubit is entangled with the photon, said Kuzmich: "Conversion from matter to light becomes efficient in one direction because emission from all the atoms add together to create a preferred forward direction, similar to how radio frequency antennas are able to emit directionally."

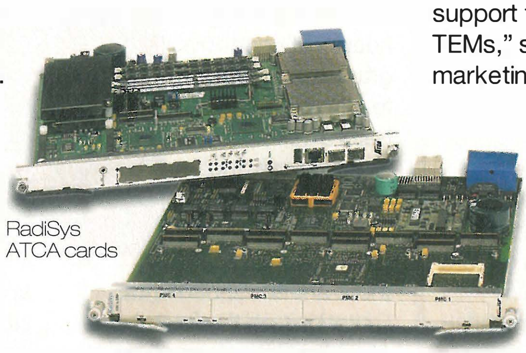
The team's next step is to create a second quantum node, a receiver, to read the data encoded in photons sent over fibre links.

Common-platform ATCA charges ahead

Almost every major Merchant Switch Fabrics (MSF) vendor will use the Advanced Telecom Computing Architecture (AdvancedTCA) platform in its reference designs over the next four years, says research firm In-Stat/MDR.

This is an immediate result of reduced R&D budgets in the telecom field and the flexibility that AdvancedTCA offers. "While the advancement of the AdvancedTCA is seen as beneficial to all merchant networking silicon, this is especially true for MSFs. This is because, more than any other kind of device in the "networking silicon continuum", MSFs interact most directly with the host chassis of the application in question."

"As such, if a MSF vendor is able to demonstrate its fabric working in an AdvancedTCA chassis, perhaps as part of a reference design, and an equipment maker is contemplating moving into the PICMG form-factor, that equipment maker knows it can also use this particular MSF without re-engineering everything," said in In-Stat/MDR's report *"AdvancedTCA Accelerates Merchant Switch Fabrics".*



RadiSys ATCA cards

The AdvancedTCA standard defines a common-platform architecture, aimed at next generation of carrier grade communications equipment and it's based on reusable designs and commercially available components. Its form-factor was proposed by PICMG (PCI Industrial Computer Manufacturers Group).

RadiSys supplies AdvancedTCA building blocks that have been tested and fully validated in all types of network conditions. It has just launched the SYS-6000 Linux blade server for control plane applications, part of the Promentum family of AdvancedTCA products.

"TEMs [telecom equipment makers] need a stable product, a truly dedicated platform in this space. The whole RadiSys business model is to support the need of the TEMs," said Fred Yentz, marketing VP at RadiSyS.

To "fully support" the TEMs, RadiSys has also founded the RadiSys Alliance Program, which already boasts twelve members, including the operating systems (OS) supplier Wind River, Linux OS software and tools suppler MontaVista Software and middleware firms Clovis Solutions and GoAhead Software among others.

"The TEMs are moving from building platforms to using them, so they need validated systems to achieve that; they need to know they have partners to jointly work with them,"said Yentz.

"We are encouraging developers of different [AdvancedTCA] building blocks to join our alliance," he added.

UK RFID tagging a success

The UK Government is claiming success for its 'Chipping of Goods Initiative', in which £5.5m was invested in radio frequency identification (RFID) tagging.

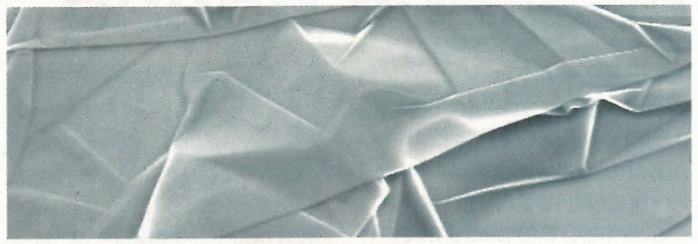
Eight case studies sponsored by the initiative benefited from using RFID technology, said Hazel Blears, the home office minister responsible for reducing crime.

"Manufacturers, retailers, consumers, the police and other enforcement agencies will all benefit from the wider adoption of this technology. In fact, the only group not to benefit are the criminals," said Blears.

The programme, led by the Police Scientific Development Branch, aims to reduce property crime by improving the traceability of stolen goods.

"It was also established to show the clear business benefits that can be gained from adopting such technology," she added.

Sheet lightning

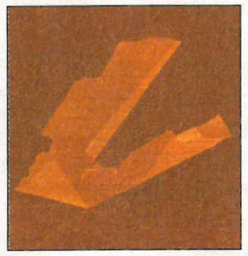


Stripping a single sheet of carbon atoms from graphite has led to the promise of fast switching transistors.

Research at the University of Manchester and Chernogolovka, Russia, has found that the sheets of graphene could form ambipolar field effect transistors that showed almost no electron scattering.

This leads to very high electron mobility, for which engineers currently have to use materials such as gallium arsenide (GaAs), gallium nitride (GaN) or indium phosphide (InP).

Professor Andre Geim at Manchester, who led the research, said there was no reason why wafers could not be made covered with a graphene layer.



"Computer engineers will need graphene wafers a few inches in size, before considering graphene as 'the next big thing'. However, all the omens are good, as there are no fundamental limitations on the lateral size of carbon nanofabric," he said.

Fabricating a wafer of, say, silicon and adding a graphene layer could be significantly cheaper than GaAs or InP.

Applications are wide ranging, added Geim. "As carbon nanotubes are basically made from rolled-up narrow stripes of graphene, any of the thousands of applications currently considered for nanotubes renowned for their unique properties can also apply to graphene itself."

Graphene, said the team, "is stable, highly flexible and strong and remarkably conductive".

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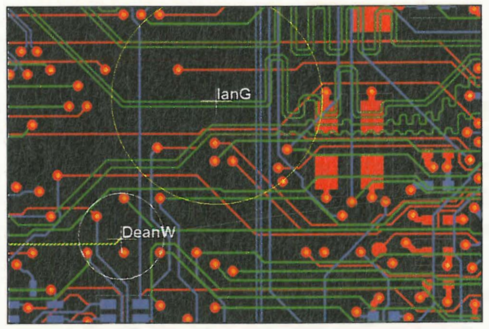
All hands to the pump

Too many cooks spoil the broth, or many hands make light work. Which is correct?

Well, EDA tools supplier Mentor Graphics reckons it's the latter when it comes to laying out complex printed circuit boards (PCBs). The firm has produced a tool that allows up to 15 designers to work simultaneously on a single PCB.

Called XtremePCB, the software oversees the actions of multiple designers who all work on the same database. Any changes by one designer are immediately shown on the screens of his or her peers.



The team can decide how they split up the design, perhaps into digital and analogue sections, or with different nets being assigned to each engineer.

Avoiding conflict between designers is the greatest challenge for the software. Mentor uses 'force-fields', which automatically light up when two engineers get too close on the board.

All this relies on constant communication between the layout engineers, which can be verbal, or through the tool itself. The latter option allows for distributed design teams, said Mentor.

UK processor board firm Radstone Technology tested the software for Mentor on one of its VME-bus boards.

The 16-layer board contained 7,000 nets and 12,500 vias. Radstone took it easy using two designers working together.

"XtremePCB allowed us to have two designers working simultaneously on the design of a complex board and reduce our layout cycle time by 40 to 50 percent," said Ian McCormick, CAD manager at Radstone.

Safe scanning for cancer

Combining PET and MRI scanning technology could give a safe method of screening for cancer.

Dr Adrian Carpenter of the University of Cambridge's Wolfson Brain Imaging Centre has built a prototype that brings the best of both medical technologies.

Positron emission tomography (PET) is good at spotting chemical uptake in the body, while magnetic resonance imaging (MRI) is associated with providing high anatomical detail.

The existing scanning technique to spot cancers is PET-CT, but this uses higher radiation levels than PET, the latter being two or three times the annual background dose in the UK.

However, combining PET and MRI is, on the face of it, very tricky. PET uses photomultiplier tubes to detect gamma rays given off when a positron annihilates an electron. These tubes cannot work inside a magnetic field, which is clearly fundamental to the workings of an MRI scanner.

Carpenter designed a new magnet for the MRI part of the scanner, with zones of low magnetic field to site the photomultiplier tubes. These were further protected by mu-metal screens.

With the two techniques working together, radiologists will be able to spot the increased activity associated with cancer and exactly where it is relative to other body tissue.

Linux gets UK Government thumbs-up

Pilot schemes to test open source software such as Linux in the UK Government departments and the public sector have proven a success.

So much so that the Office of Government Commerce (OGC) has issued a report stating: "Open source software is now a viable desktop alternative for the majority of government users."

The move could pave the way for Linux to move to the desktop, displacing proprietary operating systems such as Microsoft.

The report said that interoperability is no longer an issue and that using open source software can lead to "significant savings".

Pilot schemes were carried out with IBM and Sun Microsystems. Sites included Central Scotland Police, Office of Water Services (OFWAT) and Powys County Council.

Data was also obtained from trials at the MoD Defence Academy and West Sussex County Council.

The number of users in the trials ranged from tens to thousands, but all found savings and noted features such as improved reliability.

"These pilots have provided us with valuable evidence on open source software. They show it could support government bodies by offering efficient and cost-effective IT solutions," said OGC chief executive, John Oughton.

Organisations considering a move to open source software should carefully assess the long-term costs and factors such as training and maintenance, said the OGC.

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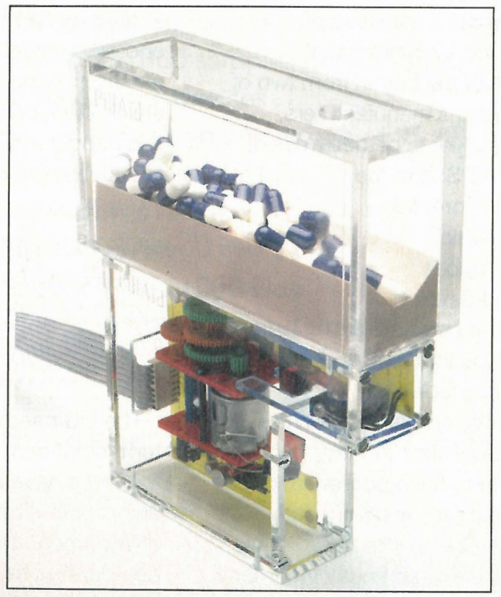
Student simplifies medication administration

Brunel University student Katrin Svabo Bech has designed a system to help patients take the correct pills at the correct time at home.

Called PillAid, the concept includes smartcards and a personal pill dispenser to control dosing.

In Bech's scheme, patients are given a healthcare smartcard that contains medical history, current medication and an electronic prescription form. "When new medication is prescribed, the GP logs this information onto the card," said Brunel. "The patient then gives the card to the pharmacist for processing."


The PillAid dispenser prototype, designed to take the confusion out of medicine consumption

The chemist provides medicine in a PillAid compatible container. "Once home, the patient places the dispensing unit into the PillAid and inserts the smartcard into the system."

Now knowing the time and dosage of each medication, PillAid activates in-built visual and audio reminders to tell the user when they need to take their medicine. The user pushes a button to initiate dispensing and this information is recorded onto the smartcard for the GP to analyse later.

Paul Turnock, director of industrial design at Brunel said: "We are very impressed with the all-round solution Katrin has developed with PillAid. This is exactly what our students are aiming for – creative solutions that impact everyday life."

TOP 10 TIPS

Project Planning

- Use past (good!) projects as a guide
- Think of every little detail of the jobs that need to be done
- Write the whole lot down somewhere
- Group each of the smallest tasks into main tasks that are to be done by each department
- Use a decent project-planning tool – Gantt charts are excellent for this kind of thing
- For each of the tasks, work out how long each little bit will take
- Add in known staff holidays and add in a few days here and there for holidays not booked
- Double the time taken to do the whole lot, because when you present the project to management, you just KNOW they will halve the time you have put down, just because... well... they can!
- Schedule loads of meetings at regular intervals to track progress, because it WILL slip!
- Take all your (permanent) staff out for a well-deserved beer when they've delivered, because you're quite likely to ask them to do the whole thing all over again for your next project!

This month's Top Ten Tips were sent in by Douglas Ponsford, senior team leader in an automotive company.

If you'd like to send us your top five or top ten tips on any subject you like, please write to the Editor at **EWadmin@highburybiz.com**

Dare cross the Atlantic

Graham Margetson looks at the differences between UK and US reactions to the WEEE and RoHS directives disposal of electronic goods

The consultation period for responses to the UK government's Waste Electrical and Electronic Equipment (WEEE) and Reduction of Hazardous Substances (RoHS) implementation proposals closed on the 29th October 2004. Those who have read the documents will realise that on the horizon are major changes in terms of materials used and how products are manufactured.

With both directives, the onus is on the producer to take responsibility for its end-of-life products. In relation to WEEE, producers will have to finance the recycling, recovery and disposal of electronic goods. By 2007, any product containing the banned substances laid out in RoHS will not be allowed for sale. Therefore, a whole re-evaluation of the manufacturing process has to be undertaken. Both, European and US companies will be affected very significantly by the new regulations, as will other major world manufacturers who export to the EU.

For Europe, companies have become accustomed to operating in the context of the EU environmental directives. Although many will see the legislation as a harsh reality, at least there are clear guidelines and implementation dates to be adhered to.

Across the pond, the picture is very different. Indeed, the WEEE and RoHS directives raise greater issues to US businesses than they do to the EU – both in the short and long term.

If companies from the US wish to export their products to the EU, they must be prepared to adhere to the varying requirements of each country's WEEE and RoHS regulations; the producer responsibility is relevant wherever the importing company is based. A well-known US electronics giant got its fingers financially and environmentally burnt in the Netherlands when it was banned from importing a particular product that contained a banned substance in that country. Instances such as this highlight the fact that electronics waste is certainly a hot topic in the US.

Indeed, these issues are so important to businesses in the US that the National Electronics Product Stewardship Initiative (NEPSI) was set up. A grouping of industry, state government and environmental organisations, NEPSI aimed to co-ordinate the issue of electronic products management. However, without the buy-in from two of its major electronics manufacturers, NEPSI's future is yet to be determined.

Other than NEPSI and the Environmental Protection Agency (EPA), which continues to propose regulations and develop initiatives and incentives, the stark reality is that there is no actual federal law in the US that compares to WEEE or RoHS, only guidelines. Indeed, California is the only state to have passed law relating to electronics recovery and recycling, which came into force in July 2004. It is, however, fair to say that many states take a proactive approach to guidelines, initiatives and incentives but without specific regulations, it is still up to companies to comply.

> *"One US electronics giant got its fingers burnt in the Netherlands where it was banned from importing a particular product that contained a banned substance in that country"*

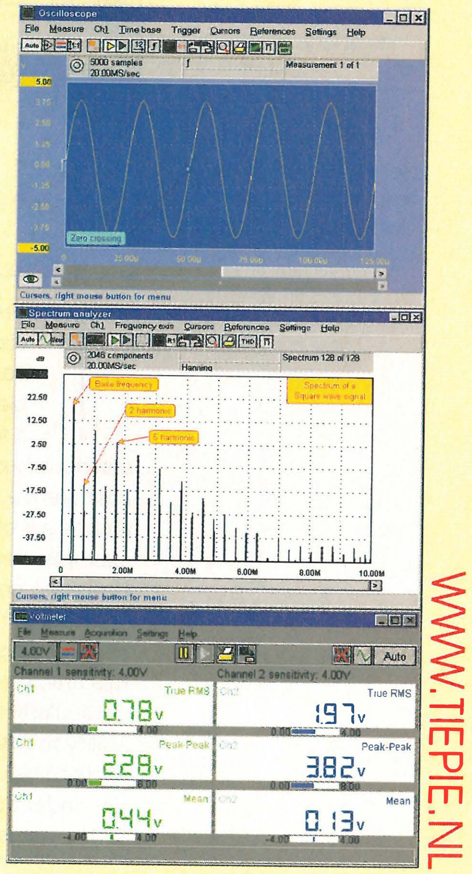
Because so many of the world's major players are based in the US and the volumes are so much greater, in terms of producer responsibility and indeed consumer waste, the problems are magnified and the stakes are raised. This is why US companies are getting involved in electronics waste initiatives and are seeking counsel from the EU.

Indeed, demonstrating the 'sit up and take notice' attitude from the major electronics players, *The Plug-In To eCycling Campaign*, a partnership of several of the biggest electronics companies including Sony, Panasonic and AT&T has been formed to raise US's awareness of the value of reusing and recycling electronics.

In principle, one cannot deny that US companies are being proactive and are prepared to work with each other, consumers and the EU to alleviate the growing problem. However, as demonstrated by NEPSI, with no federal law and sporadic guidelines, no one has to do anything. Although legislative proposals are drafted, none are being passed. Until this happens, it is difficult to see the situation improving.

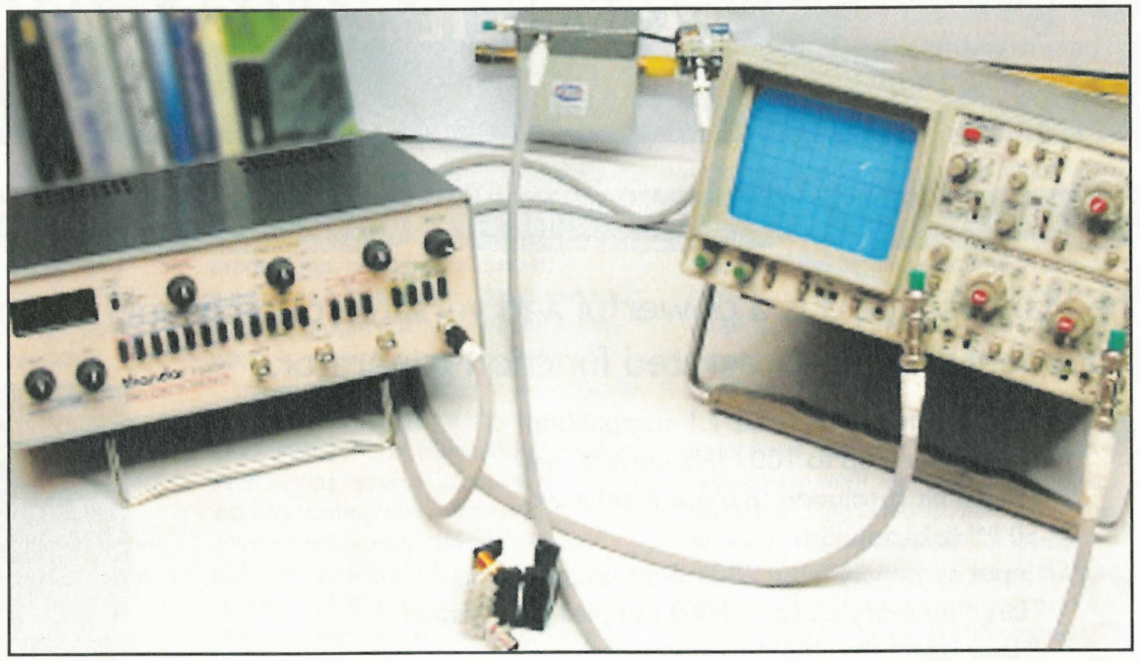
The US needs to look now at long-term solutions. If US electronics manufacturers have to adapt manufacturing and distribution methods for the EU's environment then, maybe, the US should be adapting its products to secure its own country's future. Delaying the inevitable could result in much greater long-term penalties financially and, more importantly, environmentally.

Graham Margetson is managing director of Foresite Systems, a firm that deals with waste compliance.



Understanding EMC

You didn't think you could tackle EMC yourself. Ian Darney, however, says you can



Set-up for susceptibility test, showing near end of test rig. In the foreground is the current transformer

There was a time when, during a discussion of electromagnetic compatibility (EMC), the phrase "it's a black art" would have been greeted with a few wry smiles. Not any more. EMC is a serious business. Overcoming the curse of interference requires the preparation of a suitably arcane set of rituals, such as the EMC test plan for example, and the crossing of palms with silver. However, perceptions will have to change.

EMC is a branch of science and, therefore, capable of analysis and control. The purpose of this article is to demonstrate that it is not particularly difficult. Then, armed with the ability to make engineering decisions on EMC for themselves, circuit designers are no longer dependent on the expensive advice of self-styled gurus.

Test equipment

The first step is to assemble the tools for the job: signal generator, oscilloscope and a PC with mathematical software. Special purpose equipment is also needed, the minimum requirement being a voltage injection transformer and a current monitor transformer. It is also useful to have a simple test rig available, to confirm that the equipment is functioning accurately. All of the special purpose equipment can be easily constructed, using components readily available.

Since the spectrum of frequencies associated with EMC is beyond the scope of any single instrument, it is necessary to limit the range involved in any particular set of tests. Since the simplest devices and the simplest analyses are at the lower frequencies, this seems the best place to start.

Voltage injection transformer

A voltage injection transformer was constructed from a split-core ferrite, part number 04 31 173 951, supplied by the Fair-Rite Products Corp. One hundred turns of 28 gauge enamelled copper wire (ECW) were wound onto half of the assembly to provide the primary winding. A 240Ω and a 68Ω resistor were added in parallel with this winding, and the terminals were connected to a 50Ω BNC panel-mounting jack. A secondary winding consisted of a single turn of ECW on the opposite core and this was connected to another BNC jack, via a 51Ω resistor. **Figure 1** is a circuit diagram of the assembly.

The twin-core ferrite assembly is supplied with a plastic case that allows the transformer to be clamped round the cable under test. Cables of up to 15mm can be accommodated. In normal use, the primary is supplied with an input from the signal generator, and transformer action creates a signal in series with the loop under test. Since the monitor turn is also a single turn winding, it can be used to measure the voltage injected into the cable.

The set-up of **Figure 2** was used to check the bandwidth of the transformer. A sinusoidal signal at a particular frequency was applied to the primary and this input voltage was monitored on channel 1 of the oscilloscope. The output voltage from the monitor turn was fed to channel 2 of the oscilloscope. The peak-to-peak amplitude of both signals was recorded and the test repeated at a number of spot frequencies.

By calculating the ratio of output to input at each frequency, any variations in the response of the signal generator and oscilloscope can be removed from the results, leaving a curve that defines the frequency response of the voltage injection transformer. **Figure 3** shows that the useful range of this particular transformer is from 2kHz to 2MHz.

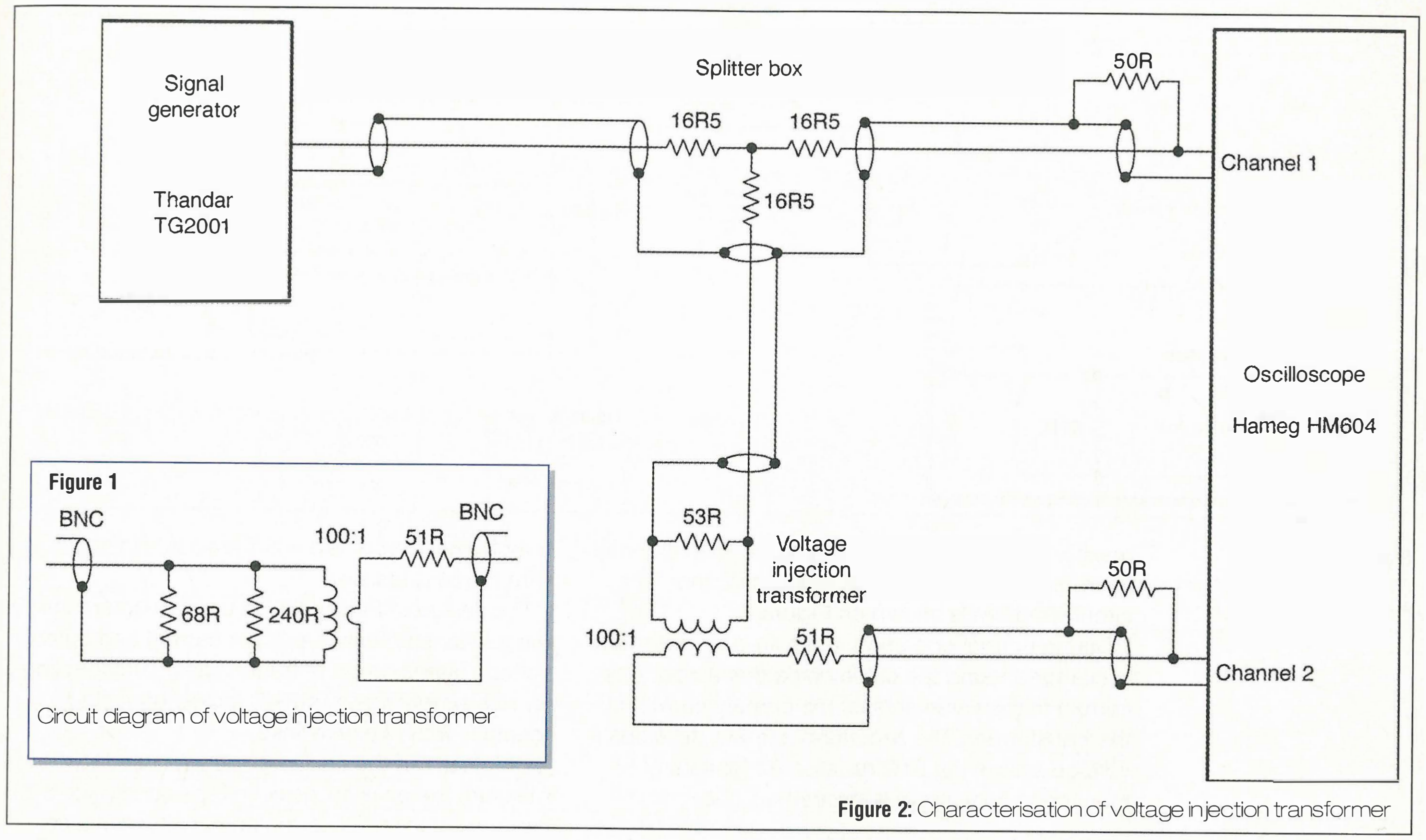


Figure 1

Circuit diagram of voltage injection transformer

Figure 2: Characterisation of voltage injection transformer

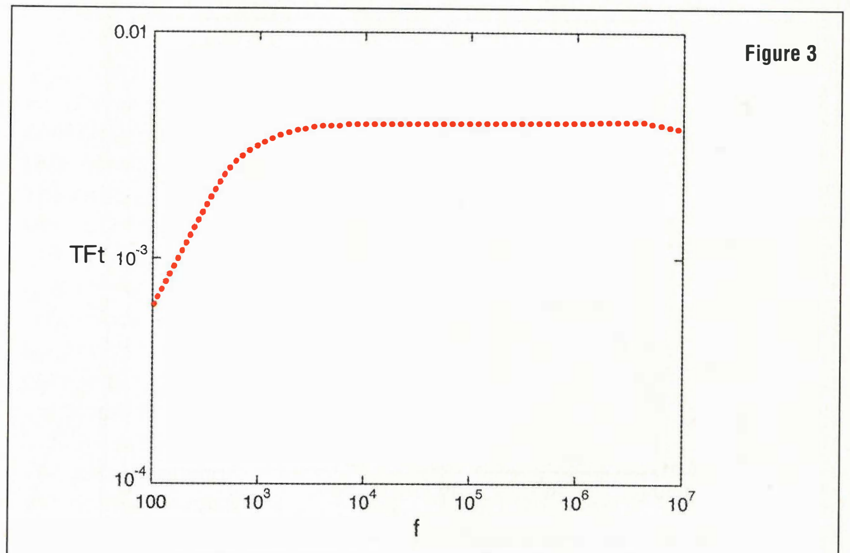


Figure 3

Transfer characteristic of voltage injection transformer

Current monitor transformer

The construction of the current monitor transformer was similar. One hundred turns of 28 gauge ECW were wound on to one half of a split core ferrite, part number 04 31 173 951, to act as a secondary winding and was loaded by a 51Ω

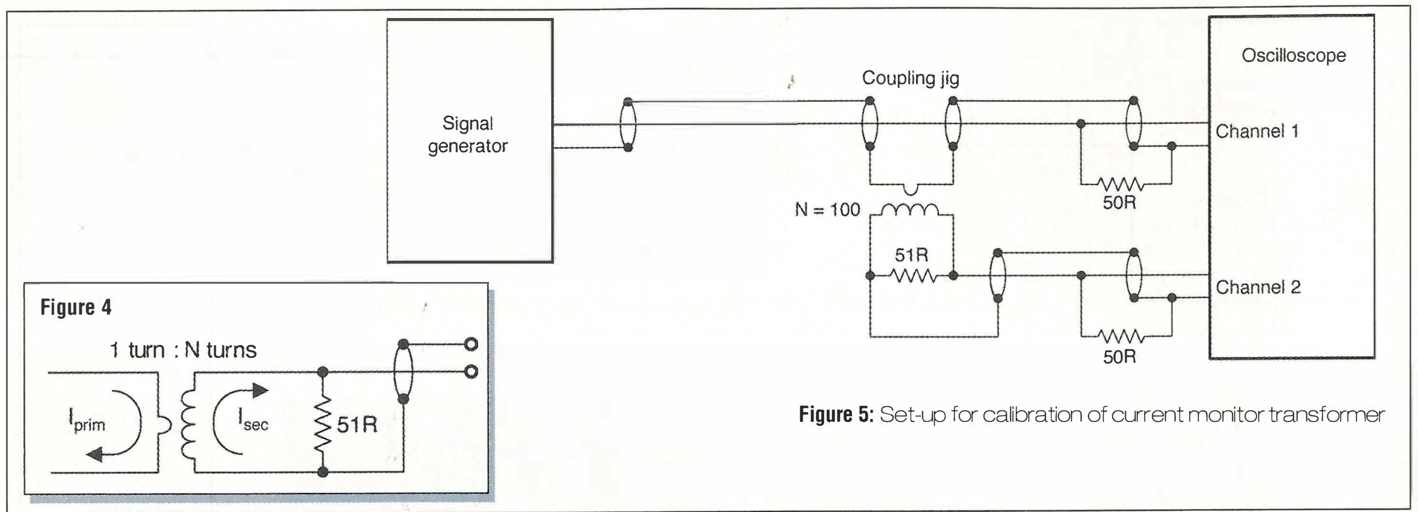


Figure 5: Set-up for calibration of current monitor transformer

Figure 4 (inset): Circuit diagram of current monitor transformer

resistor. A BNC jack was used to allow an external instrument to interface with the transformer. The circuit diagram is shown on **Figure 4**.

During normal operation, the twin-core assembly is clamped round the cable being monitored. Any current in the cable acts as the primary current in the transformer. The secondary current develops a voltage across the 51Ω resistor. As far as any monitoring instrument is concerned, the transformer output is a voltage source in series with the 51Ω resistor.

The set-up of **Figure 5** was used to determine the relationship between input current and output voltage over a range of frequencies. The coupling jig was simply a pair of BNC jacks connected together with two wire links.

Channel 1 of the oscilloscope was used to measure the peak-to-peak voltage across the 50Ω input resistance. Since the primary current also flows through this resistance, it is a simple matter to calculate the value of this current.

Channel 2 of the oscilloscope displays a sine wave, with amplitude proportional to the output voltage of the secondary winding. Since the secondary voltage is effectively in series with the 51Ω and 50Ω resistors, and the voltage at channel 2 is across the 50Ω component, it is easy to calculate the voltage at the secondary winding.

Given knowledge of the transformer input current and output voltage at a set of spot frequencies, the next step is to draw a graph of the ratio between these two values – the transfer impedance. This is shown on **Figure 6**.

Using data from this test, it is possible to measure the output voltage of the secondary winding and to deduce the amplitude of the primary current. If the frequency does not correlate precisely with one of those used during the calibration process, then interpolation of the results will give the required value for the current.

However, such an approach is rather cumbersome. A better method is to derive a circuit model of the transformer from the test data. That is, to postulate the existence of a circuit model that will reproduce the response shown in Figure 6. Initially, the component values in the model would be pure estimates. Using mathematical software, it does not take many iterations to come up with **Figure 7**.

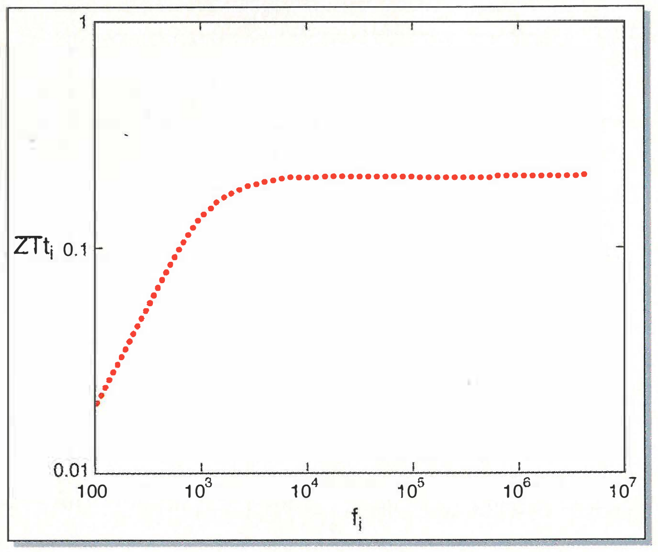


Figure 6: Transfer impedance of current monitor transformer

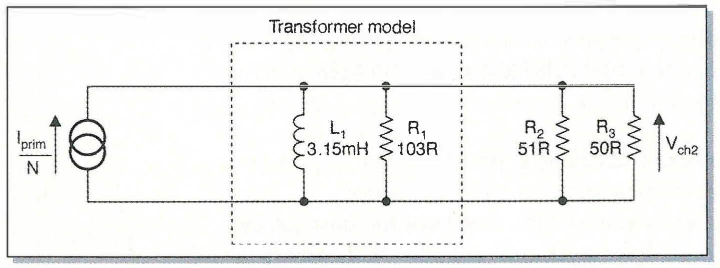


Figure 7: Circuit model for secondary loop of current transformer

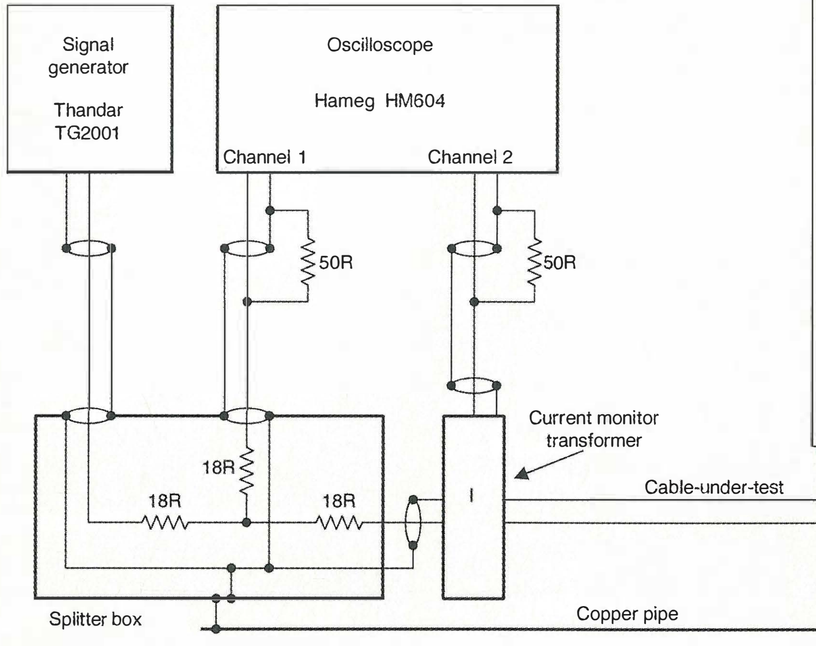


Figure 10: Emission measurements on the test rig

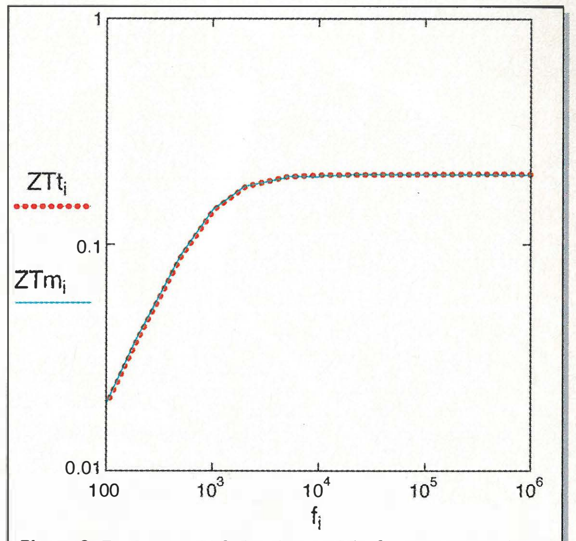


Figure 8: Response of circuit model of current monitor transformer

The response of this model is illustrated in **Figure 8**, together with a copy of the curve derived from the test results. It is obvious that any deviation between the two curves is well within the accuracy to be expected from the test measurements.

The final result is the existence of a circuit model that can be used to relate measured voltage on the oscilloscope to the amplitude of the current in the cable under test.

The test rig

At this point, the test equipment was ready for use. All that remained to be done was to find something to test, which initially would give predictable results. So a test rig was designed and built. It consisted of a length of 15mm diameter copper pipe installed round the walls of a room. A wooden batten was clamped along the pipe and a cable fixed to the wood with removable tie-wraps. The batten provided a fixed separation between cable and copper pipe over the entire 11.7m length of the assembly. The cross section of the test rig is illustrated in **Figure 9**.

Emission test

The first test was of the emission properties of a length of 50Ω coaxial cable, type RG58, when fitted to the installation in the configuration shown on **Figure 10**. The cable is terminated by a load of approximately 50Ω at each end. The splitter box at the near end allows the cable input to be monitored by channel 1 of the oscilloscope. The current monitor transformer enables the common mode current to be monitored by channel 2.

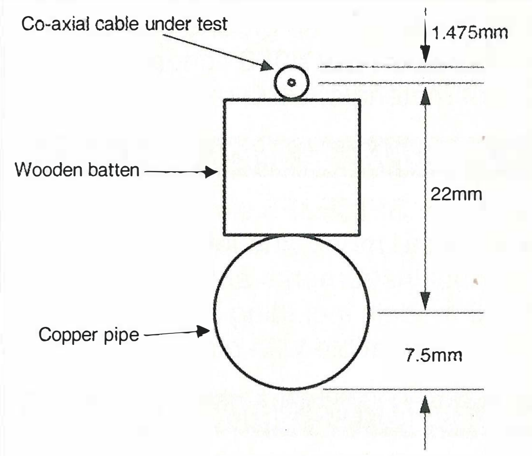


Figure 9: Cross-section of the test rig

The ratio of output to input is a current divided by a voltage. This parameter has the dimensions of 'admittance'. Since the current is not in the same circuit branch as the voltage, the logical term for the measured parameter is 'transfer admittance'.

The frequency response of the set-up is illustrated in **Figure 11**. This curve gives a fair indication of the emission characteristics, since sinusoidal current in a conductor creates both a

magnetic field and an electric field at the surface of the conductor and these fields radiate outwards from the assembly.

This curve can also be used to create a circuit model, the requirement being that the model should replicate the actual response. It is not particularly difficult to postulate a circuit model, assign approximate values to the component values and then use mathematical software to modify those values. Very few iterations were needed to create **Figure 12**.

In this model, the 0.5Ω resistor represents the resistance of the inner conductor, 0.33Ω represents the resistance of the screen and 0.01Ω represents the resistance of the copper pipe. The 9μH inductor represents the inductance of the loop formed by screen and copper pipe. Since the physical parameters are reasonably well defined, it is possible to confirm that the 9μH value is entirely plausible.

It is not surprising that at 1kHz most of the signal current flows in the common-mode loop. The resistance of the copper pipe is much less than that of the screen of the coaxial cable. However, above 10kHz, the situation improves, due to the 9μH inductance.

Figure 13 shows the response of this model, superimposed on the results obtained from the actual test. It is clear that the model can be used to predict the response of this particular configuration, up to about 100kHz.

However, above 100kHz, the two curves deviate. One possible reason for this is that the test measurements were inaccurate. This is entirely plausible, since the signals at channel 2 of the oscilloscope were extremely low and the instrument was operating at maximum sensitivity. Another possibility is that some new coupling mechanism was coming into play, one that the simple circuit model does not replicate.

Susceptibility test

The set-up for a susceptibility test is shown on **Figure 14**. Here, the source is the voltage injection transformer, representing the effect of external interference in the common mode loop, and the "victim" circuit is the signal carried by the coaxial cable. Channel 1 of the oscilloscope monitors the former, whilst channel 2 monitors the latter. Again, the key parameter is the transfer admittance – output current divided by input voltage.

The response of this test is shown by the dotted curve with circled data points in **Figure 15**. Also shown is the response of the circuit model of **Figure 16**, shown as the solid curve. As with the previous test, there is good correlation between

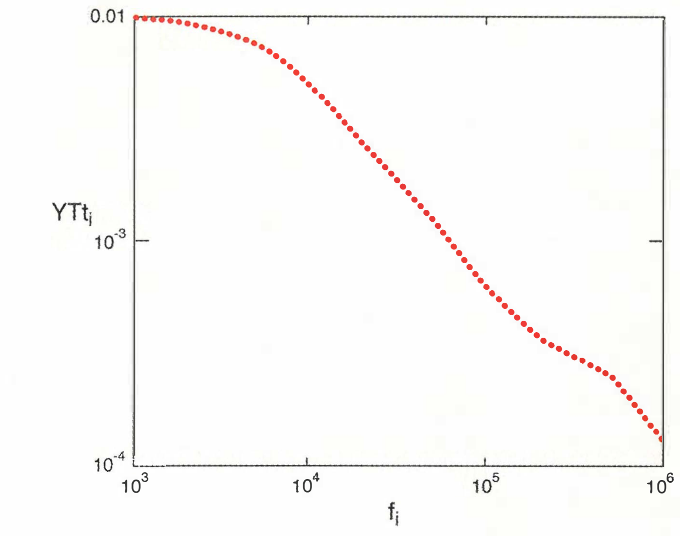


Figure 11: Transfer admittance derived from emission test of Figure 10

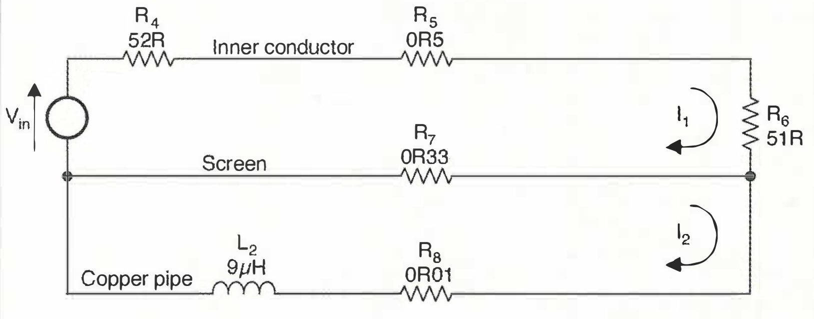


Figure 12: Circuit model of emission test

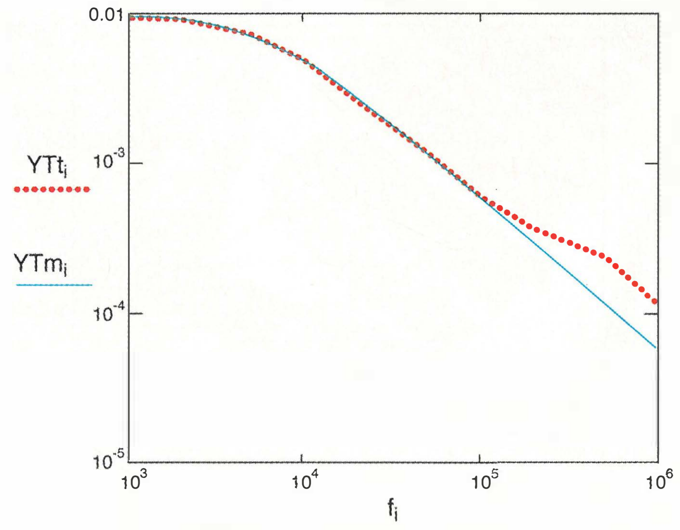
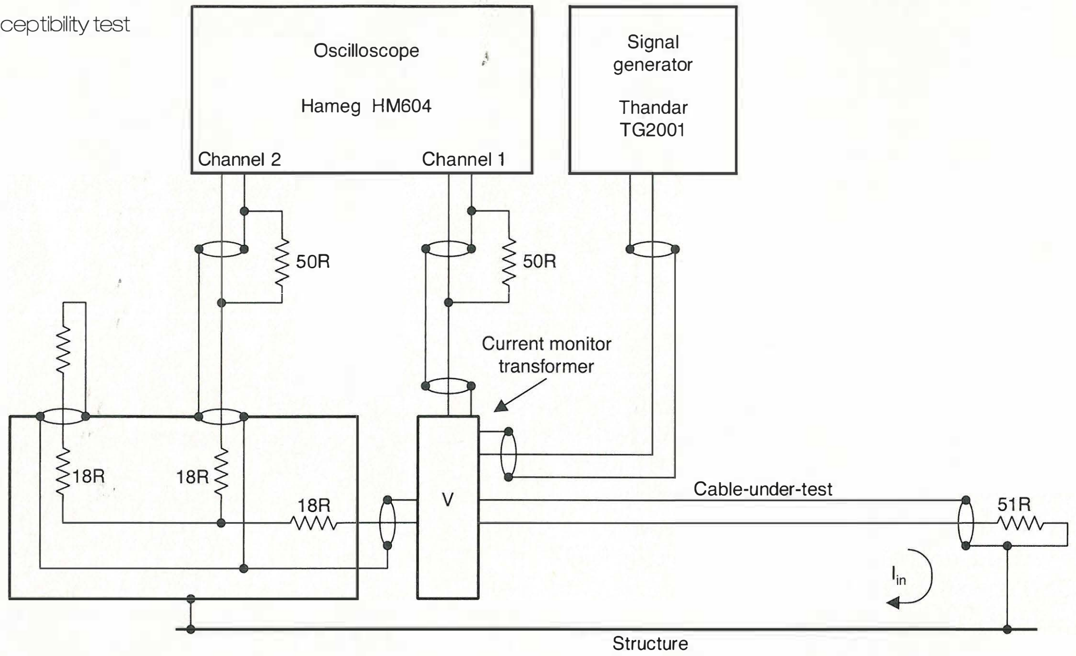


Figure 13: Response of circuit model of emission test. Solid blue curve – response of circuit model of **Figure 12**. Dotted red curve – response of set-up of **Figure 10**

Figure 14: Set-up for susceptibility test



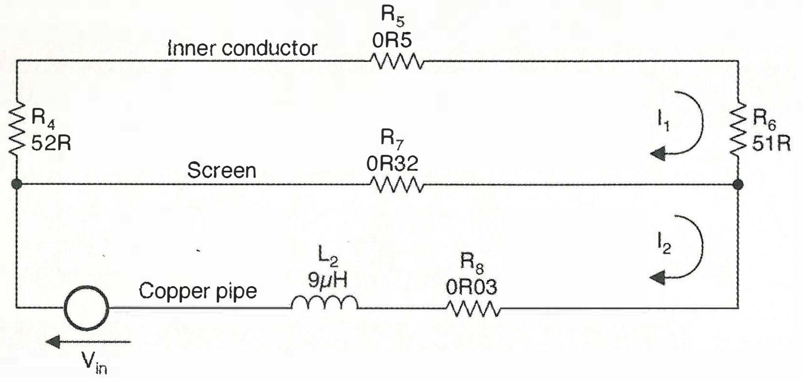


Figure 16: Circuit model for susceptibility test

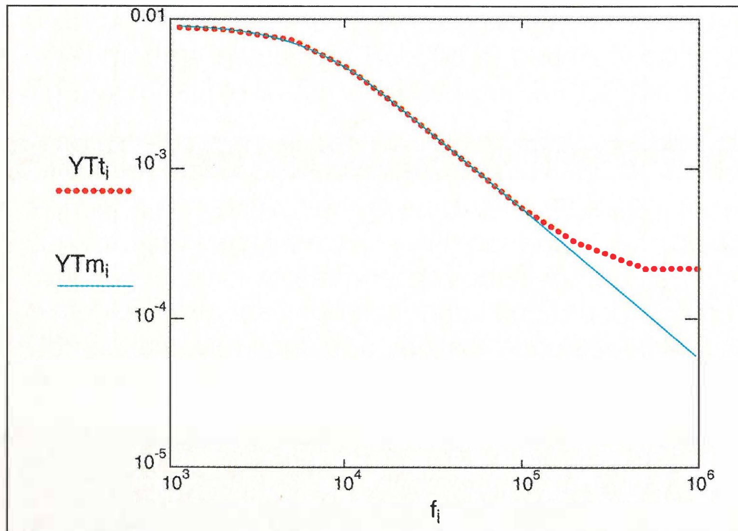


Figure 15: Response from the susceptibility test of the set-up, and from the circuit model. Blue line – response for **Figure 16**; red line – response for **Figure 14**

the two curves up to 100kHz and then the deviation becomes noticeable.

More importantly, though, another correlation emerges. The curves for susceptibility and emission are substantially the same. Perhaps this is not surprising in retrospect, when the two circuit models are compared. It is not difficult to show that, had the passive components of Figures 12 and 16 been the same, the transfer admittance curves would have been identical.

Conclusion

This article has described how two transformers can be constructed to carry out EMC checks during the bench-testing phase of a project. It has shown how they can be characterised and used to carry out simple emission and susceptibility checks. Most importantly, it shows how circuit models can be constructed to replicate the test results. These circuit models allow a much clearer picture of the coupling mechanism to emerge.

It is reasonable to expect that further development of the test equipment and circuit models will enable the observed anomalies to be resolved. However, the main point is that EMC is not a hyper-complex subject, understandable only by a few. It is as amenable to the design approach as any other aspect of electronics.

Detailed information on test data and formulae, including a step-by-step guide to the calculations, can be found in chapter 7 at:

www.designemc.info

Crystal filter simulations

Stef Niewiadomski has come up with a good and low-cost way of simulating crystal filters

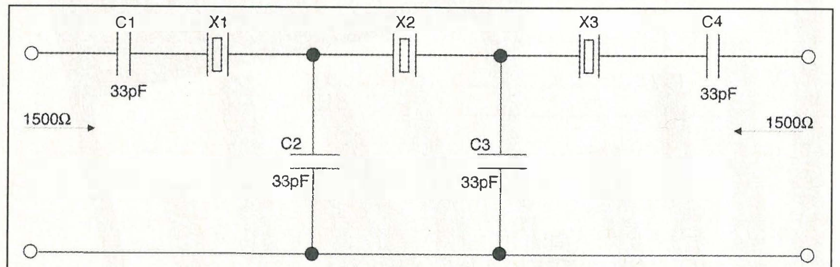


Figure 1: Circuit diagram of three crystal 4.433MHz SSB Cohn-type filter designed for 1500W drive and termination impedances

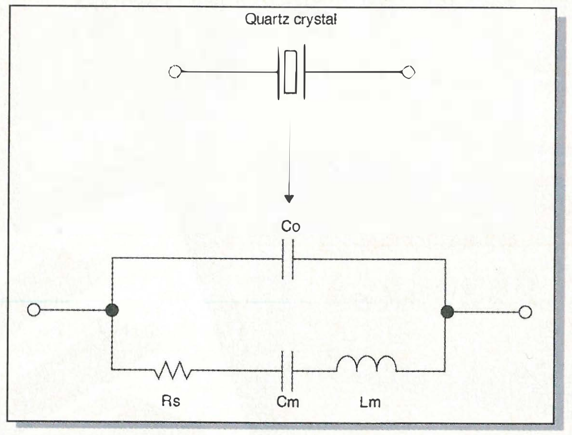


Figure 2 (inset): Quartz crystal symbol and its electrical equivalent circuit

Two obstacles have stood in the way of amateurs simulating crystal filter designs. Firstly, the difficulty and expense of obtaining an analogue (usually Spice-based) simulator, and secondly, the non-availability of traceable and reliable crystal parameters with which to model filter behaviour. This article will show that both of these obstacles have now been overcome.

I recently searched the web for a low-cost analogue simulator and found the free-of-charge SWCAD III on Linear Technology's website. It includes a circuit simulator, waveform viewer and schematic capture. Although this package is intended for the simulation of Linear Technology's range of switching regulators, it is a general-purpose tool and is eminently suitable for verifying many analogue circuits before building them. This simulation package was used to obtain the results shown here.

Simple 4.433MHz SSB filter

Figure 1 shows the circuit diagram of a three crystal 4.433MHz SSB filter, intended for use as an IF filter in an SSB receiver. This may seem like a strange IF frequency, but 4.433MHz crystals are very easy and cheap to obtain, because they are produced in their millions for use as colour burst crystals in TV sets. The filter is designed for source and termination impedances of 1500Ω. The good thing about this filter is that it uses crystals of nominally the same frequency, rather than many so-called "half-lattice" filters that need crystals with certain offsets, to operate correctly.

This filter (and other similar three-crystal filters) is a well-known circuit. I thought I'd start with this relatively simple circuit before progressing on to more complex filters, since first we need to understand how crystal behaviour can be modelled.

Crystal equivalent circuit

The behaviour of passive components such as resistors, capacitors and inductors is well understood, but how does a crystal behave at various frequencies? It's not too difficult to set up a test circuit with a signal generator and some sort of voltage measurement tool, and actually measure how a crystal responds, but it is not immediately obvious how to simulate a quartz crystal. What we need is an 'electrical equivalent circuit' of a crystal in terms of components that we understand and which are simple to simulate. **Figure 2** shows such an equivalent circuit of a crystal often used to analyse crystal resonances and simulate crystals on an analogue simulator.

The shunt capacitance C_o is the only real physical value in the equivalent circuit. This parameter is primarily formed from the electrodes of the crystal plus the strays of the holder, and can be measured with a capacitance meter. The motional arm components (C_m, L_m and R_s), on the other hand, are equivalents and therefore not real, but are useful when the behaviour of the crystal is being explained or predicted. Note that this equivalent is for the fundamental response only, and additional motional arms can be added for overtones and spurious responses.

Figure 3 shows how this equivalent circuit behaves at different frequencies. It is the peaks and troughs seen in the frequency response that are exploited in crystal-based filters.

An analogue simulator needs values for the four main components in the equivalent circuit to be able to accurately predict the crystal's behaviour. A typical set of values, found on the web is:

Crystal frequency: 4MHz
L_m: 197mH
C_m: 3.55fF (0.00355pF)
R_s: 48Ω
C_o: 3.5pF

As with much web-based information, the original source of this data is uncertain and so it is of no great value when the behaviour of filters using different batches of crystals needs to be checked.

I needed parameters for a range of crystals to investigate a number of filters. **Table 1** (page xx) contains measured parameters for a number of crystals from one vendor of crystals. For each crystal nominal frequency, five crystals have been analysed and their R_s, C_m, C_o and L_m values are shown in the table. These values would allow me to investigate the effect of using sets of identical crystals in a filter, but from different batches, on the response of the filter. The frequencies were chosen as being commonly used ones for amateur filter design.

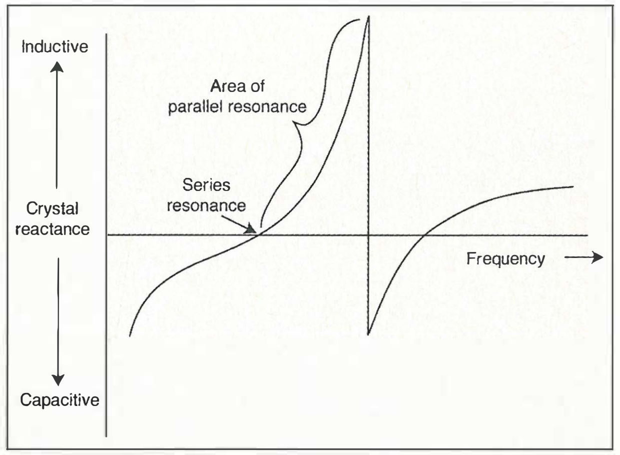


Figure 3: Plot of quartz crystal reactance versus frequency

Simulation results

Figure 4 shows the SWCAD III schematic of the filter from Figure 1. There are three versions of the filter, each identical except for the drive and termination resistors. I wanted to investigate the effect on the response of the filter of driving and

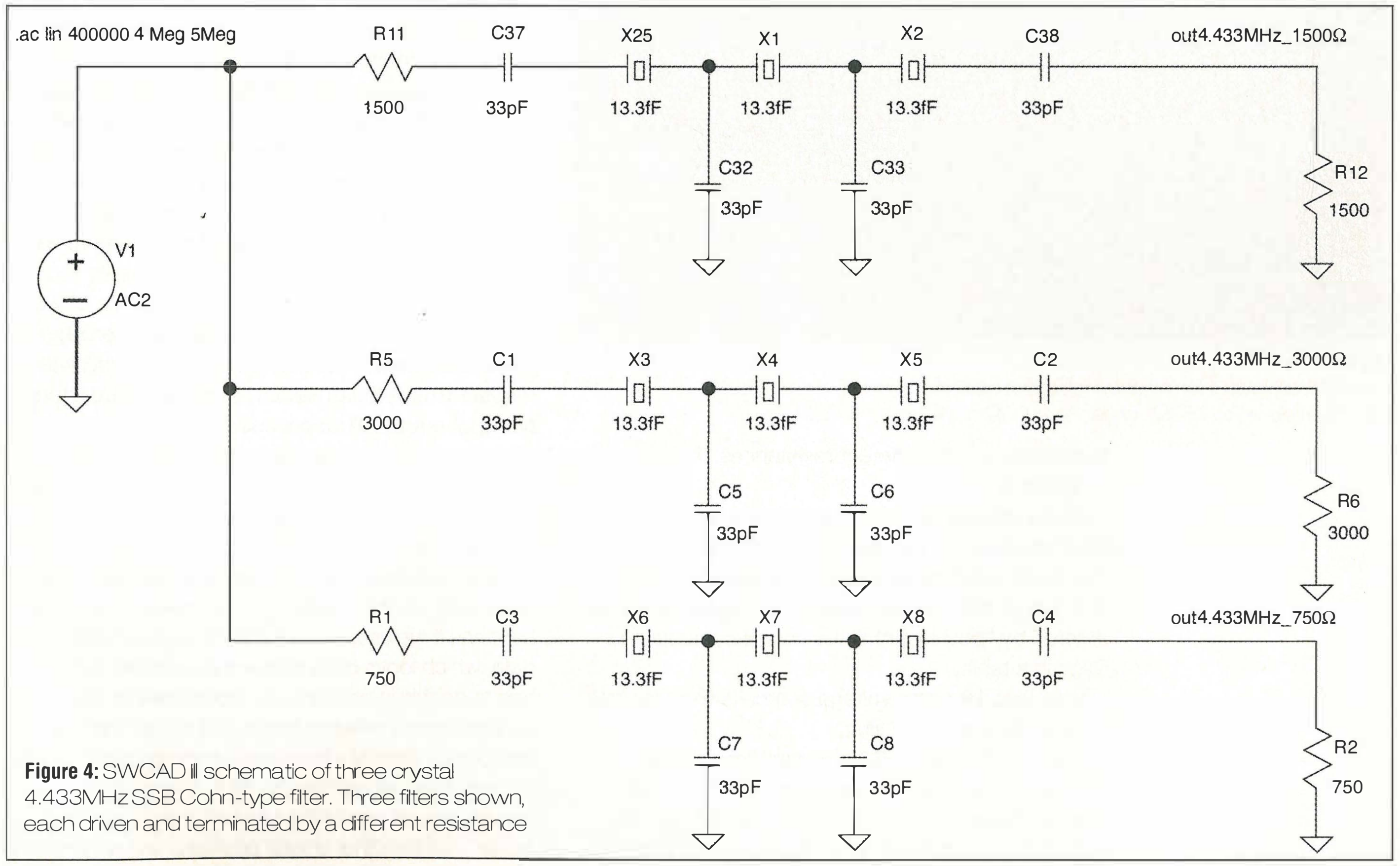


Figure 4: SWCAD III schematic of three crystal 4.433MHz SSB Cohn-type filter. Three filters shown, each driven and terminated by a different resistance

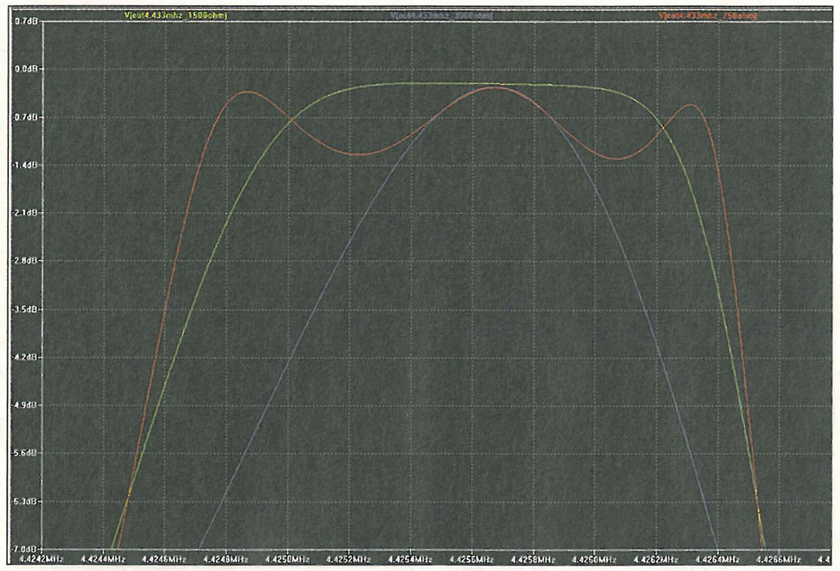


Figure 6: Simulated passband response of 4.433MHz three-crystal SSB filter for different drive and termination resistances (crystal number one model used). Red line relates to 750Ω , green to 1500Ω and blue to 3000Ω

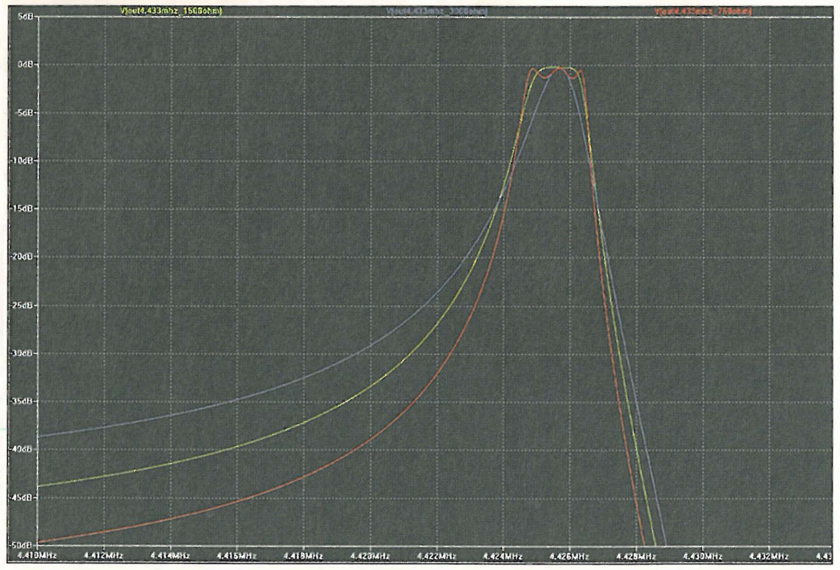


Figure 7: Simulated stopband response of 4.433MHz three-crystal SSB filter for different drive and termination resistance of crystal number two model. Red line relates to 750Ω , green to 1500Ω and blue to 3000Ω

terminating it with different resistances: 1500Ω, 3000Ω and 750Ω.

All the crystals are identical in this schematic: I have used crystal number 1 data from Table 1. The schematic shows the 13.3fF value set for C_m, and the full set of equivalent circuit values have been entered by "pushing into" the crystal symbols and filling in a table.

Note that the same voltage source is used for the three instances of the filter.

The ".ac lin 400000 4Meg 5Meg" line in Figure 4 means "generate an AC sweep of 400000 linearly-spaced frequencies from 4MHz to 5MHz". On the voltage source symbol, V1 is its circuit designation and AC2 means an AC source of 2V amplitude. The reason I chose 2V is explained later. These simulation parameters can easily be changed to suit the sweep needed for the circuit being simulated. Note that 400000 plot points is a large number, which would have taken hours on an old mainframe computer. On a 1.6GHz laptop this takes just a few seconds.

Figure 6 shows the simulated passband response of this filter, plotted for the three different drive and termination resistances. The 1500Ω response, which is the value where we expect the flattest response, is shown in green. This is indeed the response we get: the passband is flat and the -6dB bandwidth is about 2040Hz, which is the value the filter was designed to achieve. The red line shows the 750Ω response, and the effect on the passband: about 1dB of ripple can be seen. The blue line shows the 3000Ω response, and a narrowing of the passband can clearly be seen; the -6dB bandwidth is now about 1540Hz, probably on the lower limit for good speech reception (remember this is intended to be an SSB filter).

The centre frequency of the three responses is about 4.4256MHz.

The stopband response of the filter is shown in **Figure 7**, again for the 3000Ω, 1500Ω and 750Ω cases. This plot is interesting in that it shows how the 1dB of passband ripple in the 750Ω case has been "traded" for improved stopband response. At -36dB, the 750Ω response is about 6.5kHz narrower than the 1500Ω response, giving a worthwhile reduction in adjacent channel interference. As long as 1dB of passband ripple can be tolerated, all that is needed to achieve this improved stopband response is to drive and terminate the filter with the higher impedance value. In real terms, 1dB of passband ripple is trivial and would not be noticed against the other sources of passband ripple in the transmitter to receiver communication path.

Figures 6 and 7 show why an AC source of 2V was used, rather than 1V, to drive the filter. By default the amplitude plots are shown in dB with respect to 1V: the drive and terminating resistors, being of equal value, produce a potentiometer effect giving an apparent 6dB of loss, even if the filter itself is lossless. By setting the source to 2V, this effect is compensated for and the filter's insertion loss of about 0.2dB can be seen.

These simulation results were obtained using the 4.433MHz crystal number 1's parameters, but what happens if we use, say, 4.433MHz crystal number 3's data, which looks quite different to number 1's? If we had to do this in practice, we would have to buy crystals from a different batch and re-test the filter's response, which is a time-consuming process. Using the simulator, all we have to do is change the parameters on one of the crystals, then "copy and paste" into the other crystal positions and re-simulate.

Figure 8 shows the results from using 4.433MHz crystal number 3's parameters. Comparing them with Figure 6, no significant difference can be seen, except that the centre frequency has now moved by a small amount to 4.4285MHz. This shows that using crystals of different nominal frequencies is fine, as long they are all the same (within, say, 100Hz) in a given filter.

It would be an interesting exercise to try a mixture of crystal parameters from Table 1 in the same filter simulation.

This example shows how easy it is to investigate different circuit options using a simulator.

More complex SSB filter

The three-crystal filter is pretty simple, so it's worth checking out a more complex SSB filter, as shown in **Figure 9**, intended for use as an IF filter, but, also, maybe as a sideband filter in a transmitter. This uses 6MHz crystals and so we will use the 6.0MHz crystal number 1 parameters from Table 1.

Figures 10 and **11** show the results obtained. It can be seen that this is a very good SSB filter, having a -6dB bandwidth of 2700Hz and a -60dB bandwidth of 5920Hz, giving a 6:60dB shape factor of 1:2.2. A commercially produced SSB crystal filter with this sort of shape factor would be expensive, so it's worth noting that it is achieved with a handful of cheap crystals and capacitors.

The ultimate stopband response is shown going off towards -100dB, but it should be noted that this is unlikely to be achieved in practice because of leakage around the filter, and the non-ideal characteristics of the capacitors and the crystals. Typically, simulators do not model these real effects and so all simulation results need to be interpreted with a degree of common sense.

Three-crystal CW filter

Figure 12 shows the SWCAD III schematic of a three crystal "Hawker" CW filter, centred nominally on 12MHz. The original design for this filter used 9MHz crystals, but since I had parameters for 12MHz, I tried this filter at 12MHz.

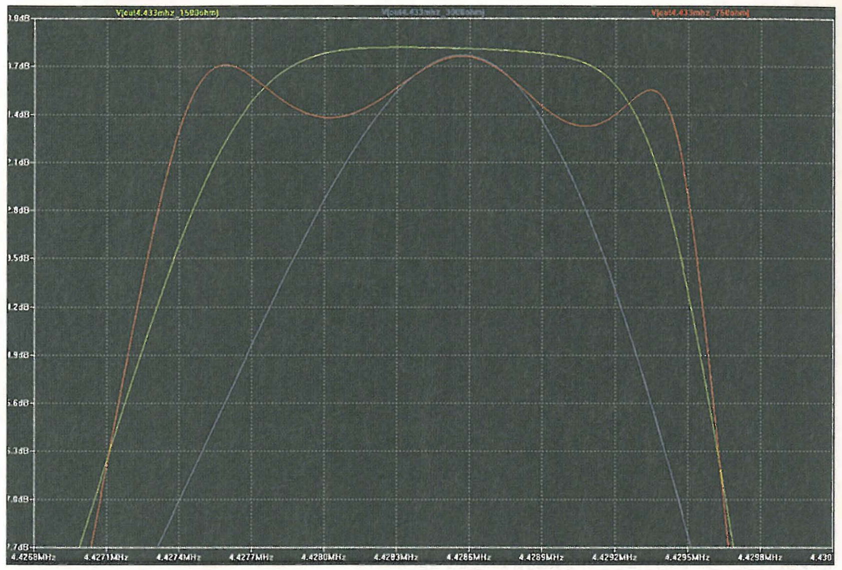


Figure 8: Simulated stopband response of 4.433MHz three-crystal SSB filter for different drive and termination resistance of crystal number three model. Red line relates to 750Ω , green to 1500Ω and blue to 3000Ω

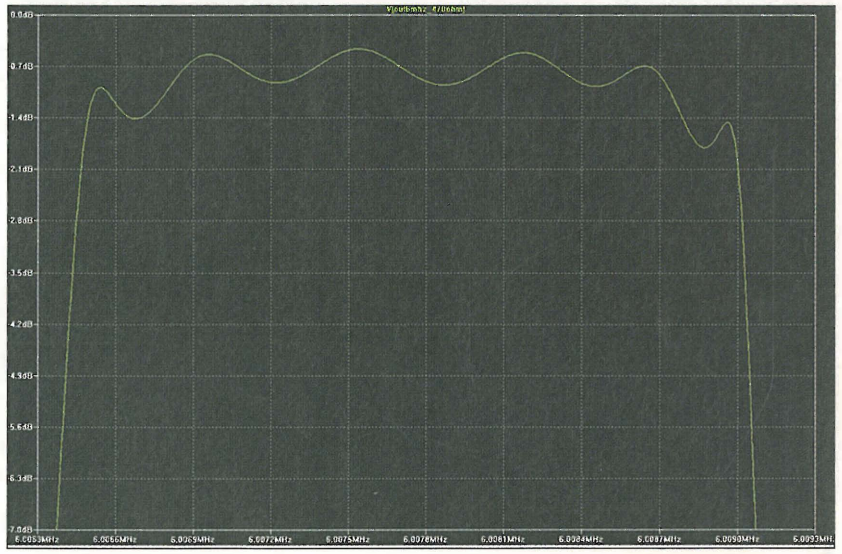


Figure 10: Simulated passband response of six-crystal 6.0MHz SSB filter (crystal number one). -6dB bandwith =2700Hz

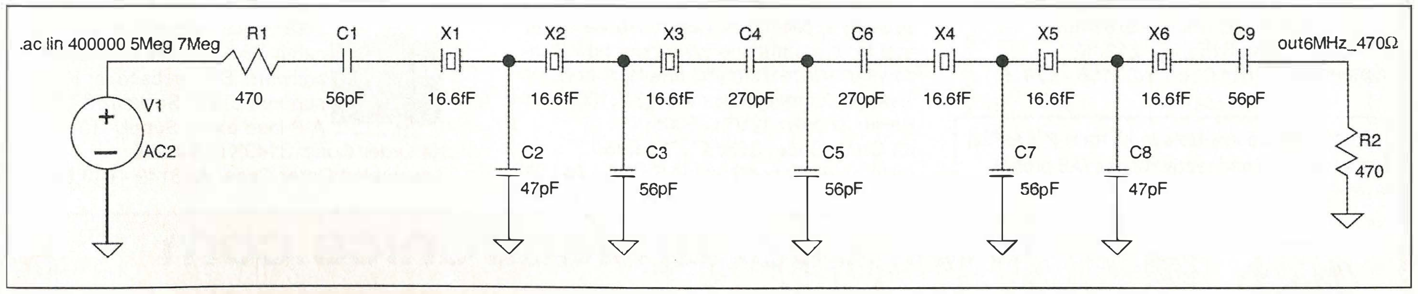


Figure 9: SWCAD III schematic of six crystal 6.0MHz SSB filter. Filter driven and terminated by 470Ω.

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Simulation results are shown in **Figure 13**. This filter has an insertion loss of 4dB, a -6dB (with respect to the passband response) bandwidth of 525Hz and a -60dB bandwidth of about 5620Hz. This would make an excellent CW filter in a receiver.

Simulator hints

Here are a few hints about this simulator that caught me out initially:

- Spice only accepts Meg as meaning million (for example in Megaohm). The annotations M and m mean milli in this package;
- SWCAD III calculates phase response as well as amplitude response (as shown in my results). Phase response plotting can be turned on and off by left-clicking in the phase scale display area (on the right hand side) and ticking the box;
- Many Spice simulators run a DC analysis of a circuit before running an AC analysis. This often means that all nodes in a circuit need a DC path to the voltage source, or to ground, to successfully establish the DC conditions. This can be achieved by adding very high value resistors from all DC-isolated nodes to ground. SWCAD III does not have this restriction, but it is worth bearing in mind for other simulators.

Driving and terminating the filters

There are many ways to include crystal filters in real applications. **Figure 14** shows some of them.

In Figure 14 (a), the filter's drive impedance is given by the drain resistor of the dual-gate MOSFET that has been used as the mixer. The filter is terminated with a resistor, whose DC effect is isolated from the following transistor stage by a blocking capacitor.

In Figure 14 (b) the mixer (and maybe also the local oscillator) uses an NE602 IC, whose output impedance of 1500Ω drives the filter. Again a resistor terminates the filter, in parallel with the input impedance of the MC1350 IF amplifier. Typically, the NE602 has output and input impedances of 1500Ω and the MC1350 has an input impedance of 3000Ω.

If these impedances do not match the needs of the filter, a broadband transformer needs to be used to transform the impedance. Sometimes it can be a good idea to insert a resistor attenuator pad (of maybe 3dB) between the secondary of the transformer and the filter.

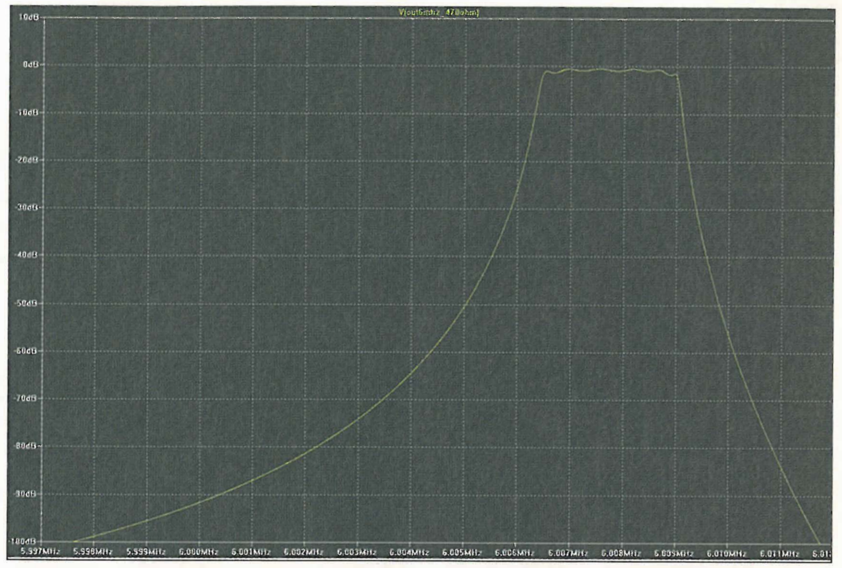


Figure 11: Simulated stopband response of six-crystal 6.0MHz SSB filter (crystal number one). -60dB bandwidth =5920Hz.

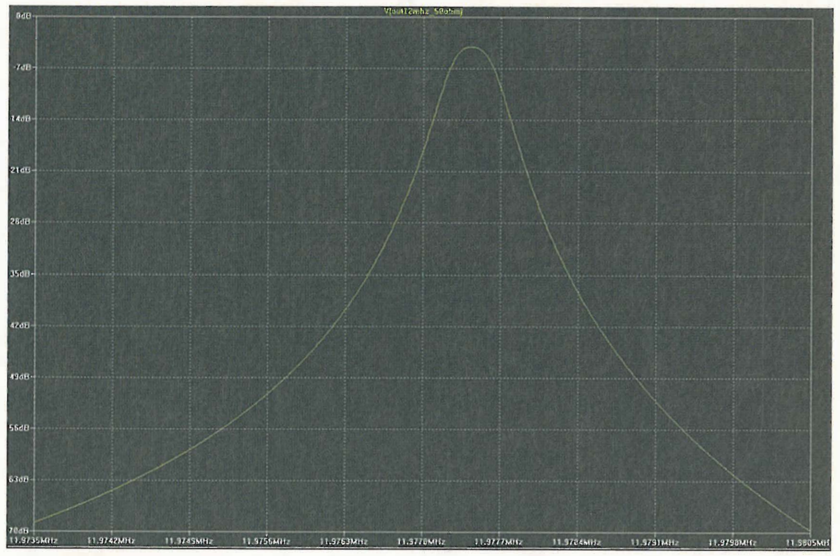


Figure 13: Simulation response of "Hawker" CW filter. -60dB bandwidth = 5620Hz

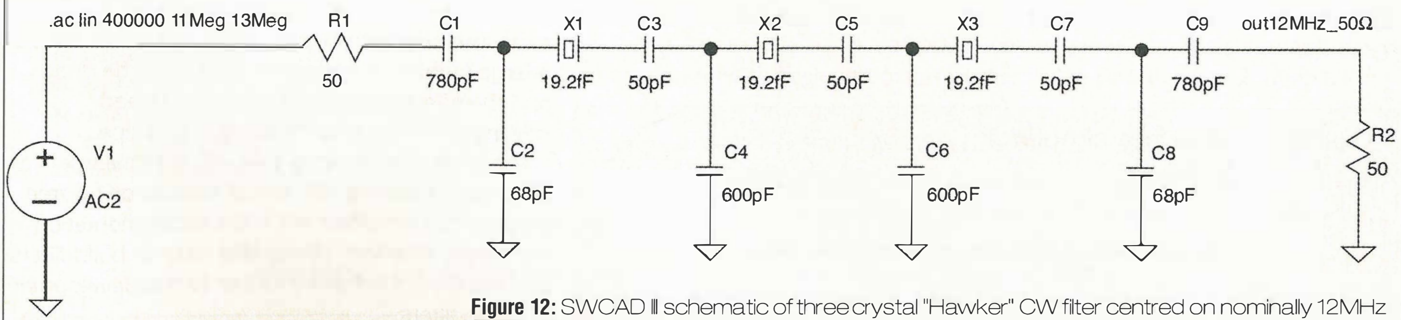


Figure 12: SWCAD III schematic of three crystal "Hawker" CW filter centred on nominally 12MHz

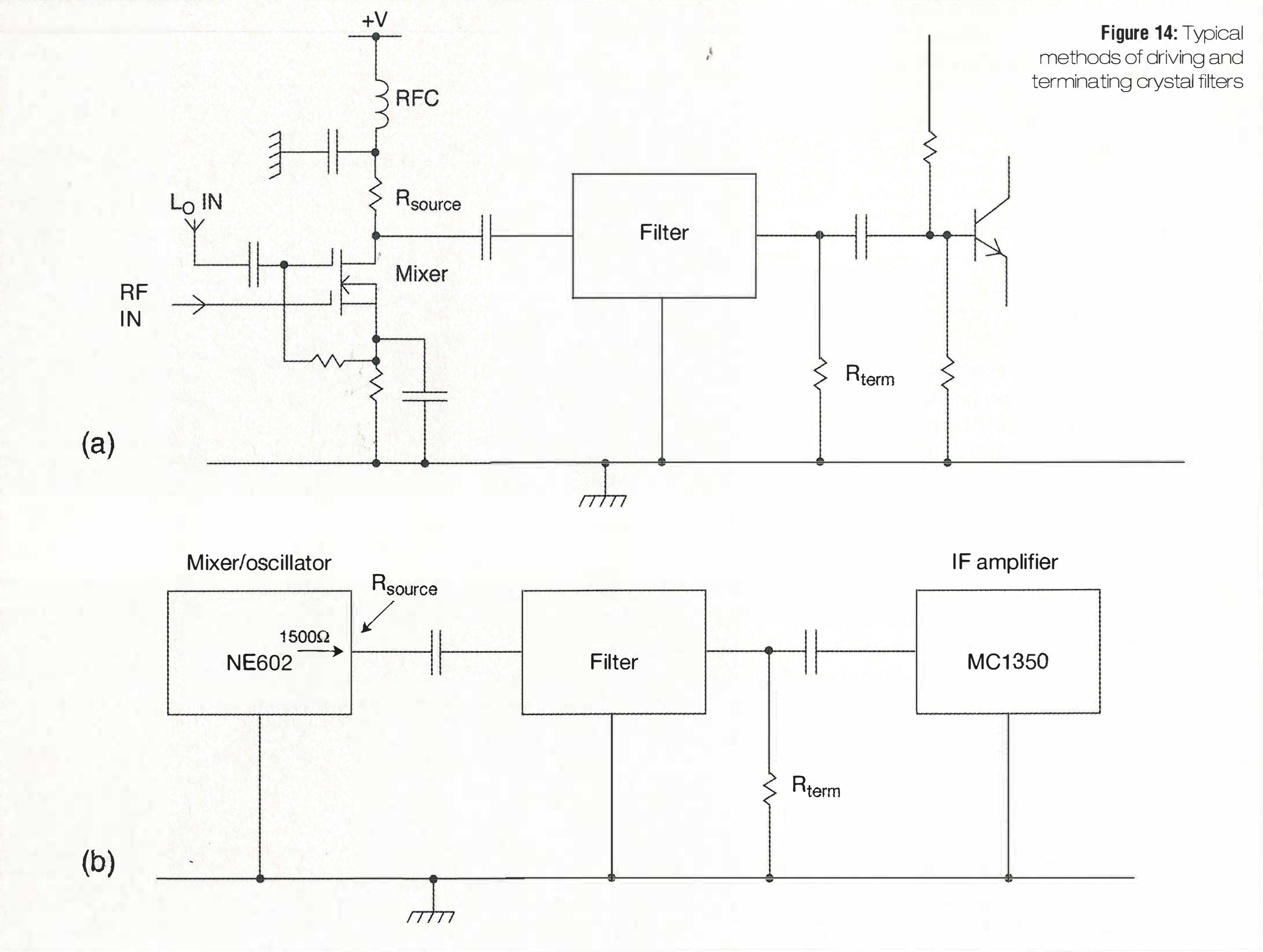


Figure 14: Typical methods of driving and terminating crystal filters

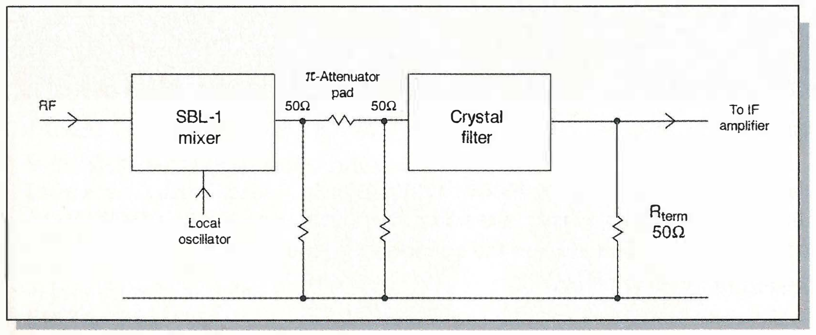


Figure 15: SBL-1 passive mixer with resistor π-attenuator pad between mixer and crystal filter

Another configuration is shown in **Figure 15**. Here, an SBL-1 passive balanced mixer is used to generate the IF signal. To get the best performance from these mixers it is best to terminate them resistively with 50Ω over a broad frequency range. To achieve this a pi-attenuator of say 3dB has been inserted between the SBL-1 and the crystal filter. Here, the filter needs to be designed to operate with 50Ω drive and termination.

Conclusion

An analogue simulator is a great way of experimenting with circuit values, especially where a large number of experiments need to be done and the effects are subtle and would need advanced test gear to measure in practice.

The Linear Technology SWCAD III simulator is an easy way of getting into circuit simulation for free.

Use of the simulator will allow experimentation with these effective, cheap and easy to build filters, and hopefully contribute further to the development of these filters.

Getting hold of the simulator

The schematic capture and Spice simulator package used in these experiments was downloaded free of charge from

http://www.linear.com/software/

My thanks go to Linear Technology for making this package available to all.

Table 1: Measured parameters for a number of crystals

Nominal crystal frequency (MHz)	Crystal number	Co (pf)	Rs (Ω)	Cm (fF)	Lm (mH)
3.579545	1	3.1	35.5	11.6	170.7
	2	3.1	24.5	10.6	186.1
	3	3.2	23.5	10.9	181.9
	4	3.1	33.0	11.3	174.5
	5	3.2	26.2	11.2	175.8
4.000000	1	3.6	14.6	12.5	126.3
	2	3.6	18.7	11.2	141.9
	3	3.7	16.0	12.4	127.5
	4	3.6	13.0	12.1	130.4
	5	3.6	17.5	11.2	141.3
4.433619	1	3.9	12.0	13.3	97.3
	2	3.8	14.7	14.7	87.6
	3	3.8	25.7	16.3	79.3
	4	3.9	17.0	15.1	85.3
	5	3.7	23.2	15.6	82.9
6.000000	1	3.5	6.8	16.6	42.3
	2	3.6	7.6	16.4	43.0
	3	3.5	9.0	16.2	43.5
	4	3.6	8.7	16.2	43.5
	5	3.5	8.8	15.9	44.2
12.000000	1	4.4	5.9	19.2	9.2
	2	4.4	5.9	19.7	9.0
	3	4.5	9.7	19.2	9.2
	4	4.4	5.4	20.1	8.8
	5	4.4	5.1	19.7	8.9
16.000000	1	4.9	3.1	21.0	4.7
	2	4.9	10.9	21.5	4.6
	3	5.6	4.3	20.8	4.8
	4	4.9	3.3	20.7	4.8
	5	5.0	5.5	20.5	4.8

Harnessing Wave POWER

Gregg Grant looks into the history of wave-generating energy and how to make the most of it.

Wind generates energy in many ways: by itself, but also by creating waves on the seas and oceans, which, in turn, generate energy too. At similar wind speeds, there is more wind power at a coastal location than at Ben Nevis or Snowdonia, as seen in **Table 1**.

In a gale, waves can reach some 25m from trough to crest. Measurements have shown that the average power of waves in the Atlantic Ocean, over a 12-month period, is around 100kW per metre of wave front. However this figure drops by about half close to the British coastline.

Table 1: Change in air density with elevation

Elevation (metres)	*Change in density*
0	100%
500	99%
1000	97%
2000	94%
3000	91%
4000	88%
5000	85%

The energy increases with the square of the wave height and varies with time, the peak, for example, coinciding with the peak energy demand during winter.

Past waves

Wave energy is not a new idea. It's a descendant of the water wheel, the earliest example of which is the Persian Wheel, dating from 200BC. By around 85BC, water wheels were being used to grind corn and two probable mill sites have been tentatively identified close to Hadrian's Wall in northern England.

Another example is the sophisticated battery of mills at Barbegal in southern France. It's possible that this arrangement produced enough flour for 80,000 people in its final version, towards the end of the Roman Empire. Water mills proliferated in Britain throughout the Middle Ages and remained a major part of agricultural and industrial life until the coming of steam power in the mid-18th century.

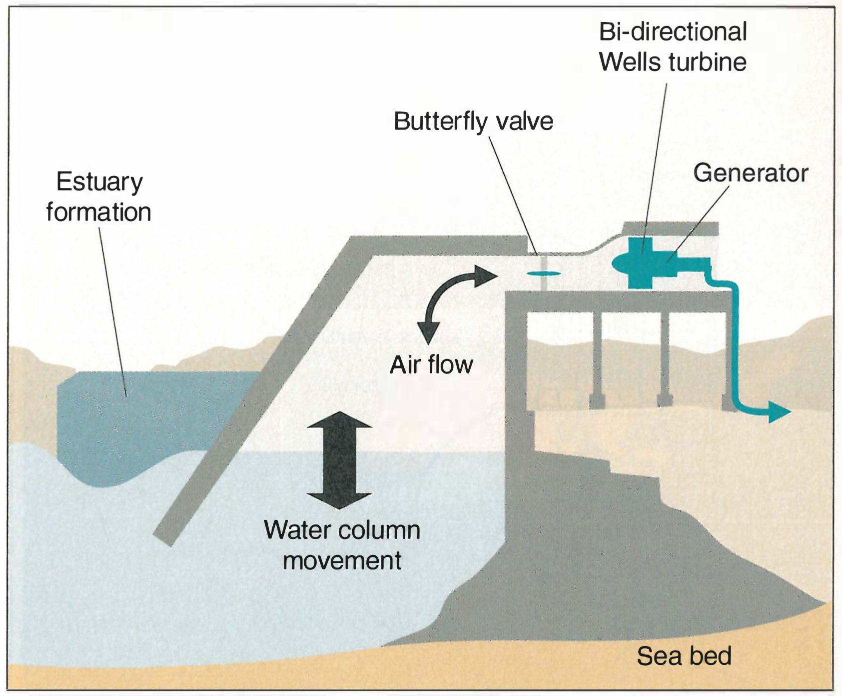
In the final year of that century however, came the first patent application for a wave energy device, filed in Paris by a father and son called Girard. This was basically a massive lever, with its fulcrum on the shore and its body floating on the open sea. As the body rose and fell with the waves, the lever's up and down motion could be used to drive mills, saws and others.

Thomas Edison also saw great potential in wave energy. He proposed that dynamos moored in a harbour and driven by the waves could power harbour-warning lights.

Compared to wind power, wave power is still in its early stages. Wave power studies in Japan began in the 1940s, because it was thought that wave power for small islands had a future.

British interest in the subject dates from 1944. During the Allied invasion of Europe, landing craft were faced with problems, which pushed the Admiralty into setting up the Research Laboratory Group Waves. In time, this laboratory became the National Institute of Oceanography, now known as the Institute of Oceanographic Sciences (IOS).

As a result of the Institute's work, especially during the early years of the North Sea oil boom, engineers and scientists discovered how waves behaved and what was required to capture their motion and transform it into useful energy. They knew how to absorb a fluctuating supply and use it so that the lights wouldn't so much as flicker let alone go out.



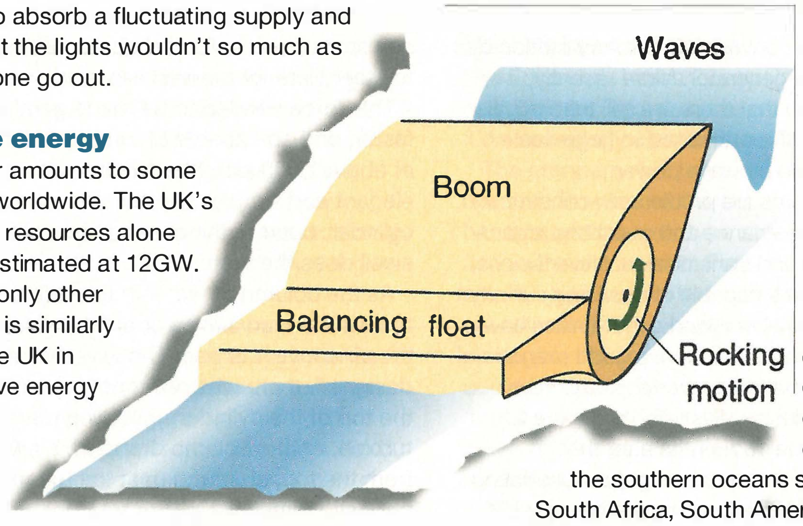


Figure 1 (left): Rocking boom converter

Figure 2 (above): Islay wave power system

Available energy

Wave power amounts to some 10^{12} Watts worldwide. The UK's wave power resources alone have been estimated at 12GW. Indeed, the only other country that is similarly placed to the UK in terms of wave energy is Japan.

An ocean wave hitting the UK's western coastline has a power level that varies from virtually zero on calm days to some 10,000kW where the biggest waves are concerned. The average power is around 70kW/m.

In terms of total power, estimates suggest 1TW hitting the coast – a figure close to the planet's current electricity production. In the open ocean, the energy available is roughly ten times the coastal figure and near to the world's current power consumption.

Such figures mean coping with the highest demand for half an hour on the coldest day of a savagely cold winter. Furthermore, this energy source won't dry up.

Much of the current information on wave dynamics has come from satellites such as the European Space Agency's (ESA's) ERS-1 vehicles, launched in 1991. Many of these vehicles have on-board radar altimeters that give sea surface data, wind speed and wave height.

As a result of this type of monitoring, countries with coastlines facing the southern oceans such as Australia, South Africa, South America and New Zealand have as great a potential for wave power generation as those in the northern hemisphere.

The Islay experiment

A number of imaginative wave energy devices have been proposed, some of which have not even made it to the design stage. Others have been built and tested at sites in Europe and America. The best of these extract about half of available wave energy and convert about half of that into electrical power.

If the power level were 60kW/m, the output power would be around a quarter of this, 15kW/m of wave front intercepted by the converting device, one example of which is the Rocking Boom converter, shown in **Figure 1**.

In practical terms, the slow, oscillatory motion of

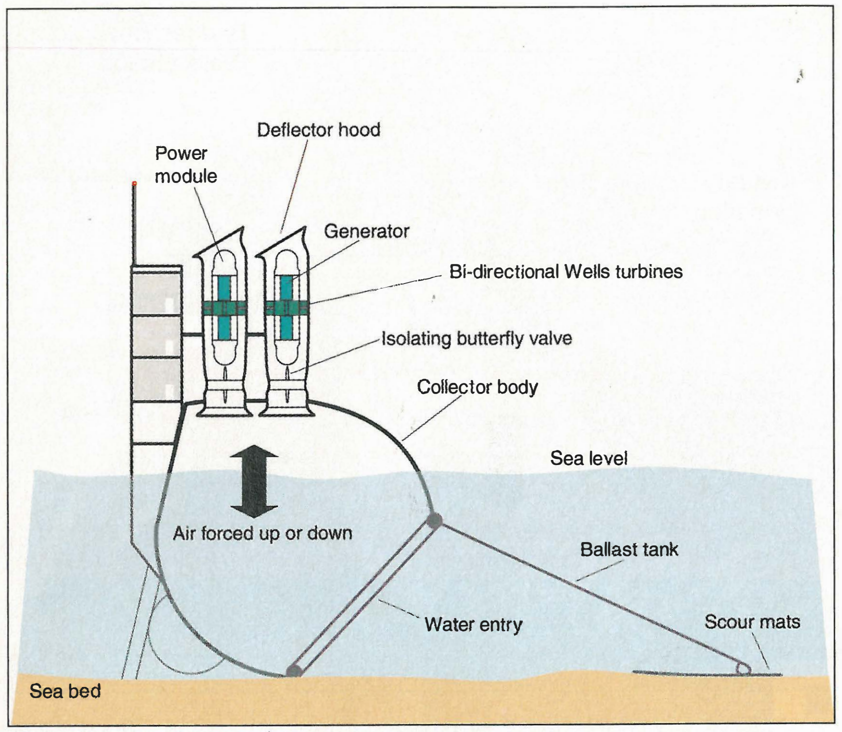


Figure 3 : The final version of the Osprey system

the waves must be converted into rotary motion by a turbine, to drive a generator. More recently, research has shown that there are still theoretical and technical difficulties attached to large-scale electricity generation by wave power.

Among the concerns are problems in construction, difficulties with maintenance and questions regarding energy transfer and transmission. Nevertheless, scaled-down systems capable of providing sufficient power to small coastal or island communities have been built and put into operation, a good example of which is the shore-based converter on the Inner Hebridean island of Islay, illustrated in **Figure 2**.

In May 1987, some 18 months after the Norwegian government had brought an Oscillating Water Column (OWC) device into service, the UK government decided to support the building of a wave energy device on Islay.

Built by a team from Queen's University Belfast (QUB), led by Professor Trevor Whittaker, the Islay unit was a hybrid of two modified Norwegian wave energy devices, the OWC and the Tapering Channel (Tapchan).

In effect a concrete fortress, designed to cope with wave pressure of 40t/m, the waves were caught in a V-shaped trough that, as it became narrower, accelerated the wave movement. Consequently, they sped to the end of the trough, stormed into the OWC and forced a shaft of air upwards, which rotated a turbine.

In shallow water, however, there is an energy loss from friction, which means that the 70kW/m obtainable in the ocean swell is reduced to 8kW/m inshore. Nevertheless, the modified Tapchan (the V-shaped trough) increased the inshore value to around 25kW/m.

The Islay station weighed in at 450t, some 70% of which had been pre-cast in Northern Ireland and shipped to the site at Portnahaven. It was this structure that withstood the Atlantic Ocean for seven winters and won its designer, Professor Whittaker, the prestigious Royal Society's Esso Energy award in 1994, just as the government decided to cut off support for the work.

However, the Islay project was the inspiration for other wave generators, in particular the one at Porto Cachorro, on Pico Island in the Azores.

The Oscillating Water Column (OWC)

The inventor of this ingenious device was Professor Yoshio Masuda, a former Commander in the Japanese navy. He was the first man to realise that water could be used to power a column of air which, in turn, could be used to generate electricity. The problem was that, whilst waves hit the shore every seven to eight seconds, they frequently do so with such force that they can smash sea walls and do tremendous damage to steel piers, or moored vessels.

This force needed to be made gentler and faster, and so capable of turning a turbo generator at above1,000rpm. Masuda's solution was at once elegant and simple: trap the waves inside a cylinder, open to the ocean at its base. The ocean swell does the rest.

As the column of water in the cylinder mimicked the waves every seven or eight seconds, it forced the air above it to rise. The way the device was designed, there was only one exit for the air: at the top of the cylinder, powering past an air turbine. As the column dropped, air was sucked in from the top, storming past the turbine in the opposite direction.

Masuda had patented a wave-powered navigation buoy as early as 1947.

Salter's duck

The duck is an invention of scientist-engineer Professor Stephen Salter. It has been tested in a 30m x 12m tank at 1/50th scale. The spine of the structure on which the ducks pivot had a diameter of 10cm. Later, a larger model of 1/15th scale, with a spine diameter of 1m was tested on Loch Ness in Scotland.

Salter envisaged that a full-scale duck in the open sea would have a spine 15m in diameter with the duck's beak – made of concrete – measuring more than 30m. To produce between 30MW and 50MW of electrical power would require some 30 ducks mounted on one spine with separators between each one, giving a wave energy generating device some 1,200m long.

Since 1981, Professor Salter has modified and improved the design of both his brainchild and its method of converting wave motion into electrical power. That said, his duck remains one of the few devices designed to operate – and survive – in the roughest seas on the planet.

The Wells turbine

Professor Alan Wells, another QUB man, designed a turbine that is now named after him. It takes air from either above or below as the OWC sucks and blows in response to the ocean waves.

The turbine however has another important feature: no matter what route the air takes, the turbine always rotates in the same direction. The Wells turbine may, though, be replaced in the future by variable pitch turbines, which some renewable energy experts regard as the way forward. The reasoning is that they will begin to spin more quickly, even in a calm sea, thus being more efficient.

The OSPREY system

Professor Wells was also the designer of the Ocean Swell-Powered Renewable EnergY (OSPREY) system. In 1993, the OSPREY was offered industrial support by, among others, British Steel, the General Electric Company (GEC), Scottish Hydroelectric and Atomic Energy Authority (AEA) Technology, but not by the government of the day.

The first design suffered from a lack of ballast and, after some re-designing, the system was designed to have four of its creator's turbines, each rated at 500kW (**Figure 3**).

The machine was, in effect, a 28m-high OWC, standing on the ocean floor 14m deep, with the turbines and generator above the water. Located some 300m off Dounreay, in the north of Scotland, the device's generating efficiency was rated at 60% and annual availability at 91%, giving a yearly power output of 3.3GWh.

Looking like nothing so much as a twin conning-towered submarine, the collection area was 20m wide, 20m deep and 20m high, with its roof above the waves. The twin towers housed the four Wells turbines and a GEC Flowpak generator.

The system was designed to supply a fixed power to the national grid and to enable the turbines to operate at the optimum mean speed. Sadly, however, the OSPREY did not survive even calm water, let alone the harsh conditions off the north coast of Scotland and so was discontinued in the late 1990s.

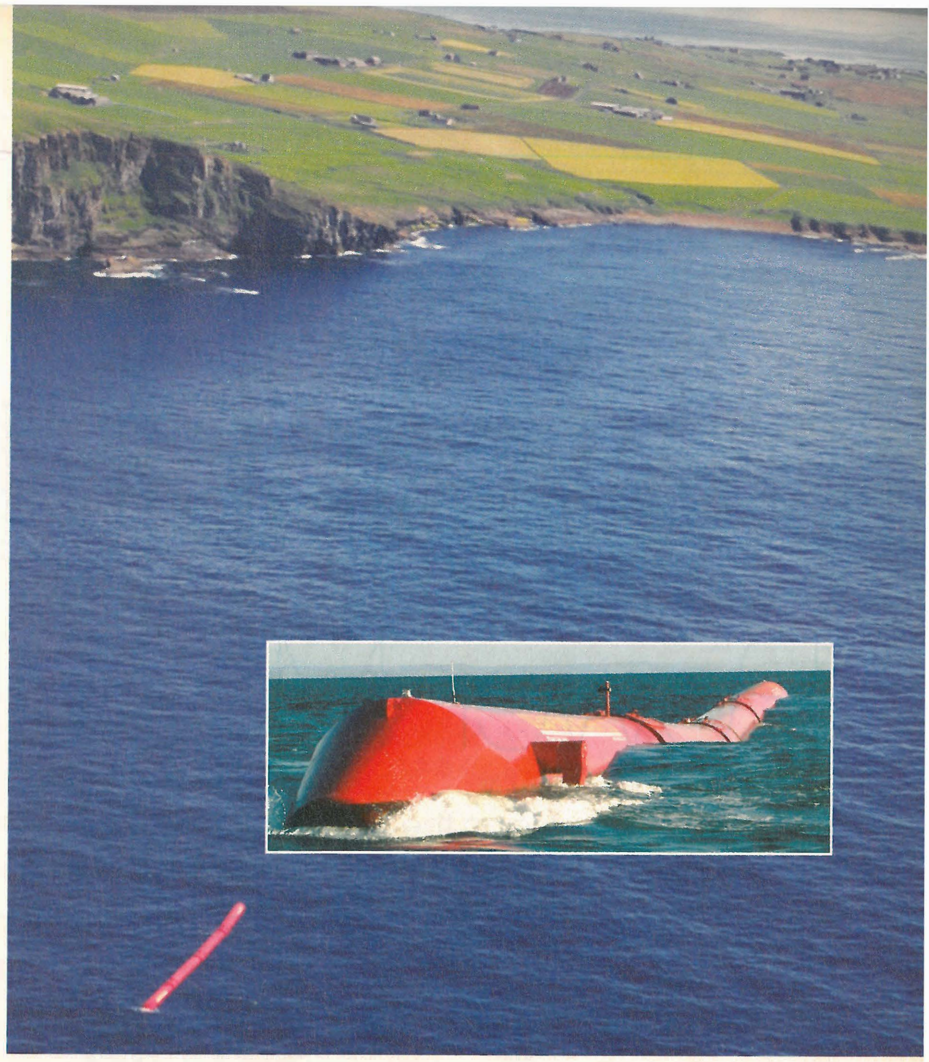


Figure 4 and inset : The Pelamis system in operation

The Pelamis device

The Edinburgh-based Ocean Power Delivery Ltd. designed the Pelamis wave energy converter, basing it on technology used by the offshore industry.

The company – in tandem with its partners Scottish Power and the construction giant Amec – has brought its prototype system on stream after five years of research. **Figure 4** and **inset** show what Pelamis looks like in operation, each individual cylinder being around the size of four railway carriages. It's envisaged that the individual units could be arranged as a 'wave farm' of interlinked 'multi-machines,' the power generated being taken ashore by a single cable. This is the first full-scale sea trial for wave conversion technology and it's estimated that a typical 30MW farm could be accommodated in 1km^2 of ocean, providing electrical power to some 20,000 homes.

Looking ahead

Writing in 1980 Sir Hermann Bondi, a former chief scientific advisor to the UK government, noted that if the nation failed to exploit its natural energy resources, no one else would do it for them. He also observed that, back then, the government of the day had no single preferred solution in renewable energy, which explains why the generating industry has shown reluctance to get involved.

That said, no renewable power generation technology currently meets the three iconic tests: technical reliability, economic viability and environmental acceptability. Pelamis could change this, with sea power becoming a reality at last.

Simulating Power Mosfets (part 4)

Using the Micro-cap6 software, Cyril Bateman explores simulation of distortion in audio power Mosfet amplifiers

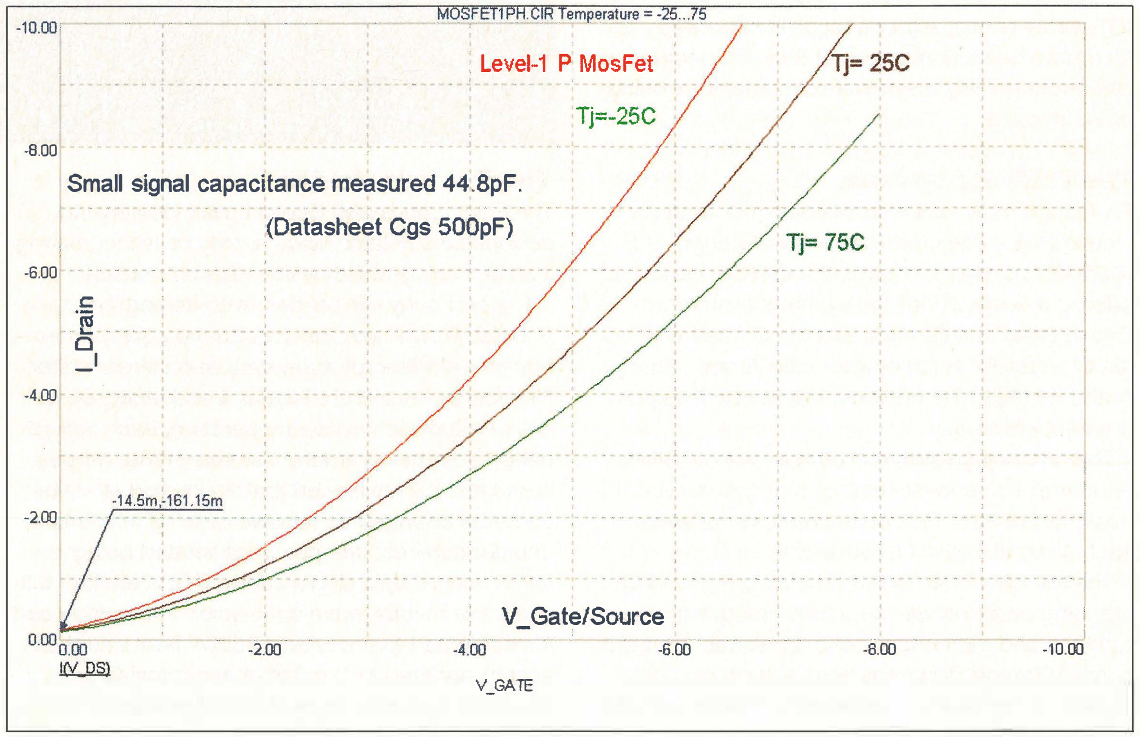


Figure 1: These transfer characteristics were plotted using the Level-1 model for a popular lateral power Mosfet used in amplifier circuits

Spice2 power Mosfet models are available in various formats, by far the most common being the Level-1 model. That is the easiest model to produce using information extracted from a datasheet. Most simulators are provided with a 'model' creation program that can produce a Level-1 model. The simplest way to identify such a model is to check the notation used within a schematic circuit, Level-1 models are numbered as M1, M2 etc., while the slightly larger, usually more capable subcircuit models will be identified as X1, X2 etc.

When modelling a typical audio power amplifier, two important criteria are the bias current applied to the power devices and amplifier distortion. Using power Mosfet output stages, correct modelling of the device's sub-threshold region – the area of low drain current as the transfer characteristic changes from almost no drain current to commencing a square law characteristic – is crucial. If sub-threshold is badly modelled, the reported bias current will be wrong and crossover distortion usually overstated, leading to gross errors.

Spice2 Level-1 models were designed to simulate a small signal Mosfet so cannot accurately model a power Mosfet in this sub-threshold region. Two common problems emerge; perhaps the worst is when the model indicates significant drain current with zero gate-source voltage, invalidating the simulated bias current. The second and more usual problem is the model's drain current gate-source transfer curves cannot follow that measured for the power Mosfet, so overstate the drain currents for small drive voltages. Both faults are clearly evident in this plot made using a Level-1 model as shown in **Figure 1**.

Subcircuit models vary widely in modelling ability, ranging from a simple Level-1 with added external capacitances and diodes to better model those found in a power Mosfet, to a complex model able to accurately replicate the Mosfet behaviour when used in either linear or switching circuits. A side effect of Spice2 is that the more complex the model used, the greater the convergence difficulty. Since switching applications are the most common, makers may provide the least complex subcircuit able to accurately model switching applications. Such subcircuits may not work well when used to design an audio amplifier.

Identifying good audio models

A good model able to properly model bias currents and distortion may be identified by examining the netlist using a text editor, such as Windows Notepad. Many models clearly state their originating method, date created and known limitations in use. Of these the creation date is significant because of the many improvements made in recent years to the power Mosfet manufacturing processes. Almost certainly an outdated model will not be worth evaluating.

The most certain method, regardless of model level or subcircuit, is, to run a DC plot to ascertain the transfer characteristics using the datasheet temperatures and voltages, then compare your simulation with the datasheet values. Displaying the sub-threshold region will confirm just how well or badly this region has been modelled with change of temperature.

A variety of behaviours can be observed by comparing plots from different models, Level-1 or subcircuits, intended to model the same or identical/equivalent transistors. In addition to the two faults already discussed, the temperature characteristics of many models change too little with temperature, very much less than shown in the datasheets. Using a model supplied with your simulator or by the transistor maker, does not guarantee the model is suitable for use designing audio amplifiers. See **Figures 2** to **4**.

Spice2 Level-2 and Level-3 models which include a value for 'NFS' or 'Fast Surface State Density'[1] may simulate this sub-threshold region quite well, but even for these models a confirming plot is still

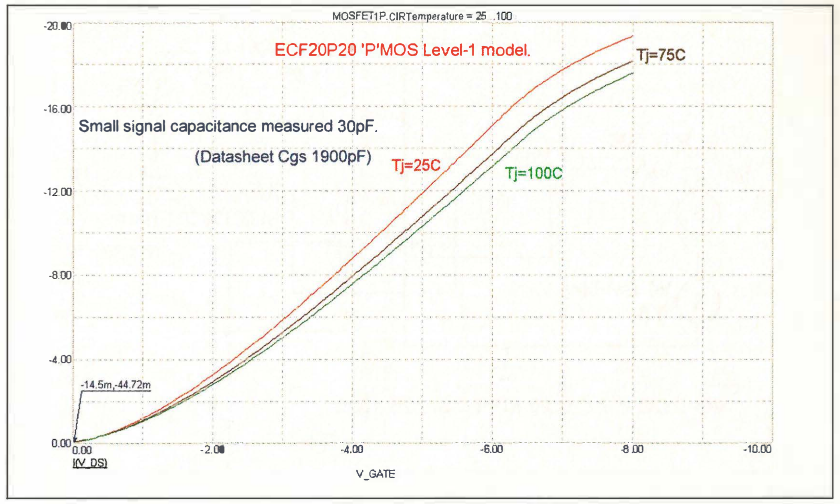


Figure 2: Another Level-1 model showing poor correlation with the datasheet curves

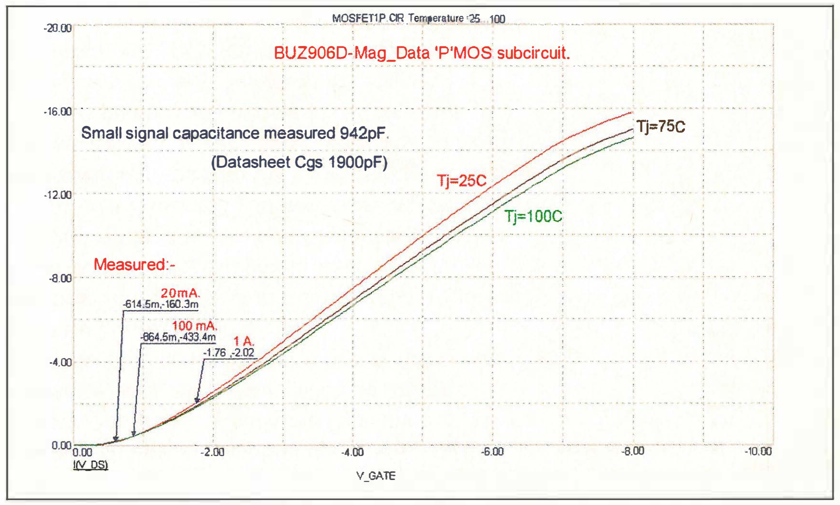


Figure 3: At 2A and lesser currents as shown, drain current is at least double that actually measured on my samples

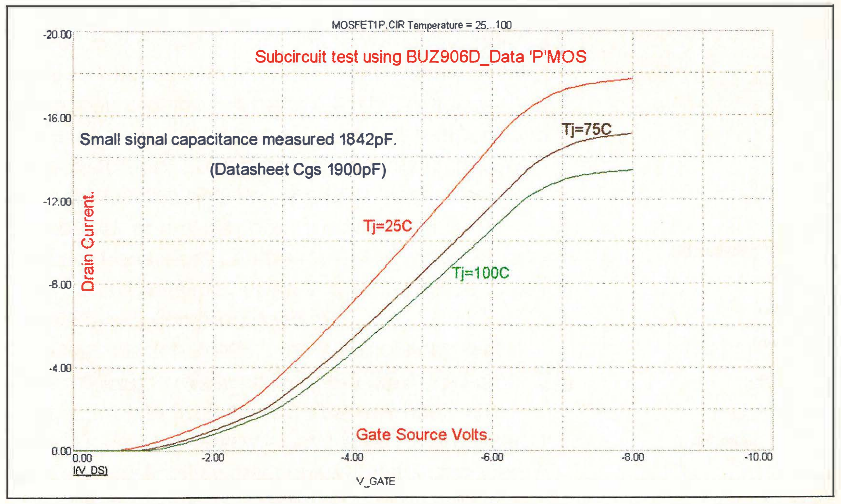


Figure 4: This plot shows close agreement with measured values below 3A and with datasheet values up to some 12A

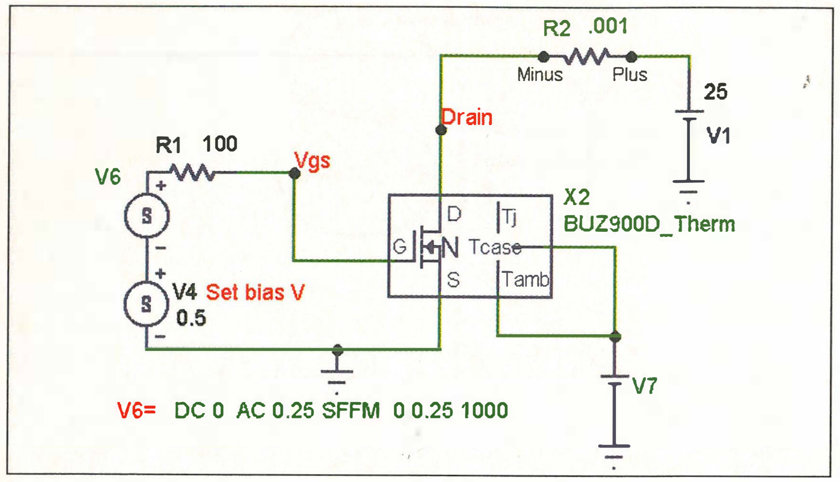


Figure 5: This circuit can be used to make certain the Mosfet capacitances are correctly modelled as needed to simulate an amplifier's closed loop frequency response. Reverse the DC voltages shown, when checking a P Mosfet.

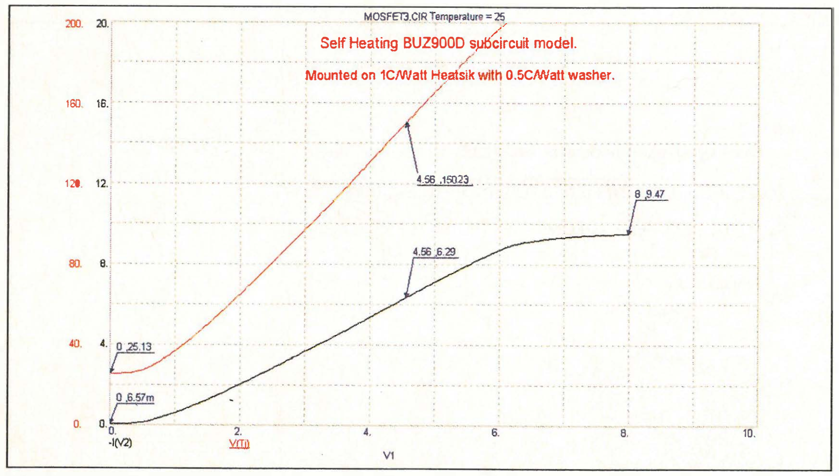


Figure 6: A plot using a self-heating model with 0.5°C washer and 1°C heatsink. With less than 5V drive, the transistor junction temperature exceeds its permitted maximum. With increasing junction temperature, the $R_{ds(on)}$ increases sufficiently to reduce drain current from the infinite heatsink value to just 9.5A

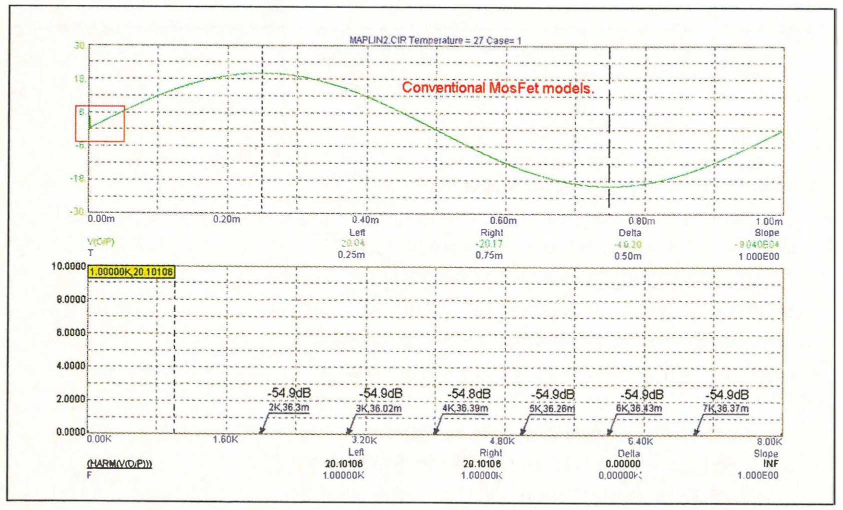


Figure 7: Using the model from Figure 1 with its complement in the Maplin amplifier circuit, shows a significant start-up transient caused by the models' excessive no-bias drain current. This is reflected in the exceptionally poor distortion simulations.

advised, before using such models for audio design.

No doubt at some time you will need to model the AC small signal frequency response in order to check an amplifier's closed loop stability, this requires one further check of a model. A power Mosfet exhibits significant input capacitances which can be modelled using the bias current and drain-source voltage as used in the amplifier. This was not well modelled in **Figures 1** to **3**.

Power Mosfet characteristics do change with temperature, especially in the sub-threshold region, which determines drain current with small gate-source voltages, so affects bias current and crossover distortion. On resistance $R_{ds(on)}$ increases rapidly with junction temperature. In a closed loop feedback system, if the Mosfet gate-source drive voltage is increased to maintain the desired output current. The increasing of $R_{ds(on)}$ increases the power dissipated in the transistor, further increasing junction temperature. Eventually, it may result in device failure.

Such changes can easily be missed using traditional models with the simulation temperature set by the Spice2 controlled global junction temperature become apparent using a 'self-heating' model, the subject of my last article. A self-heating model continuously monitors power dissipated in the device to determine its junction temperature and the Mosfet characteristics, so provides a most realistic modelling of bias currents, harmonic distortions and $R_{ds(on)}$. See **Figure 6**.

Modelling distortion using Spice2

The basic Spice2 software provides a variety of methods to examine circuit distortion, however, one method, called 'DISTO' is best avoided because it calculates distortion using an AC small signal analysis, so is not representative of a power amplifier.

The more usual large signal distortion calculations use a Fourier transform to calculate distortion components, having completed a transient analysis of the circuit. This can be output either as individual harmonic components related to the fundamental, or as a running total of %THD.

MC6 provides a variety of maths functions called 'DSP' operators, which can be used together with the Fourier transform to provide different outputs. 'HARM' produces the amplitude of individual harmonics of the waveform, while 'THD' provides the running sum of the total harmonic distortion as a percentage of the fundamental amplitude. 'IHD' indicates the percent distortion of individual harmonics and 'FFT' returns the classic Fourier transform.

Crucial to any FFT or distortion simulation using Spice2 is the component models used. Spice2 will perform an FFT or distortion calculation for any waveform, whether poorly modelled or not. So, unless adequate models are used, substantial errors can result. This is not a failing of Spice2 itself, which will calculate the mathematics correctly, but solely due to using poor models. One common failing is the circuit being simulated may take time to stabilise.

Performing distortion simulations using just a single cycle may seem natural, but care is needed to ensure no start-up transients occur, which will affect the Fourier transform, otherwise Spice2 will include the transients in its FFT calculations. Using the model illustrated in **Figure 1**, which does not model bias currents well, a notable start-up transient occurs. Using a single cycle Fourier transform as shown, this transient further degrades the model's ability, as shown in **Figure 7**.

One way to avoid this is to simulate for a sufficient number of cycles, to ensure the circuit/simulation has completely stabilised and then make certain Spice2 calculates using only the last complete cycle. Care must be taken to ensure one complete cycle, no more no less is used for the Fourier calculation and powers of two data points, at least 1024 and up to a maximum of 262,144 are used. The more data points, the more accurate the Fourier calculation, but the longer the time needed for a simulation. Particular simulators each vary slightly in their methods/requirements for a Fourier transform so please first read the manual for your software.

Enabling the DSP data box in MC6 ensures the desired number of data points will be used.

Provided no visible start-up transients can be seen in the amplifier output waveform, then a single cycle measurement of harmonic distortion may be acceptable. One way to confirm the simulation is accurate is to repeat the simulation but now using a very much smaller time step or a much longer simulation time. If the two answers agree, then the original faster simulation time can be used with confidence. However, amplifier circuits usually do need a number of calculation cycles to allow the Spice2 simulation to fully stabilise for accurate distortion results.

Why use self-heating models?

A particular limitation when modelling distortion the power Mosfets is that Spice2 models every component using a common temperature, indicated by the note which heads each output plot. For many components, instructing Spice2 to model using, say, a 55°C junction or ambient temperature may well be appropriate but not for the power output stage, which may experience junction temperatures ranging from as low as 40°C to significantly above 100°C. Using the conventional, mostly Level-1 models supplied with my simulator, I had no choice but to accept a global simulation temperature. This restriction can only be fully overcome by using self-heating models.

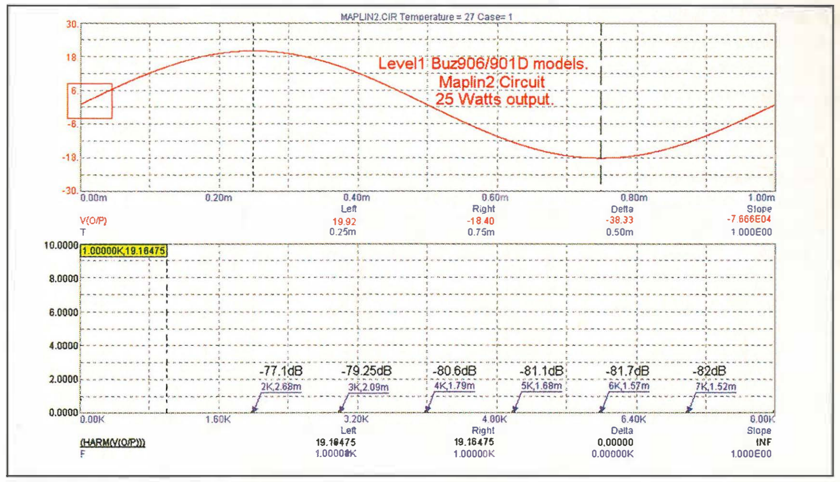


Figure 8: Using Level-1 models of Figure 3 shows improved distortion simulations but still there are gross errors compared with actual measured results.

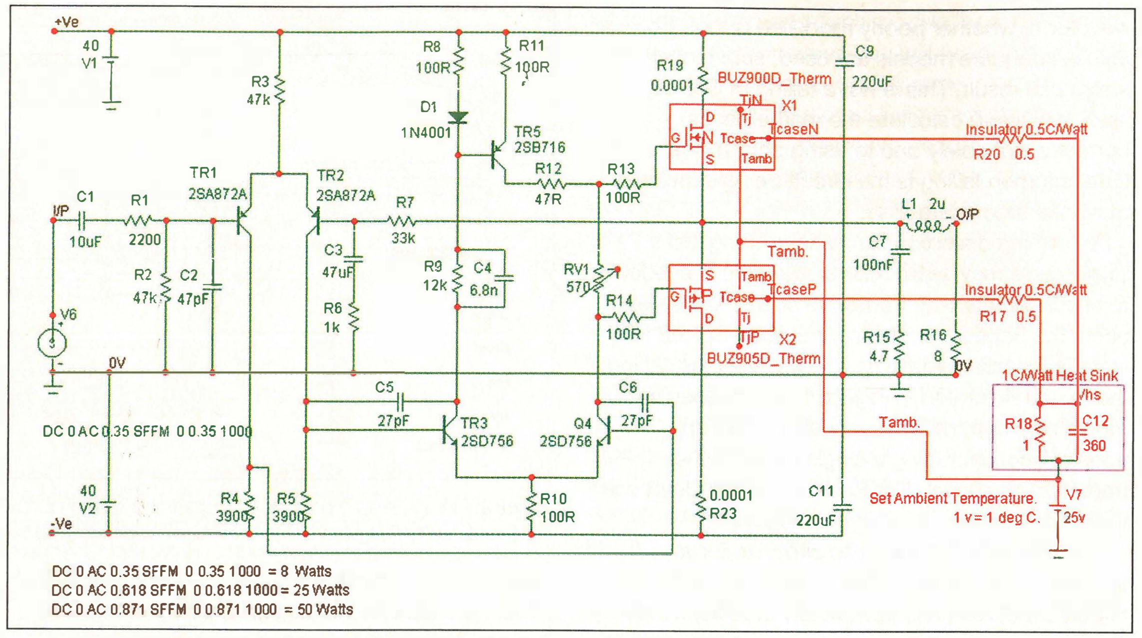
In my last article I showed how self-heating power Mosfet models can be developed using parameters extracted from the datasheet, similar self-heating models can also be developed for all power transistors and any driver stage device needed, which dissipates power so runs hot, introducing a new era in more accurate modelling of a power amplifier.

When modelling distortion of a conventional power Mosfet audio amplifier, the model's behaviour in the crossover region (as one device is turning off and the other commencing to conduct, in the low current sub-threshold region) is crucial since bias currents are usually much smaller than 1A. Power Mosfet characteristics change dramatically with junction temperature.

Using a self-heating model which monitors the dissipated power, hence changes the model's characteristics with junction temperature in real time, can provide the most realistic, practical simulations for bias current, junction temperature and distortion. Such a model can easily be used together with a heatsink model to replicate the behaviour of real devices. The output pair of Mosfet transistors can be modelled mounted on individual heatsinks, or as shown in **Figure 9**, both can share a common heatsink.

Using this schematic, I modelled distortion at three power levels, a nominal 8W, 25W and 50W output into an 8Ω load using the self-heating models developed in my last article. All simulated results are slightly worse, but well within a couple of dB of those actually measured for the amplifier with 0.005% at 8W, 0.0043% at 50W and the 0.0042% shown for 25W output shown in **Figure 10**.

Figure 9: The Maplin amplifier circuit now fitted with a pair of self-heating models. Both transistors are shown using insulating washers mounted onto a common 1°C heatsink with bias current set to 100mA.



Simulating an output transistor dissipating significant power in a typical audio power amplifier, the self-heating model clearly shows how junction temperatures change with the power dissipated within a single cycle at 1kHz, as one transistor switches off and the other conducts. Due to the transistor's thermal mass, each junction reaches its maximum temperature just as the transistor is about to switch off. See **Figure 11**.

In addition to better modelling for bias currents and distortion, a self-heating model can provide realistic indications of junction temperature with change of heatsink but also with time when subject to a continuous signal. Mounted on a typical 1°C/W heatsink, the transistor junction temperature and heatsink temperatures can take some time to peak and fully stabilise. Initially, the transistor junction temperature increases very quickly, but due to its mass the heatsink temperature changes slowly. Until the heatsink approaches its final temperature, transistor junction and case temperatures both increase as shown in **Figure 12**.

As seen in **Figure 11**, with a typical amplifier providing some 50W output, its two output devices each dissipate a similar power level, for almost half the period of each cycle. With both output devices attached to a common 1°C/W heatsink and using thermal insulating washers, at 1kHz the junction temperatures increase steadily by some 1.5 to 2°C each half-cycle until the transistor approaches its switch off.

Then for the next half-cycle each junction temperature reduces rather less, until the transistor again turns on.

Subjected to a constant 1kHz signal for 350 cycles, or little over one third of a second, junction temperatures rose by some 7°C. Following an initially rapid rise, at the end of this time the junction temperature increase was slowing down but was still well short of the expected 85°C junction mean stabilised temperature. With 20 watts average dissipation measured for each device, attaining a stable final T_{case} of 75°C and heatsink at 65°C would take very much longer, around 25 minutes. After running a 1000 seconds simulation at this output power, the curves were almost horizontal and simulated temperatures were within 0.5°C of the above values.

At lower frequencies, transistor junction temperature increases rather more within each half cycle. After 50 repetitions of a 100Hz signal, junction temperatures were seen to increase some 4.5°C each cycle and 10°C during these fifty cycles or half a second, peaking to some 47.5°C from an initial 37°C at the end of the first complete cycle as shown in **Figure 13**.

Proving the self-heating model

Having produced a self-heating thermal model, we should prove that it does work correctly. Using a sinewave stimulus, simply calculate the power dissipated by the subcircuit Mosfet model from the product of the voltage drop between the external drain and source terminals shown in the schematic and its through current, when used with an infinite heatsink at a 25°C ambient. The maker's datasheet shows the TO3 case's, thermal resistance as 0.5°C/W, so simply multiply the power dissipated by 0.5 then add 25 for ambient temperature to the result to obtain the expected junction temperature.

Conclusions

To accurately model distortions in a power amplifier with Mosfet output devices, it is essential that the model accurately predicts the device's behaviour for small drain currents in the sub-threshold region, while subject to the large drain-source voltages used in a power amplifier. Datasheets mostly concentrate on larger drain currents with much smaller drain-source voltage.

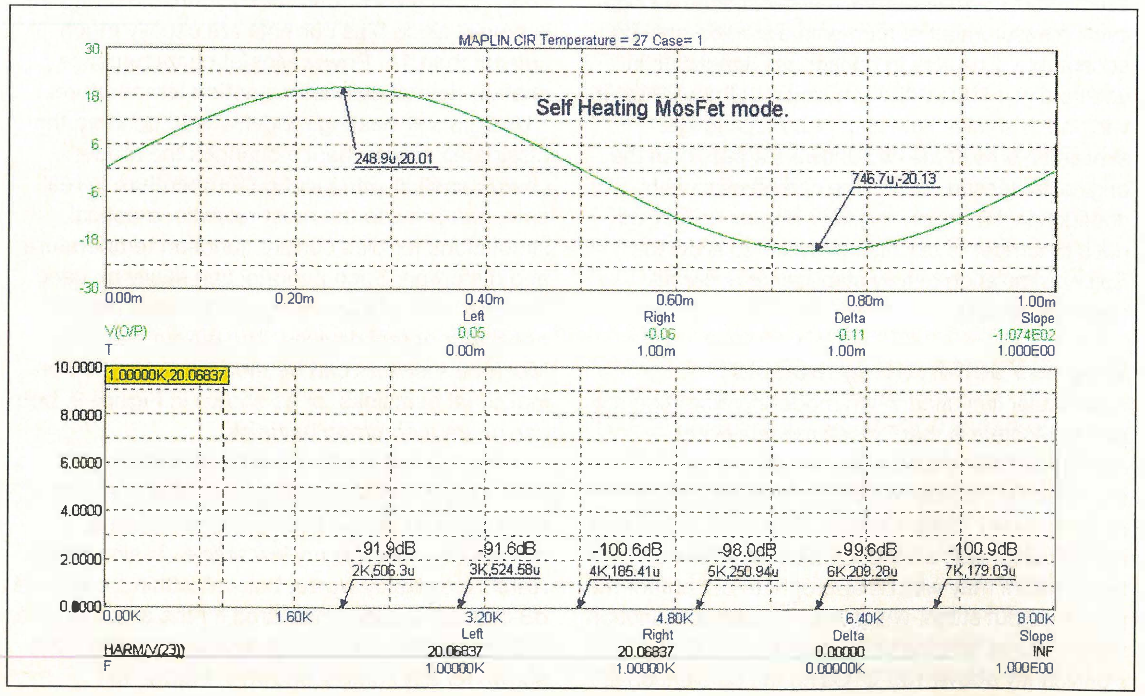


Figure 10: This simulation, using the self-heating models fitted in the Maplin amplifier, shows excellent correlation within a couple of dB of the measured results.

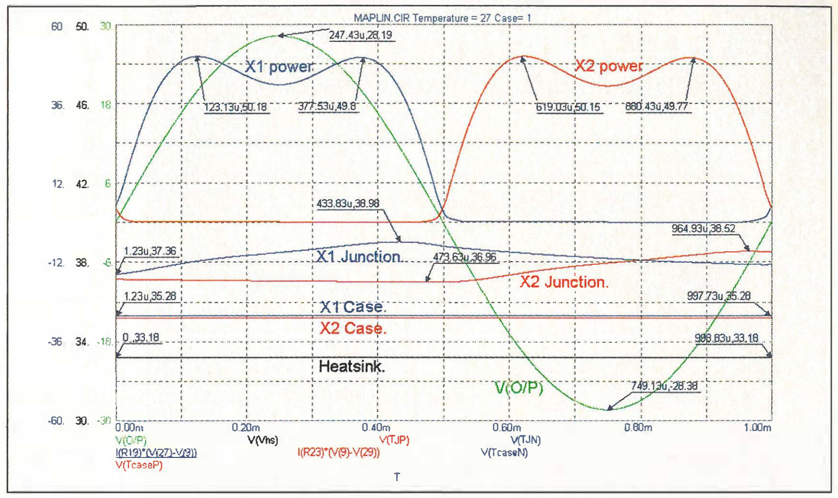


Figure 11: The Figure 9 schematic produced this plot of one cycle at 1kHz, showing power dissipated in each output transistor, together with junction temperatures increasing within each cycle at 1kHz. The lower lines show heatsink and transistor case temperatures

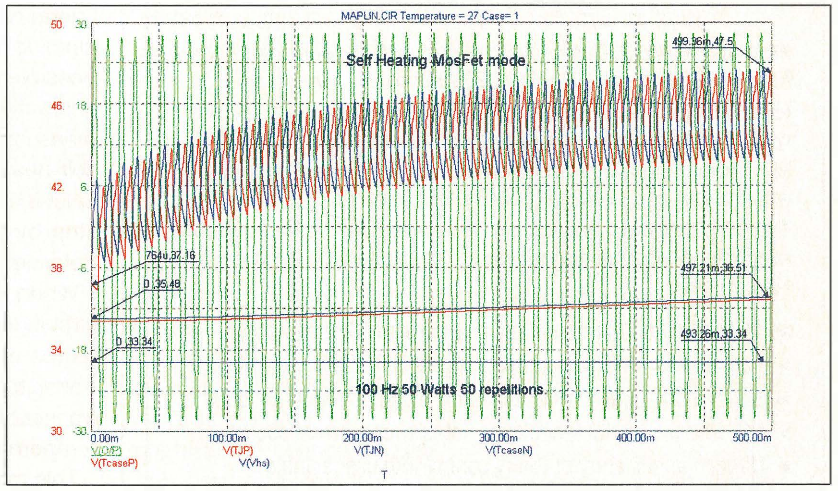


Figure 12: This plot illustrates how quickly temperatures increase in half a second with 50W output at 100Hz.

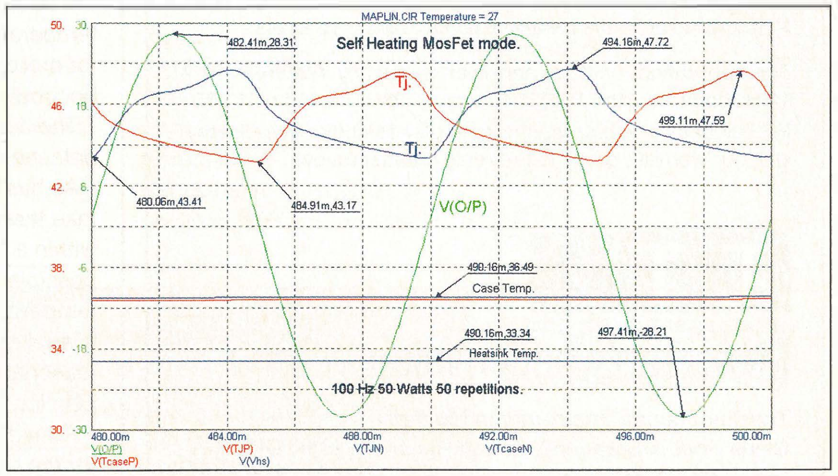
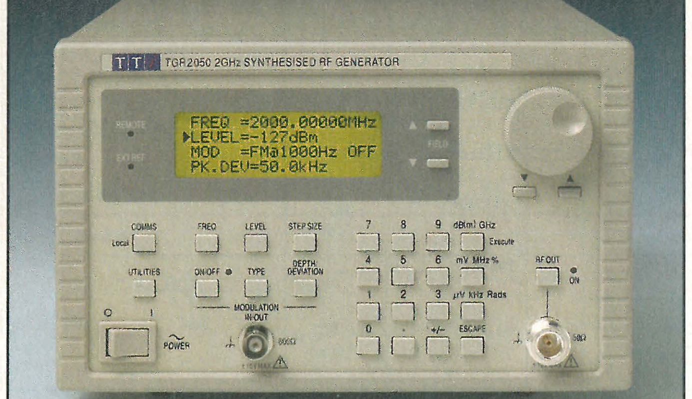


Figure 13: The last complete cycle from Figure 12 shows junction temperatures rising and falling more within each cycle. Stability has not been reached so temperatures continue to increase. Reaching stability after some 25 minutes, with junctions at 85°C, cases at 75°C and heatsink reaching a hot 65°C, since each Mosfet transistor dissipates some 20W



For example, the datasheet transfer curves for my chosen devices assumed a 10V drain-source voltage and plotted currents up to the 16A maximum, making the curves for currents below 3A cramped and difficult to read accurately. The drain-source voltage used in a 50W power amplifier would be 35V or more and 3A drain current can produce some 50W of audio.

Dissipating power in an amplifier circuit increases the junction temperature of a transistor with corresponding changes in its transfer characteristics. Power Mosfet characteristics in this sub-threshold region change noticeably with junction temperature, but in a simulation using conventional Spice2 models, transistor characteristics are determined according to the temperature chosen for the simulation. Using such conventional models, Spice2 assumes transistor junction temperature remains constant and device characteristics also remain constant, so cannot replicate the actual behaviour of a real transistor.

More realistic simulations require using device characteristics which can change in line with change in junction temperatures. Such self-heating models are now possible and can be produced from the datasheet transfer characteristic curves, supplemented with a few simple DC measurements of drain current in the sub-threshold region. A self-heating model provides the best possible simulations calculating for harmonic distortion and DC bias current. A step-by-step method able to create self-heating models was detailed in my last article.

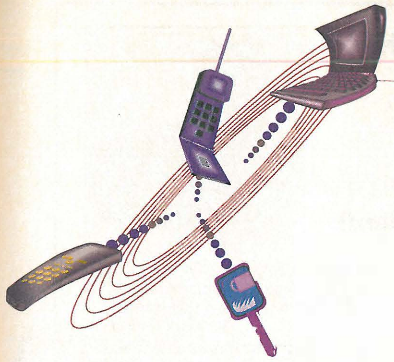
When the transistor dissipates significant power in the circuit, the self-heating model can reveal how junction temperature changes within a single cycle at 1kHz, as one transistor switches off and the other conducts. Due to the transistor's thermal mass, each junction reaches its maximum temperature just as its transistor is about to switch off.

This modelled change in junction temperature relies on using an accurate transistor thermal model, especially for the smaller capacitance values used to represent the thermal capacity of the silicon. These capacitors delay the rise of junction temperature, closely modelling a real device. When simulating for more cycles or longer periods, these capacitance values become less critical.

The accuracy of the thermal resistance value, specified in the datasheet then dominates our modelled results.

As has been demonstrated, Spice thermal simulations can take three forms, the simplest monitors the power dissipated within a transistor. By adding a few more components, it is possible to expand this to also monitor the junction temperature, providing a clearer picture as to how much stress is applied to the device. For this one, you must have a reasonable model for the transistor's thermal path from its junction to the case.

Armed with this additional information and a thermal model for the heatsink, a much improved lateral power Mosfet simulation model has been devised, one which not only monitors power dissipation and junction temperature, but uses the calculated junction temperature to continuously update the Mosfet model's characteristics.



Not just a garage door opener

By Mike Brookes

Low power radio units or short range devices (SRDs) are seen by many as garage door opening devices or car key fobs, but hardly high-tech.

For the last three years, the SRD industry has been deeply involved with the European Radio Administration in a major exercise to change this image and expand the application of SRD technology.

The 'ruling' European body for telecommunications policies – CEPT (Conference Europienne de Poste & Telecommunications), determined that the UHF band 863-870MHz be opened up to wider use by SRDs – provided that the industry could respond to the challenge of adopting technologies for the efficient use of the spectrum and at economic prices.

Compatibility studies between candidate technologies have resulted in the production of an accepted report (ECC Report 37), which promotes the use, throughout the band, of 'listen before talk' and 'adaptive frequency' agility (LBT/AFA).

Nick Long of Circle Design – an LPRA member – specified much of the LBT/AFA theory, while Sigurd Bolt Sörensen, another LPRA member, conducted much of the theoretical compatibility study.

This demands the use of transceivers at all points on a network that can 'listen' to traffic on a potential channel within the band and hop to a free channel if the first was already occupied, before transmitting to a waiting receiver station.

> *"CEPT determined that the 863-870MHz band be opened up to wider use by SRDs – provided that the industry could respond to the challenge"*

The implications of this approach are that a station 'waiting' to transmit not only has the built-in capability of 'listening' to channel traffic before transmitting, but that it also has the capability of transmitting on several other channels. It is evident that the receiving station must also have the 'intelligence' to 'listen' on several channels for its intended message before using the same technique to reply.

The concept of LBT/AFA is not new. It has been used successfully in CT2 (cordless telephone) applications in the past, but what is new is that the technology is now open for use between systems on a channel share basis, without any prior knowledge of other band users – whereas CT2 systems were broadly synchronous.

LBT/AFA will be the technology of choice for future SRD products, displacing many current, and more costly, single channel devices. For this sophisticated concept to be accepted, however, it has to be cost-effective.

Some SRD manufacturers have been developing suitable products, which are now becoming available on the open market. The price of such units, which embody microchip RF sections with associated microprocessor functions (MPU) to provide the channel search intelligence, is in the $10 range or less and is therefore affordable for almost any application conceivable.

The industry has already risen to the challenge – but what of the regulators? LBT/AFA is a 'friendly' technology that optimises the use of 'free air time'.

Will the regulators now be willing to allow SRD products into new areas of spectrum that is not used on a 100% basis by primary users and, thus, create conditions for a massive expansion in the SRD industry?

Time will tell…

The LPRA (Low Power Radio Association) is a European trade body that represents manufacturers and users of short range devices (SRDs). It is active in the production of SRD Radio standards and regulations.

Mike Brookes is LPRA's chairman.

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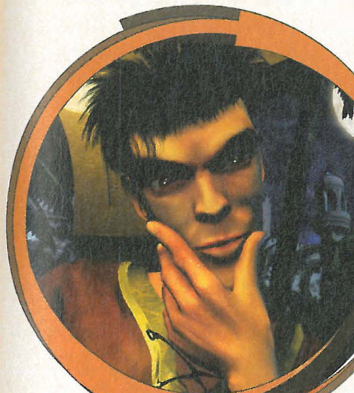


Pocket PCs and smartphones will liven up with the new Atlantis Redux video game from Tetraedge of France and The Adventure Company of Canada. In a brand new twist to the series, Atlantis Redux takes the player on a journey through time and landscapes. The high-quality graphics and visuals can be viewed at 360°. For Pocket PCs, a 100MB version is available from **www.pocketgear.com**. For Symbian and Windows Mobile SmartPhones, 5MB and 10MB versions can be downloaded from **www.handango.com**. Alternatively, less than 1MB episodes can be downloaded individually.

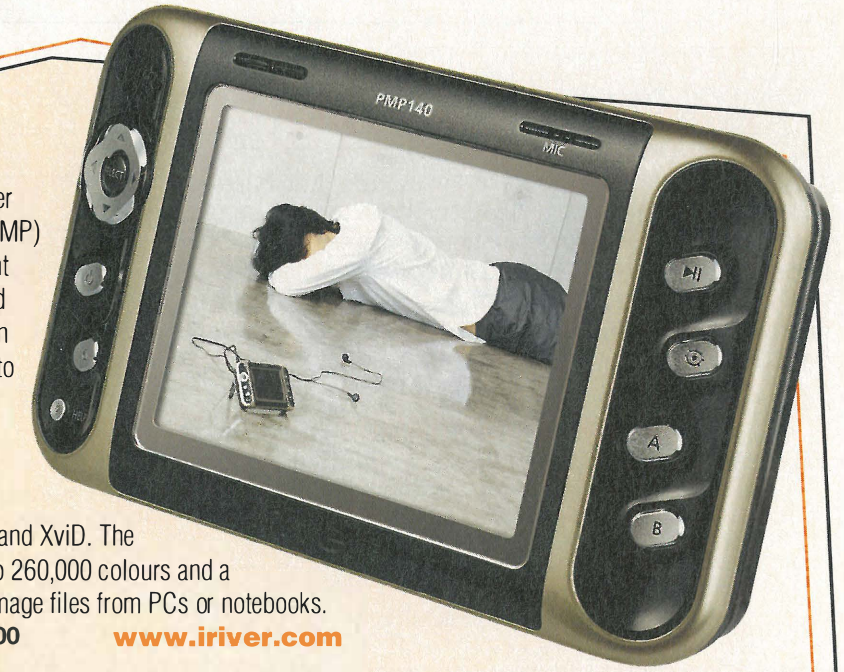
Available from $3.90 (€2.90)
www.clickgamer.com

Bird watching has just become a lot easier with the launch of HiStar's hands-free binoculars. These are focus-free, wide-angle binoculars with a headset that features a padded, adjustable headband. If the user wants to add radio headphones, this could easily be attached to this patented device. According to the inventor, Tristram Himmele, the T-8000 series is an "asset to sports enthusiasts, nature buffs and surveillance users". HiStar offers two models of the binoculars, the T-4000 and T-8000 series.

Around $50
www.sportbinox.com

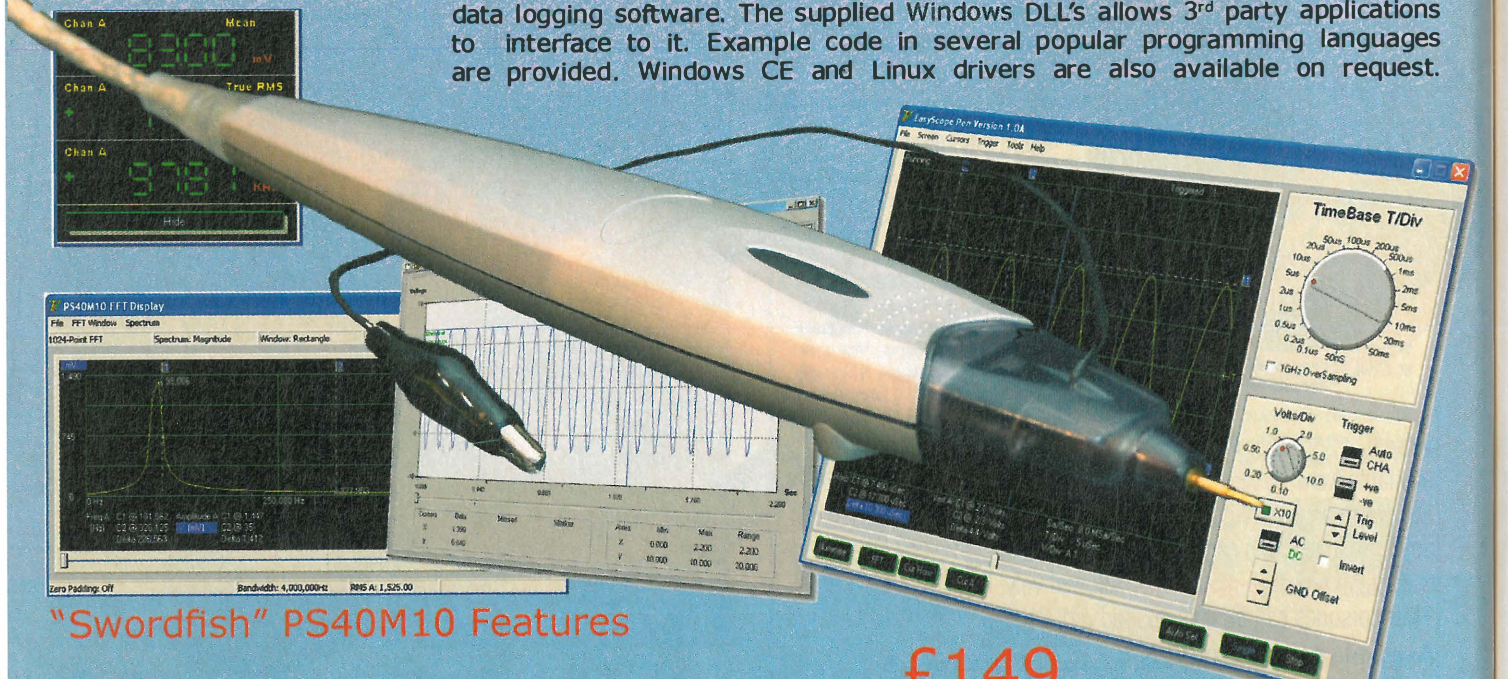
Here's looking at you, kid! Imagination Technologies let fashion designer Wayne Hemmingway (of the 'Read or Dead' label) loose on its latest digital radio set, after the stylist mentioned in a national newspaper that he would like to design the next generation. And here's the Bug. Its features include pause, rewind and record of live radio – a first of this kind, and an MP3 playback. The Bug will allow recording of sound on an SD card or an external MiniDisc player. A digital display shows artists, song titles, news, sports results and other information.

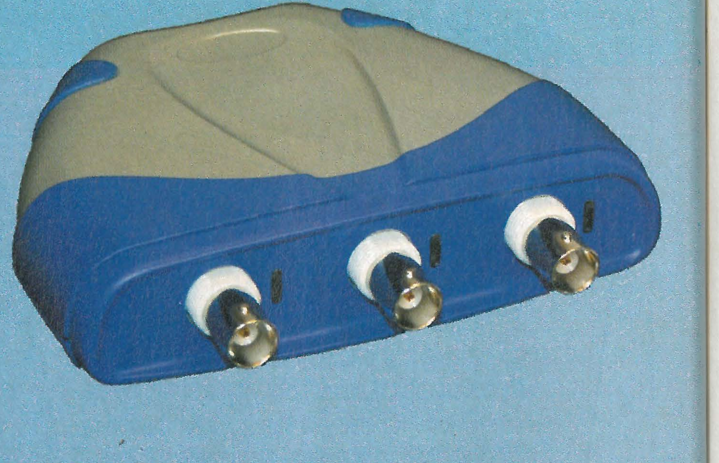
Around £150 from high street retailers
www.pure-digital.com



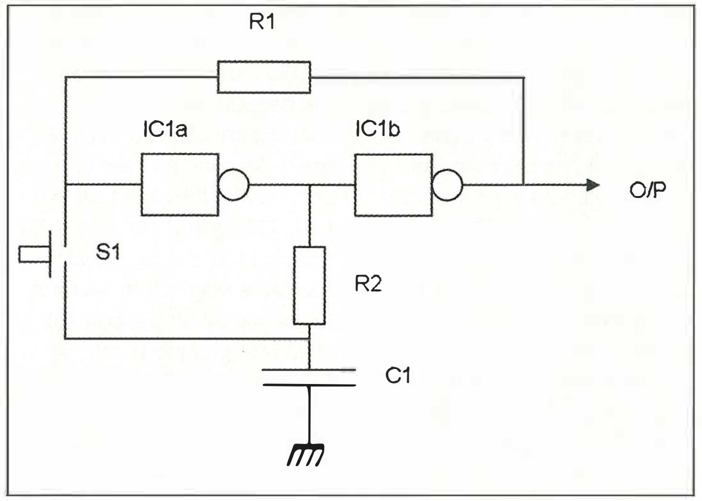
Is there a perfect travel companion? iriver claims its new Portable Media Player (PMP) is just it. This is a versatile entertainment device that offers films, music, radio and even digital snapshots, since shots taken on a digital camera can be downloaded to the PMP in seconds. Available in 20GB and 40GB versions, this Linux-based device plays MP3, ASF, WMA and WAV audio files, as well as numerous video formats, including AVI in MPEG4, DivX and XviD. The PMP series has a 3.5" display with up to 260,000 colours and a USB 2.0 port transfers audio, video or image files from PCs or notebooks.

Available on the high street for £400 **www.iriver.com**





Low-power toggle switch



This simple circuit turns a momentary action push-button switch into a bounce-free toggle action. It can be used as an 'on/off' switch. With the switch released, the logic gates draw only leakage current (around 20nA for CMOS logic). If the output of IC_{1b} is high then just about all the current is consumed by the load and none is wasted in the switch circuit.

To study the action of the circuit begin by assuming the output of IC_{1b} is low and the switch is open. R_1 couples IC_{1b} to IC_{1a} so the output of IC_{1a} is high and C_1 will be charged through R_2. As long as S_1 remains open this is a stable state.

When S_1 is closed the input to IC_{1a} becomes high, overriding the signal from IC_{1b}'s output. One gate delay later the output of IC_{1a} will go low. One more gate delay later the output of IC_{1b} will go high and this signal is fed back to IC_{1a}'s input. If S_1 is now released (or it is bouncing) the circuit will stay in this new stable state. While S_1 is open, C_1 discharges through R_2. If S_1 closes again quickly before C_1 has lost much charge there is no change in IC_{1a} and IC_{1b}. In fact, while S_1 is closed, R_1 charges C_1 up at a faster rate than R_2 is discharging it.

Note the ratio of R_1:R_2 as 1:10 is important here. By making R_1 much smaller than R_2, it guarantees that while S_1 is closed the feedback from the output of IC_{1a} back to its input (which is responsible for changes in state) is swamped by the feedback from the output of IC_{1b} (which is stopping changes in state).

If S_1 remains open for a sufficient time then C_1 will discharge to a point below the logic 0 threshold of the gate. Closing S_1 at or after this point will force the circuit to change state. This time is debounce period of the switching circuit.

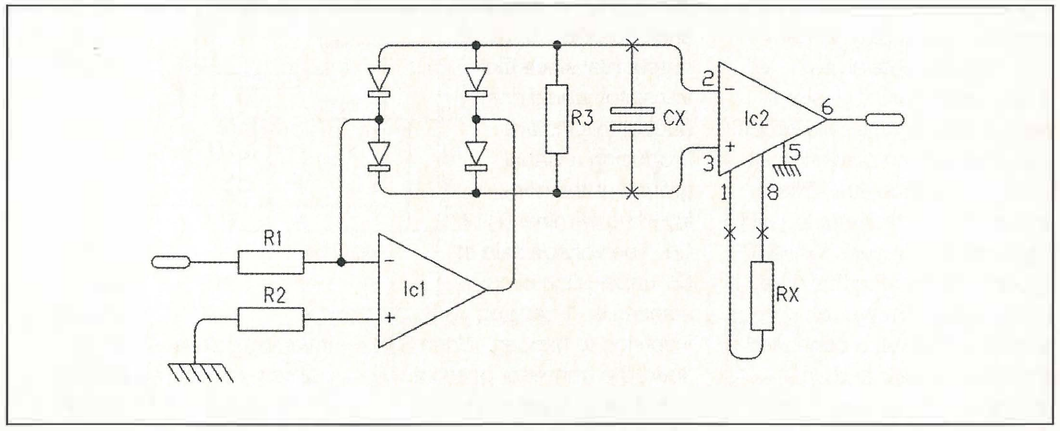
Note that the circuit will work with Schmitt triggers or with ordinary inverters because the switching action is triggered by the voltage across C_1 being a logic high or low. While the switch is closed the voltage across the capacitor is held steady by the gates. It only begins to change when the switch is released so the input of the logic gate would not see the ramp.

Current is drawn while S_1 is held down and while the C_1 is charging after a change in state. Otherwise it draws next to no power. The inverters can be 4000 series CMOS or HC or HCT and since only two gates are used they could be spare gates from a larger package. I built an example using Schmitt triggers from a 74HCT14 in a circuit running from 3V. The output from IC_{1b} was used to power the rest of the circuit and a low current LED to indicate when power was on.

C_1 4n7, R_1 10k, R_2 100k, IC_1 inverter package e.g. CD4069.

Harbanse Deogan
Leicester,
UK

Precision full-wave rectifier



The precision full wave rectifier was implemented some years ago to rectify a feed back signal in a control loop. The particular ICs were available on the board.

The circuit offers accurate rectification and in its basic form requires only two accurate resistors, R_1 and R_3.

If $R_1 = R_3$ the gain is unity. Gain = R_3/R_1. Fitting C_X of a suitable value can filter the signal. Post rectification gain can be implemented by fitting R_X. Gain = $1 + (50k/R_X)$ if IC_2 is an AMP02.

The sign can be changed by reversing the inputs of IC_2. The circuit will work reasonably well up to 10kHz with the suggested components.

IC_2 must have good common mode rejection.

R_1: 10K 0.1%
R_2: 5.1K 1%
R_3: 10K 0.1%
Diodes: 1N4148
IC_1: OP27
IC_2: AMP02

Pete Grainger
Wolverhampton,
UK

Novel "Reflectometer" uses bias current

In designing ICs, engineers are well aware that practical op-amps have input bias current (Ib) and input offset voltage (Vio) that produce error terms at the output. It can be shown [Ref.1] that for the circuit in **Figure1** (see opposite), even while the input is zero (grounded), the output continues to ramp at a rate of

$dV_o/dt = I_b/C$ Equation 1

and

$dV_o/dt = V_{io}/(RC)$ Equation 2

Designers would often employ techniques to mitigate such non-ideal effects. The work here introduces a more useful view of Ib and Vio: they could be used to determine the length (L) of a coaxial cable.

Traditionally, the technique for measuring cable length is known as Time-Domain Reflectometry or TDR (Ref.2). As an alternative to TDR, we could rely on the electromagnetic theory (Ref.3) – coaxial cylinders have a certain capacitance per length. In the case of the RG-59U cable, it is specified as 54pF/m. As cable length (L) is proportional to capacitance (C), it is plausible to use equations 1 and 2 in order to relate L to the amount of time (T) it takes for an initial Vo to reach a certain threshold voltage. Such principle was realised in the circuit of **Figure 2** (see opposite).

U1a is the integrator whose capacitance is replaced by the cable under test (CUT). After the switch (SW) is released, U1a's output ramps down from zero at a rate of Ib/C volts per second, assuming that the effect of Vio is negligible. The ramp, inverted by U1b, is compared to the wiper voltage of the potentiometer (CAL).

While the positive ramp is lower than the voltage at its pin 5, U2a's output is 'high' and the decade counters (U4-U6) are allowed to increment. As soon as the ramp crosses the threshold set by CAL, U2a goes 'low' and halts the count at a value equal to the cable length. This value is displayed by the 7-segment.

U3 is a ubiquitous astable 555 timer which provides the clock (CP) for the counters. When the SW is pressed, the output of U2b goes 'low' and resets U3. The counters, decoders (U7-U9), and 7-segments are also reset to zero by the MR coming from U2b.

It will be observed that, except for very short cuts, cable length is proportional to the time (T) that the counters are enabled. In order to calibrate the system, a reference cable with known length (Lref) is put in place of the CUT. The CAL is then tuned so that after releasing the switch, the number that is displayed is numerically equal to Lref.

Arthur E. Edang and
Neil Andrew D. Paner
Don Bosco Technical College,
Mandaluyong,
Philippines

References

R.J. Higgins, Electronics with Digital and Analog Integrated Circuits, (Prentice-Hall Inc., New Jersey, 1983), pp.358-362

TDR Fundamentals (Hewlett Application Note 62, April 1988)

N. N. Rao, Elements of Engineering Electromagnetics 4th ed. (Prentice-Hall, Inc. New Jersey, 1994), p.253

Acknowledgement

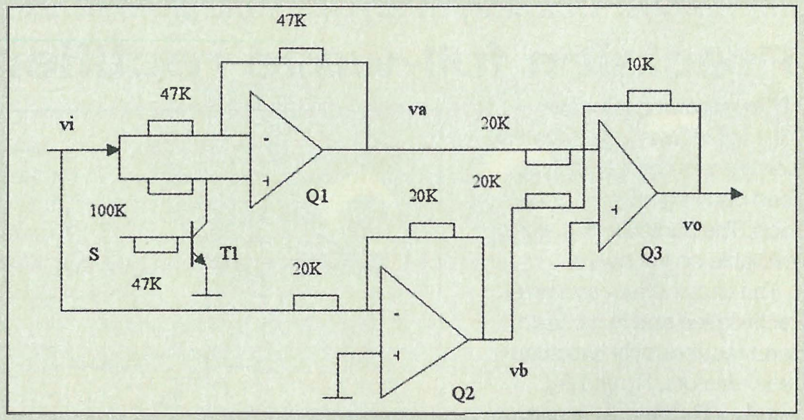
The authors would like to thank ON Semiconductor (www.onsemi.com) for providing free IC samples.

Low noise sampling gate

In digital systems processing analogue signals and in systems doing time multiplexing of analogue signals, sampling gates play a vital role. They sample given analogue signals at desired periodical intervals. This circuit idea presents an active circuit for high precision jitter-free sampling gate that would yield high precision results for the systems employing this gate.

The circuit employs an analogue inverter, a controlled analogue inverter and an analogue adder. The controlled analogue inverter employs an op-amp (Q1) and an NPN transistor T1 connected to non-inverting input (+) of Q1. When the sampling input S appearing as the control input to the base of the transistor is 'high' (+5V), the op-amp Q1 inverts the analogue input Vi at its output (Va) since the transistor would conduct at this instant producing a virtual ground at the non-inverting terminal (+) of Q1. The voltage gain of Q1 under such circumstances is -1 causing inversion to happen. When S is 'low', the transistor goes into cutoff state causing Vi to appear to both the inputs of Q1. The voltage gain of Q1 under this situation is +1 since the inverting gain offered by the circuit is -1 and the non-inverting gain is +2. This causes Va to be equal to Vi.

Therefore, when S is 'high', the output from Q1 (-Vi) and the output from Q2 (-Vi) are added up in Q3 with a voltage gain to yield an output of Vi. When S is 'low', then Q1 output Va is equal to Vi and Q2 output vb being –Vi this results in 0, { (Vi – Vi) /2 }, at the output vo of Q3.



K.Balasubramanian
European University of Lefke,
Turkish Republic of Northern
Cyprus

Novel "Reflectometer" – continued

Figure 1

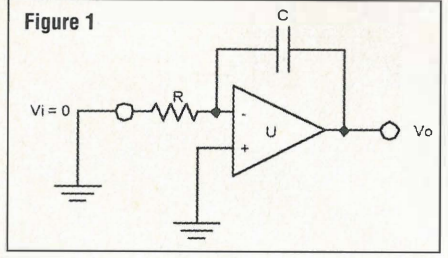
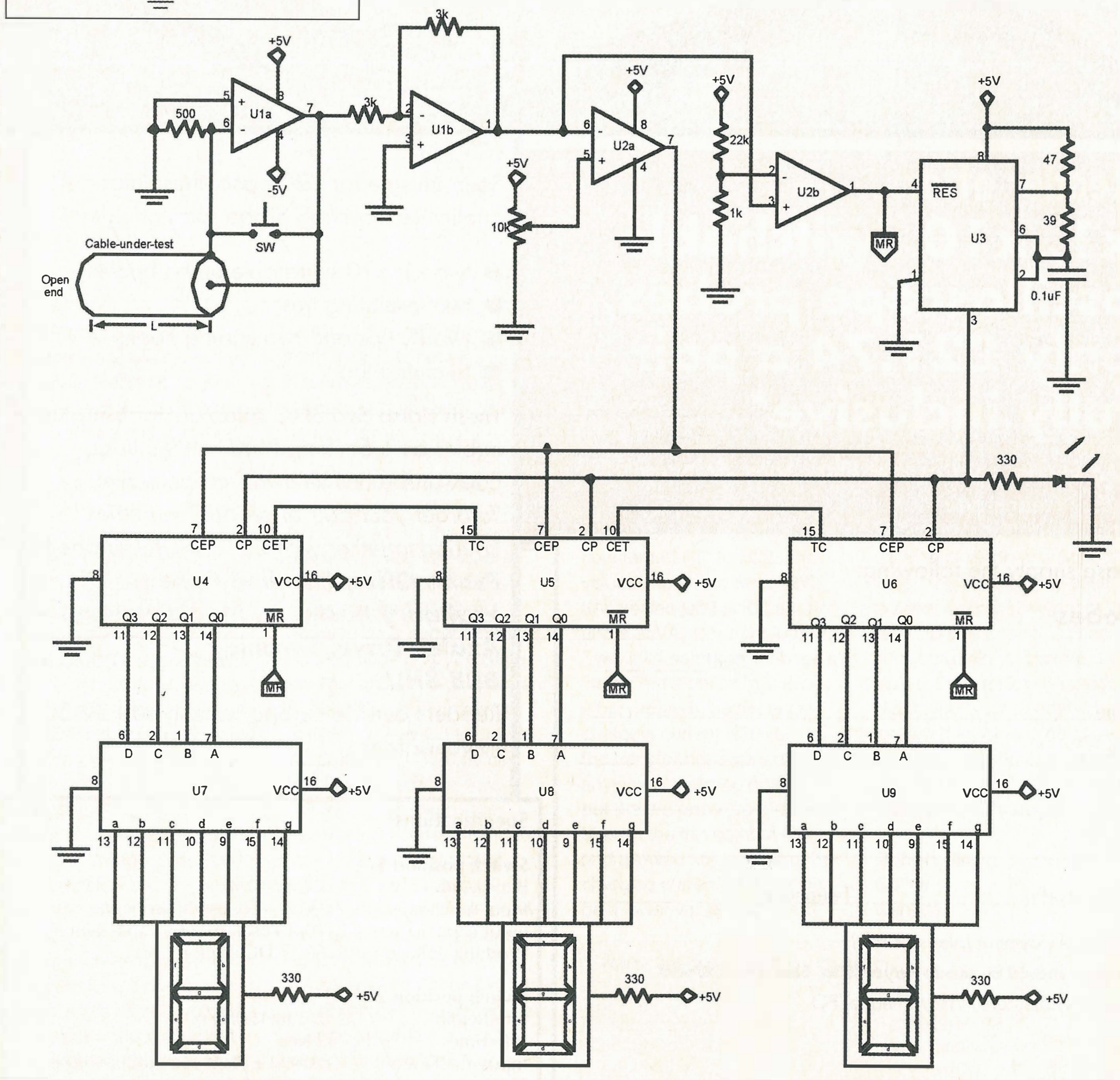


Figure 2

U1; U2: MC33172 • U3: LM555 • U4-U6: 74LS160 • U7-U9: 74LS47



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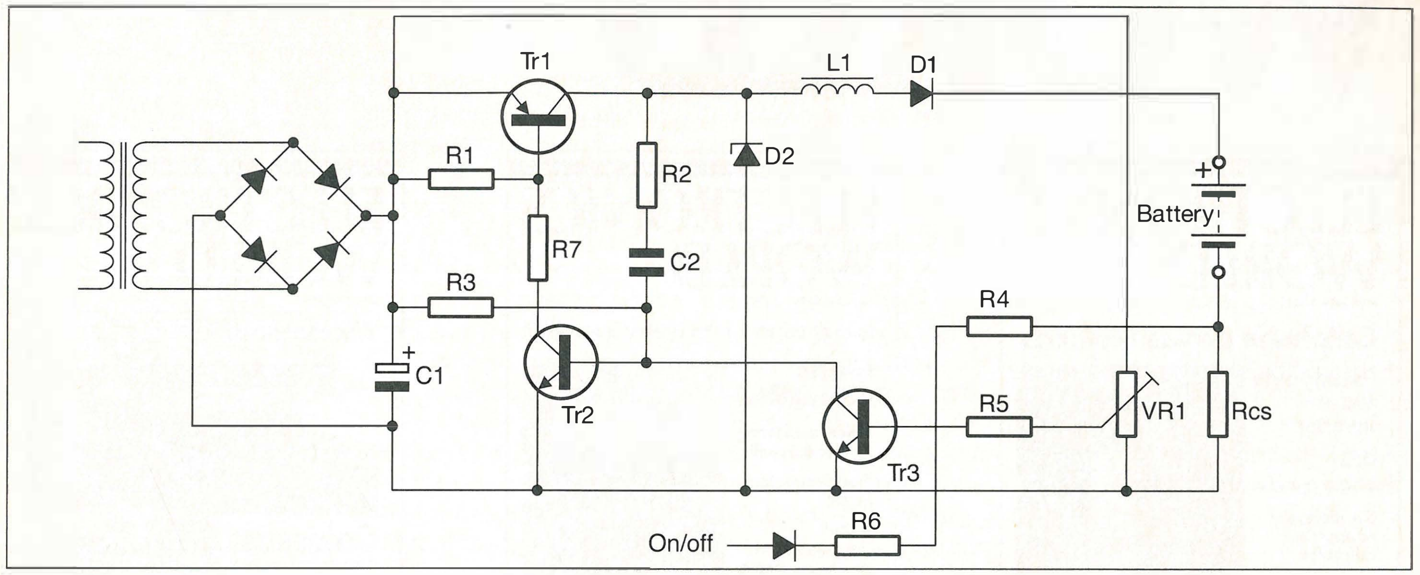
Battery charger using any transformer



This battery charger is tolerant of the rating of the transformer feeding it. Quite often, the available transformer feeds too much voltage when charging a battery that is directly connected to the bridge rectifier. The resulting current is too high and the transformer overheats. Or, the current is simply too much for charging particular battery cells.

This circuit starts pulsing the charging current as the current through the battery exceeds a set point, adjustable with P1. A complete battery charger would also need a circuit to stop charging altogether, once the battery is full. You can find one of these voltage comparators in Electronics World's June 2004 issue, for instance.

With this circuit I was able to use a low wattage transformer, small enough to fit inside the project enclosure and capable of supplying sufficient voltage and current without overheating or exceeding the battery's maximum charging current level. Also, C1 is only a small size electrolytic capacitor.

Another use of this circuit was as current source for three high-power, white LEDs in series as the load, powered from a 12V car battery. You'll need to select suitable component values for use as an LED driver.

Circuit operation

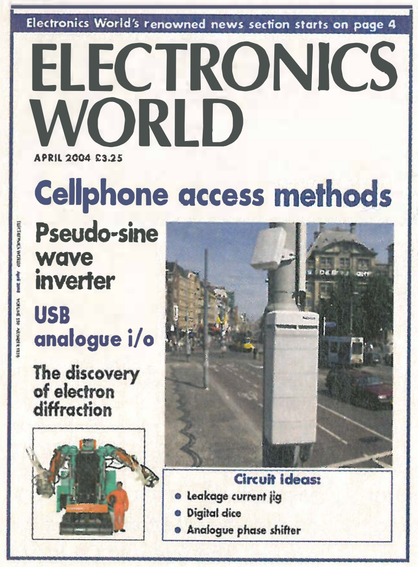
Q1 will pass current each time the voltage from the bridge rectifier exceeds the battery voltage. The base of Q1 is pulled low by Q2, which receives base current from R3. As the bridge output voltage increases, the charging current through Rcs (current sense resistor) causes Q3 to cut off Q2 and when Q1 stops conducting, its collector voltage (TP1) is driven low by the freewheeling current in inductor L1. All of this happens rather quickly. R2 and C2 make for a quick transition. As long as current in L1 keeps flowing, TP1 will be close to 0V. Meanwhile, C2 on the base of Q2 charges from a negative voltage towards a positive voltage and when Q2 receives sufficient base current, it will bring Q1 into conduction and the switching cycle repeats.

Q1 must be a fast transistor but my experiments with a Mosfet did not pan out. Q1 must be slow enough to let the charge current rise enough for Q3 to saturate. The timing of it all depends on the value of L1 (choose something between 50µH to 200µH that can take the maximum charging peak to suit your battery and transformer) and the time constant of R3 and C2. The values shown are for a 12V, 8Ah sealed lead acid battery and a 25VA, 12V transformer. Even if L1 saturates (choose a 'soft' core if possible) it is not a big problem, because the charging current is limited by the transformer's impedance anyway. P1 can be omitted but it did a good job of pre-biasing the trip point of Q3 and allowed adjustment of the charging current and Rcs can be a lower value. The on/off signal can be 0V and 5V respectively, from a charging control circuit of your own design. The value of C1 is not critical. It serves to limit the voltage spike at the moment when Q1 turns off. C1 is therefore not the typical large storage capacitor. D2 should be a 'fast' diode or a Schottky type. The circuit in my case pulsed around 30kHz and took up little space. D1 can heat up at higher current levels. Even a slow 6A diode did. If you want to omit D1, do ensure that there is no current leakage from the battery through the circuitry when the charger is not plugged in.

Robert Bliek
Calgary,
Canada

Parts listing as battery charger:

Transformer 12V, 25VA
Bridge rectifier 5A or greater on heatsink
Q1 = D45H11
Q2 = PN2222A
Q3 = 2N3904
D1 = 6A or Schottky
D2 = MUR4100
C1 = 56µF, 50V
C2 = 0.1µF
L1 = 50µH, 3A
R1 = R4 = R6 = 1K,
R2 = 560Ω
R3 = 820Ω,
R5 = 18K
Rcs = 0.27Ω, 5W
R7 = 150Ω, 1W
P1 = 10K



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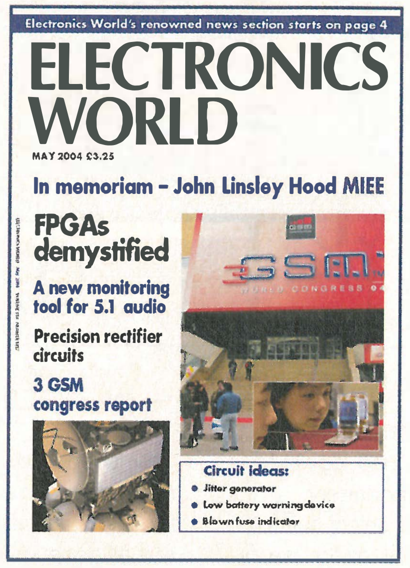

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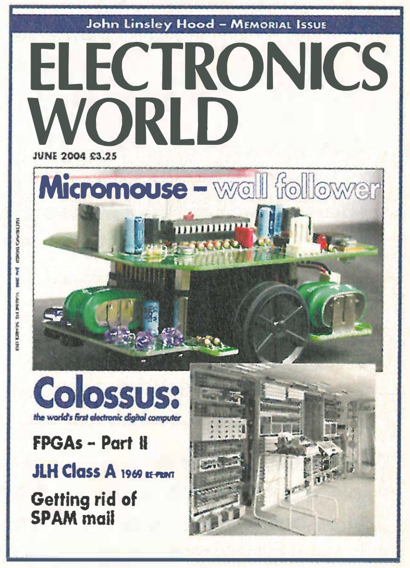

John Linsley Hood – Memorial Issue

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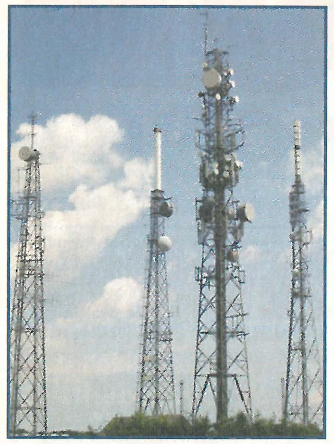


Unmentionable hazard?

Regarding the article *'Radhaz: The Unmentionable Hazard?'* in the October issue, p3, the worries about dangerous radio emissions seem to have started with the report by the two medics that they encountered a cluster of leukemia type illnesses in Californian houses that had overhead power lines nearby. If memory serves me right, nowhere did they mention that the area was in the uranium-mining belt and that there could have been other causes such as Radon gas coming out of the ground.

Also, clusters need proper statistical testing and not just objective observation as was the case of an instance in Lincolnshire some years ago, allegedly due to crop spraying.

Considering that wireless has been with us for over a hundred years (and the high voltage grid almost as long), is it not strange that the concerns are of relatively recent origin? There have been many high-powered radio stations in existence for communications and broadcasting and, since the war, many powerful radar sites all of which have covered the spectrum from VLF to UHF. I should have thought that the staff in these establishments would have been subjected to higher RF fields than the general public would encounter. Surely they would be a good group to monitor for death incidences and see if they are significantly different from the population in general.

As a young apprentice tuning GBR, I was subjected to whole body warming on more than one occasion and it appears to have had no ill effect. I am not alone with that experience.

If one looks at the figures (and the latest I have to hand are from Whitaker's Almanac for 1993), the total number of neoplastic deaths was 144,577, roughly 0.3% of the population. A deeper analysis would reveal 13,741 suffering from malignant breast neoplasms, 3,235 from leukaemia and 1,330 from benign and unspecified ones, totaling less than 20,000. Not all of these could be caused by radio emissions. Thus, the problem, if it exists, is a very small one indeed and I shall be surprised if it is found to exist at all.

S.F. Brown
Oswestry,
UK

Make maths meet physics

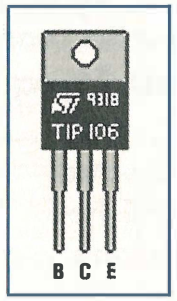
Ian Hickman's analysis of the 'Catt Anomaly', *Electronics World,* October, p38, was very informative but I feel it leaves questions unanswered. For example, where is the energy stored? In the electric and magnetic fields, to be sure, but how? Why are the electrical impedance of the transmission line and the wave velocity along it much more dependant on the dielectric between the conductors than the conductor itself?

And what happens when the wave launches itself into space out of the transmission line? Where are the moving charges that aid the propagating wave to be found?

I know it is usually easier to ask such questions than answer them, but I feel conventional analysis occasionally fails to give convincing physical explanations to match the undoubted mathematical reality. Rather than mathematics being a tool to aid understanding of physics, it seems all too often today that the mathematics is the end in itself and the actual physics is ignored. As a former antenna designer I find the disparity particularly marked in the treatment of electromagnetics.

However, I believe I can answer the above questions but would be very interested to hear of any other views on the subject.

Anthony New
Bristol,
UK



The emitter is always negative

Back in the old days when transistors were called 'three legged fuses', the structure was always PNP; the collector was supplied by the negative rail and the emitter by the ground or positive rail.

New electrons are supposed to flow in the opposite direction to the electric current, being negatively charged. This means that if the emitter is supposed to emit electrons, like the cathode of a vacuum tube, then it must be connected to the ground or negative rail, which has the preponderance of negative charge: a supply of electrons.

What then is the emitter of a PNP transistor supposed to be emitting?

Do not tell me that the emitter emits holes. These are simply moving absences of charge and I do not consider that they can be 'emitted'.

Clearly, we are not talking about protons, though no doubt someone has that theory, because protons have mass as well as charge. Radioactivity?

I, therefore, maintain that 'emitter' is a misnomer in PNP circuits.

R. Harcourt
Honiton,
UK

Experiment to end it all

With reference to the continuing series on *'Class A Imagineering'* (which I have, frankly, become bored with) can I suggest a simple experiment to once and for all produce scientific data on the performance of audio power amplifiers?

A power amplifier can be considered a 'black-box' that faithfully takes an input signal and transfers it to a loudspeaker at a larger voltage. Therefore, if the output signal is taken back to a precision amplifier and subtracted from the input signal, the resulting difference signal is the genuine contribution of the power amplifier and connecting leads. The signal back from the loudspeaker will need to be attenuated to compensate for the gain of the amplifier and a small amount of phase correction may also be needed. The returned signal from the loudspeaker should ideally be fed back to a differential amplifier so that the signal and ground wire contributions are included.

Signals of any type can then be replayed through the system and the results recorded for subsequent analysis.

Such an approach would surely produce a meaningful 'signature' of the device under test and allow amplifiers of different types to be compared.

Finally, I really don't want to comment on much of what has been written, but I really take exception to Graham Maynards criticism of the humble RC input filter. The whole purpose of this stage is to reduce the slew rate of the input signal to a rate slower than the maximum slew rate of the power amplifier itself. Should the power amplifier itself go into slew rate limiting, all benefits of the negative feedback will be lost and various internal stages of the amplifier will overload in many subtle and unpredictable ways.

You could argue that the preceding pre-amplifier stages would already have achieved that goal, but do you want to rely on that and what if the signal actually clipped on the transients just before feeding the power amplifier?

Mike Law
Slough
UK

Keeping it simple

In Mr. Maynard's article *'Class A Imagineering'*, I suspect that the later JLH class A amplifiers, with the addition of a servo loop to both remove DC offset and ensure that drive current splitting between the upper and lower power transistors are equal, would produce good results.

Simple is best. Balance in all things. Don't send the signal down strange and unnecessary paths.

I notice that in the JLH headphone amp the upper transistor ceases to be modulated and becomes a constant current source (at least in my simulations).

Malcolm Bloor
Stafford,
UK

Being at the right place...

I read with some amusement Trevor Skeggs's letter *'Powers that be', Electronics World*, September, p48 and (I think) I know what he means.

The 1968 OED (dictionary) listed the definition of powers in mathematics as "The number of times the natural log of a number is to be multiplied and returned by the inverse log function". Thus, multiplying a number's natural logarithm by zero leaves zero and the inverse log of zero is 1.

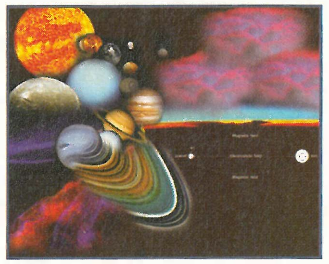
My TI data book from 1974 lists the Exclusive OR function as returning "a true output excluding the case of an AND function of either logic sense", which, if further explained, meant that the AND function can be all 0s or all 1s or an /even/ number of 1s or 0s. This meant, to me, that the output would be true only when the inputs were in a state where there was a single 0 being ORed with a single 1 (which would be true only for an odd number of 1s).

The NOR is always N for not. So you have an odd or even parity function with a single letter (the NOT of an Exclusive OR is Exclusive NOR)

Now, what would Mr. Skeggs think of the problem some early scientists had with Einstein's famous $E=MC^2$ formula? They claimed it was useless because they had different results when the formula was done with English units of measure versus metric. They completely forgot that the C^2 bit requires that the conversion factor for kph to mph also needed to be squared.

It isn't stupidity that makes these things happen but not being in the right place at the right time.

Joseph Perkins
Milford,
USA



A question of mega proportions

Congratulations to Clive Stevens for his thought-provoking article, *'An Electric Universe – Magnoflux Aether Tunnel', Electronics World*, August, p24. Of course the universe is 'electric' as is all matter and energy, so why did this article provoke the sarcastic and abusive replies in your September issue? Obviously, this is because Stevens dared to mention God.

Regarding the technicality of the subject; since cosmology contains unanswered questions of foundational importance and it is driven with pure speculation and mathematical imagineering, Stevens has every right to add his own hypothesis.

The 'Big Bang' idea as advanced by Astronomer Royal, Sir Fred Hoyle, was invoked 'tongue-in-cheek' and he was astonished that it became an established theory, but now discredited by many cosmologists. Black holes are similarly believed by many scientists to be a figment of the imagination.

NASA bases its space launches on a geocentric model of the stellatum, and Einstein and Hoyle both agreed that the mathematics describing a heliocentric and geocentric universe is identical. As educator and writer on astronomy, Walter van der Kamp succinctly put it: "Does space know place or motion rest?"

The concept of the aether has not gone away either. Mathematician and astronomer Professor G. Bouw of Cleveland, Ohio, posits aether of ultimate Planck density.

Brian V. Lamb
Quarryside,
UK

Pendulum conundrum

I wonder if I may impose on you to resolve a "situation" that has been on my mind for some time.

How is synchronisation achieved in the case of a 'dummy' pendulum on a quartz clock and with certain dynamic display toys? Magnetism is obviously involved but my reasoning suggests that if the feed were constant (DC) then the pendulum must eventually come to rest in its midway position. If, on the other hand, this were pulsed it would surely have to be precisely the same frequency as the natural one of the pendulum itself.

I look forward to a possible explanation.

C. Holwill
Portsmouth,
UK

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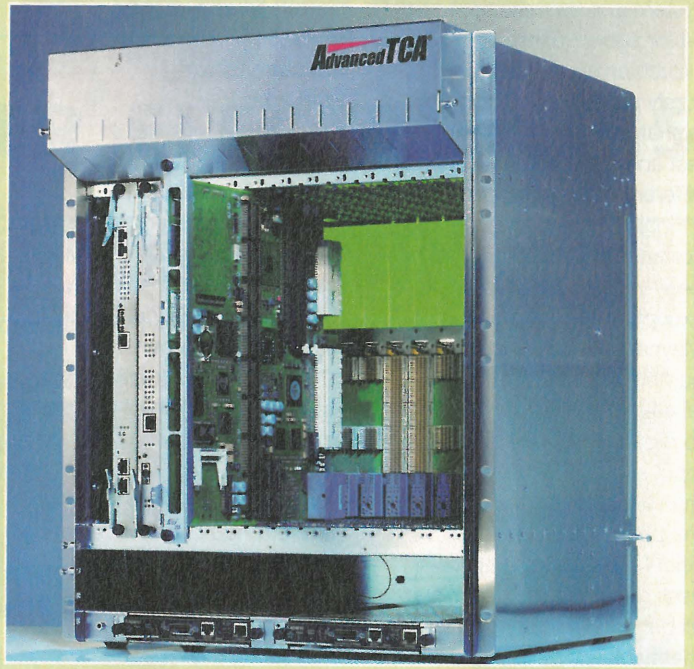
Advanced ATCA performance



Rittal has announced several new AdvancedTCA (ATCA) backplanes, ranging from a four-slot for development use or horizontally mounted systems with triple full mesh connectivity, through to a 16-slot to fit ETSI standards or 600mm rack systems.

In recent tests, the Rittal's 18-layer Nelco4000 system, based on full mesh backplane, achieved an unaided 5Gbps performance, PICMG 3 calls for 3.125Gbps.

The Rittal ATCA backplanes have dual Intelligent Platforms Management Interface (IPMI), which may be configured as either radial or bussed, depending on the shelf management controller used.

The range includes full mesh architecture, dual star, dual-dual star and dual-dual star with 1x mesh overlay.

www.rittal.co.uk

Connect to terminate

Cable installers can terminate fibre in three easy steps – stripping the cable, cleaving the fibre and crimping the connector – thanks to a factory-polished ferrule in the new AMP Netconnect LightCrimp Plus LC fibre-optic connectors from Tyco Electronics. The new additions are ideal for direct termination in premises applications, such as at patch panels and wall outlets, and in trunk cabling for either backbone or horizontal cabling.

The increasing popularity of multimode and single-mode small-form-factor connectors has emphasised the advantages of offering MT-RJ and LC connectors and related products in addition to the SC and ST-style connector products. The addition of the pre-polished, single-mode and multimode LightCrimp Plus LC connectors eliminates the need for manual polishing of LC ferrules and makes LC termination and installation faster for the installer.

www.tycoelectronics.com

Fast and furious

Intersil Corporation has launched what it claims to be the "world's fastest triple amplifier" and "the first one to break the 1GHz amplifier barrier". With a total supply current of just 25mA and the ability to run from a single supply voltage from 5V to 12V, the EL5367 is suitable for low power and high bandwidth applications such as portable, handheld and battery-powered equipment. It also drives resolutions greater than QXGA (2048pixel x 1536pixel video graphics standard) at Gain of 2 for very high-speed video and monitor applications.

The EL5367 is capable of swinging to within 1V of either supply on the output. Because of the current-feedback topology, the EL5367 does not have the normal gain-bandwidth product associated with voltage-feedback operational amplifiers.

The device is now available in 16-lead QSOP packaging for a price of $2.99 in 1,000 unit quantities.

www.intersil.com/opamps/

FINREAD's new platform

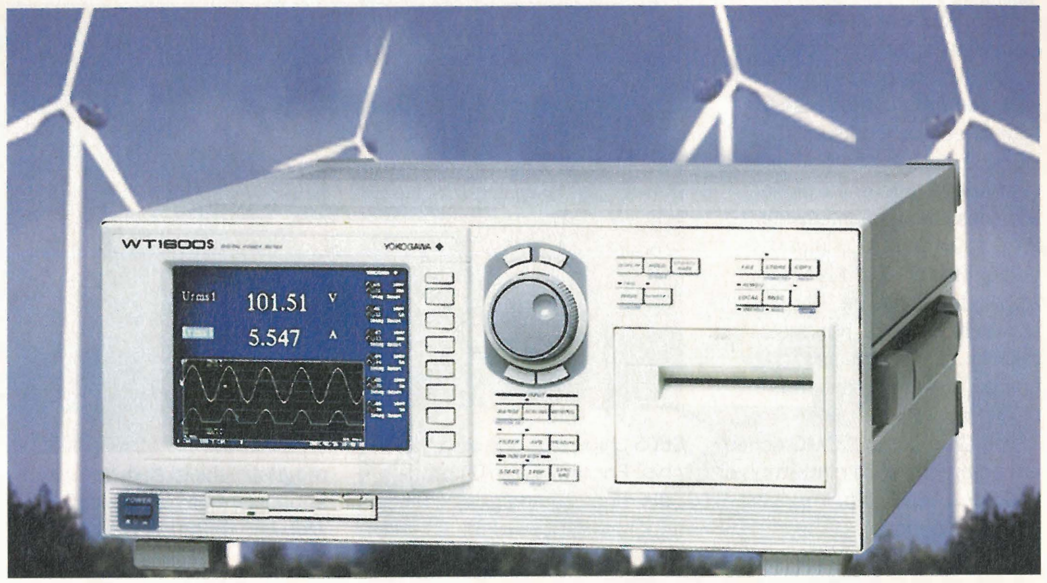
Renesas Technology has announced the availability of a platform for FINREAD smart-card readers. The architecture used is based on the Renesas ePOS (electronic point-of-sale) reference platform, a secure and scalable hardware and software reference design board that allows financial transaction terminals to be equipped with the most advanced security.

The platform uses the H8S/2215 microcontroller and an AE series security IC. Renesas says that the hardware/software combination is one of the best around to develop highly secure PC-connected, USB-powered products.

The open-standard ePOS reference platform supports Visa Smart POS, the Global Platform and EMV (Europay/Mastercard/Visa) standards, the STIP, FINREAD and JEFF software and middleware.

www.renesas.com

Small- and high-current power meter



The WT1600S from Yokogawa is a digital power meter designed to provide cost-effective measurements of both, extremely small currents in energy-saving equipment and high currents in applications involving large loads.

The WT1600S combines up to four power measurements with two input current ranges of 10mA to 5A RMS or 1A to 20A RMS, an input voltage range of 1.5V to 1kV and a frequency range of DC and 0.5Hz to 300kHz.

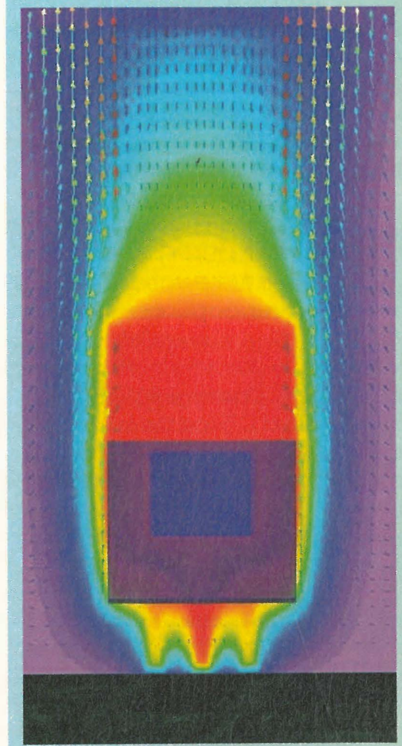
The instrument has two separate input elements for low and high current ranges, and both can be used together in a system.

A large 6.4-inch TFT colour display can show up to four power measurement parameters at once, with a choice of display formats including numeric, waveform, bargraph, vector, trend or combinations of these.

A harmonic measurement function is capable of measuring waveforms with a fundamental frequency ranging from 10Hz to 1kHz. A 10baseT Ethernet port for network or web connections is available as an option.

www.yokogawa.com/

Getting thermal with Philips ICs



Ready-to-run thermal models for Philips's power semiconductors are now available to designers via the SmartParts3D web site, announced Flomerics. Design engineers can instantly download complex, calibrated thermal models of power semiconductor packages from Philips to incorporate in their Flotherm thermal simulations. This approach saves time and increases thermal modelling accuracy as the SmartParts3D models have been created and validated by experts from Flomerics and Philips. Models are available now for the TO220 series packages, and models for isolated TO220, D2-PAK, D-PAK, SOT223, SO8 and LFPAK packages will follow soon.

The web-based library at **www.SmartParts3D.com** contains models for fans, heat sinks, air filters and interface materials as well as IC and power semiconductor packages.

The library is searchable by part family, description, manufacturer, model number and performance criteria.

Companies already contributing to SmartParts3D include Bergquist, Chomerics, Delta, Dow Corning, ETRI, Honeywell Electronic Materials, HS Marston Aerospace, Micronel, Papst, Sanyo Denki, Thermagon, Universal Air Filters and others.

www.flomerics.com

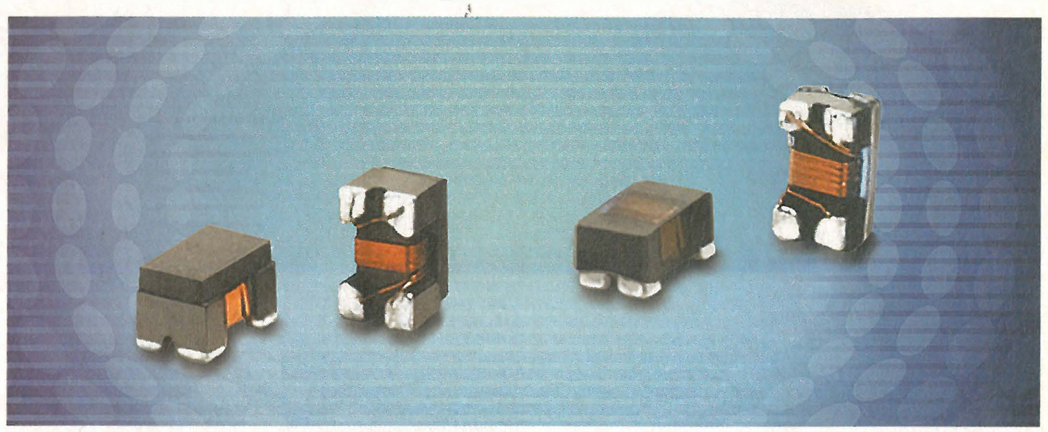
Programmable PWM controller

Intersil announced a new three-phase PWM controller with all-in-one VID for Intel VRM9, VRM10/10.1 and AMD Athlon, Athlon64 and Opteron microprocessor applications.

The ISL6566 IC has integrated MOSFET drivers that provide a precision voltage regulation with programmable VID codes. Among its other features are: 1-, 2- or 3-phase power conversion, precision core voltage regulation, differential remote voltage sensing for tighter accuracy, +/-0.5% system accuracy over temperature, adjustable reference-voltage offset for load-line programming and precision channel current sensing. It uses lossless Rds (on) current sampling and a lossless inductor DCR current sampling. It has a variable gate drive bias from 5V to 12V, up to 6-bit DAC, over-current and over-voltage protection and a selectable operation frequency up to 1.5MHz per phase.

http://www.intersil.com

Eliminate net noise with ChipChoke

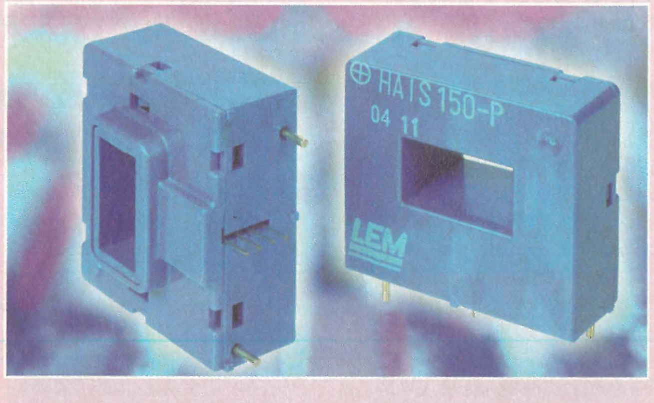


Pulse introduces the ChipChoke series or common choke modes. These products eliminate common mode noise in high-speed networks using the USB2.0 standard and other high-speed differential signal transmission applications like IEEE 1394 and LVDS (Low Voltage Differential Signaling). Applications include PCs, scanners, printers, handheld devices, digital cameras, games, set-top boxes and LCD displays.

The ChipChoke CCMC series are common mode chokes on a 0805 or a 1206 chip. There are three basic models, two on 0805 chips and one on a 1206 chip. For the two 0805 products, one has an epoxy coating and impedances of 67, 90, 120 or 180Ω and the other has a magnetic shield and impedances of 67, 90, 120, 180, 260 or 360Ω. The 1206 product has a magnetic shield and impedances of 90, 160, 260, 600, 1000 or 2200Ω.

www.pulseeng.com

ASIC-based transducer



Swiss company LEM now offers the HAIS series of low-cost, PCB-mounted current transducers, designed to operate from a single +5V power supply.

The new transducers are available with rms ratings of 50A; 100A; 150A; 200A; 400A and a measuring span of up to ±3 x IPN.

At the heart of the HAIS series is a LEM ASIC that offers a number of performance improvements, including an extended operating temperature range (-40° to +85°C) compared to traditional discrete technology.

The internal reference voltage of the ASIC is used to provide a fixed output offset of +2.5V. This voltage reference is also made available on an extra pin to enable it to be fed to the reference of an A/D converter or a DSP, for example. The user can also apply the system's voltage reference (between 2V and 2.8V) to the extra pin (Ref) to produce an output offset that is equal to the external reference. This mode can be used to cancel the Ref thermal drift.

An optional bus bar is available for nominal ratings of 50A and 100A.

www.lem.com

Trillium will thrill telecom makers

San Diego based firm Continuous Computing has introduced the Trillium IP Bearer Control Protocol (IP-BCP) offering seamless integration into networks using Bearer Independent Call Control (BICC). In addition, Continuous Computing updated the Trillium SIP and Trillium GCP (H.248/MEGACO compliant) protocol stacks to address the carrier-grade scalability needs of the VoIP and 3G wireless network deployments as carriers start to deploy IP Multimedia Subsystem (IMS) architecture. Updates include support for Transport Level Security (TLS), Signalling Compression (SIGCOMM), 3GPP-defined drafts, RFCs for specific use of SIP in R5/R6 network architecture and the addition of the redundancy module based on Trillium DFT/HA architecture. The updated SIP stack provides superior performance, PROTOS compliance and has been interoperability tested with multiple vendor solutions.

The Trillium portfolio will enable telecom manufacturers to add Call State Control Functions (CSCF), Wireless Media Gateways, SIP phones and servers, softswitches, Multimedia Resource Control Functions (MRCF) and Bearer Interworking Functions (BIWF) for the decomposed IMS architecture.

www.ccpu.com

Rechargeable Li-ion cell

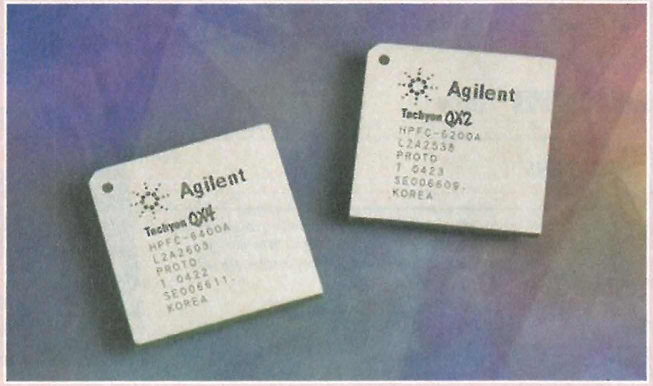
Saft used the bi-annual trade show Electronica, held in Munich in November, to launch its new, high performance, lithium-ion (Li-ion) cell.

The key benefits to this cell are the higher energy, power and improved charge/ discharge characteristics at low temperatures that it offers. The MP 176065's capacity is 6.8Ah when charged at 4.2V at +20°C. It offers 2C continuous drain capability with maximum 4C peak. Discharge is possible at a rate of C/5 and the cell benefits from a large charging window from +60°C down to -20°C.

The MP 176065 is targeted at a range of new electronic design markets, including military, medical, communications, instrumentation and tracking applications, which will be able to exploit the benefits of rechargeable lithium-ion technology for the first time.

www.saftbatteries.com

Fibre Channel for PCI Express



The industry's first 4Gbps Fibre Channel controller IC for the new PCI Express system bus has been launched by Agilent Technologies.

The Tachyon QX4 implements an eight-lane PCI Express system bus, which can support four times the bandwidth of prior PCI and PCI-X systems, up to 4Gbps.

The HPFC-6400A Tachyon QX4 Fibre Channel controller IC is suitable for RAID disk arrays, storage subsystems, virtualisation devices, storage routers, host bus adapters and host computer motherboards for mid- to high-end storage applications that use multiprocessor systems.

The Tachyon 4Gbps state-machine architecture easily scales to 8Gbps and 10Gbps. The architecture provides numerous independent functional blocks, which concurrently process inbound data, outbound data, and control and commands in hardware.

The result is simultaneous, parallel processing for maximum bandwidth, and minimum latency and I/O overhead.

www.agilent.com

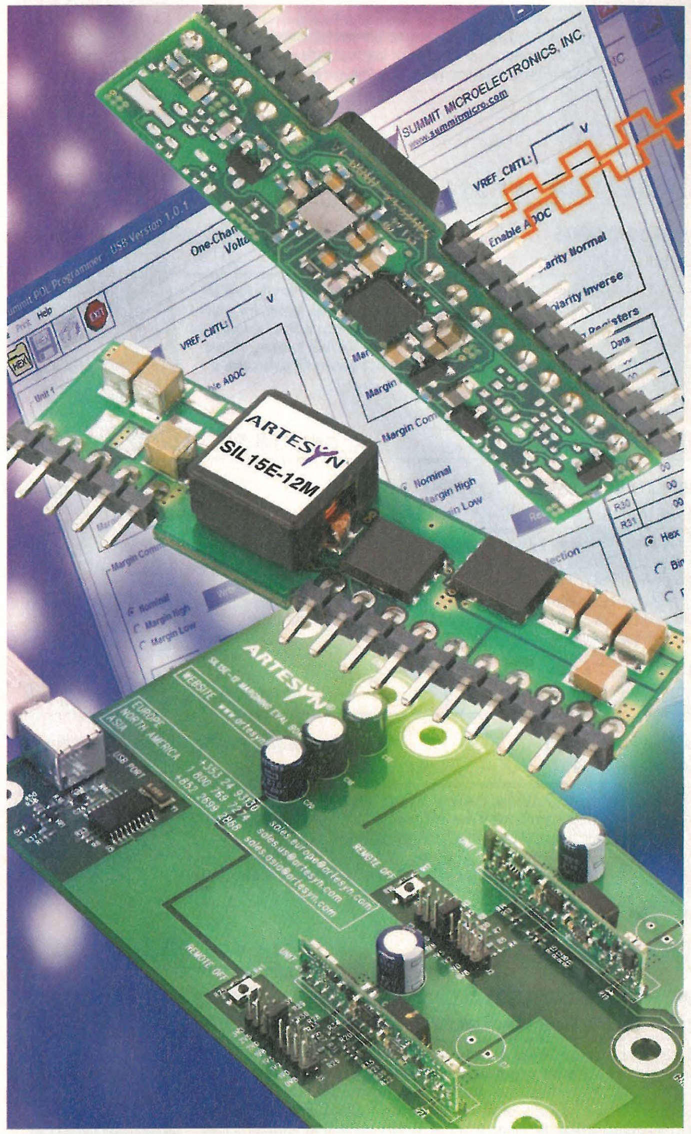
ULPI passes first tests

Semiconductor firm SMSC and USB connectivity solutions provider TransDimension announced the successful completion of high-speed USB compliance testing of the industry's first controller/transceiver solution that uses the new UTMI+ Low Pin Interface (ULPI).

TransDimension's high-speed USB controller IP, a ULPI interface block, and SMSC's USB3300 ULPI standalone physical layer transceiver (PHY), are the first products to pass the high-speed USB Implementers Forum (USB-IF) compliance testing using the new ULPI interface. ULPI modifies the well-known UTMI+ link/PHY interface to significantly reduce the pin count for discrete USB transceiver implementations supporting host, device and On-The-Go (OTG) functionality. This low pin-count interface allows for transceivers to be kept separate from the associated digital ASICs as the technology nodes become smaller and integrating the PHY becomes more complex and expensive.

www.smsc.com

Remotely configurable POL



A remotely configurable point-of-load (POL) DC/DC converter from Artesyn Technologies provides powerful control flexibility for PCB design qualification and production test. The SIL15E-12M non-isolated POL converter is based on Artesyn's 15A SIL15E high efficiency POL converter, but it also incorporates an industry-standard I2C bus interface that simplifies set-up and control.

I2C programmable features include precision setting of both the output voltage and voltage margining facilities. In addition, an active DC output control function significantly increases output voltage accuracy during normal operation and when voltage margining during system test.

SIL15E-12M POL converters have an input voltage range of 10V to 14V and a wide 0.8V to 3.36V output range. The converters use a synchronous Buck regulator topology with precision synchronous rectifier timing, and can generate up to 15A with a very high full load efficiency of 92%.

The SIL15E-12M is intended primarily for high-end applications in the telecommunication and data communication markets.

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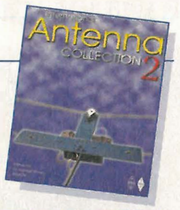

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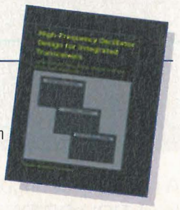
HIGH-FREQUENCY OSCILLATOR DESIGN
Johan van der Tang, Dieter Kasperkovitz & Arthur van Roermund



This text covers the analysis and design of all high-frequency oscillators required to realize integrated ransceivers for wireless and wired applications. This includes the design of oscillator types as single-hase LC oscillators, I/Q LC oscillators, multi-phase LC oscillators, and ring oscillators in various IC echnologies such as bipolar, BiCMOS, CMOS, and SOI (silicon on insulator). Starting from an in depth eview of basic oscillator theory, the authors discuss key oscillator specifications, numerous oscillator ircuit topologies, and introduce the concepts of design figures of merit (FOMs) and benchmark FOMs.

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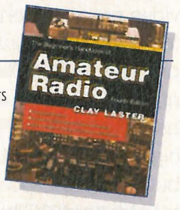
BEGINNERS HANDBOOK OF AMATEUR RADIO
Clay Laster



This text provides the reader with the necessary electronics background to begin "hamming" and to help with preparations for the FCC novice or "no-code" technician class license examinations. It covers the basics of wave propagation, power supplies and electronic circuits.

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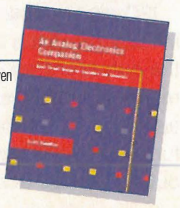
AN ANALOG ELECTRONICS COMPANION
Scott Hamilton



Engineers and scientists frequently find themselves having to get involved in electronic circuit design even though this may not be their specialty. This book is specifically designed for these situations, and has two major advantages for the inexperienced designer: it assumes little prior knowledge of electronics and it takes a modular approach, so you can find just what you need without working through a whole chapter. A major bonus and learning aid is the inclusion of a CD with the student edition of the PSpice simulation software, together with models of most of the circuits described in the book.

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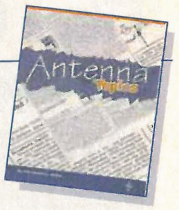

If you are interested in antennas this book is a goldmine of information and ideas on the subject. Pat Hawker has been writing his "Technical Topics" column in Radcom since 1958 and in this time has produced much excellent work in this time. This book is a chronological collection of cuttings of Pat's words over the years. Hundreds of areas and subjects are covered and many a good idea is included. Carefully indexed this book is not only a great reference work but also a history of over forty years of antenna design. At 384 pages this book is excellent value and asset to any amateur interested in antennas.

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Ian Poole

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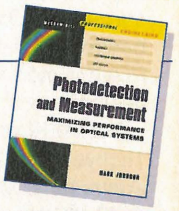

Using basic theory, fully-worked calculation, cicuit snippets and rules-of-thumb, this book conveys the know-how of good opto-electronic design, from low-noise receivers to synchronous detection. "TRY IT" topics provide light-hearted demonstrations of key points. The grad student starting in photonics and the engineer optimising an opto-electronic product will benefit particularly!

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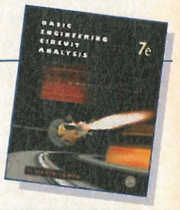

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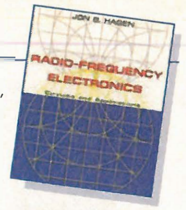

This accessible and comprehensive book provides an introduction to the basic concepts and key circuits of radio frequency systems, covering fundamental principles which apply to all radio devices, from wireless data transceivers on semiconductor chips to high-power broadcast transmitters. Topics covered include filters, amplifiers, oscillators, modulators, low-noise amplifiers, phase-locked loops, and transformers. Applications of radio frequency systems are described in such areas as communications, radio and television broadcasting, radar, and radio astronomy.

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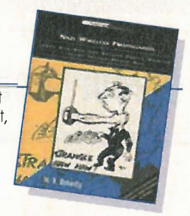

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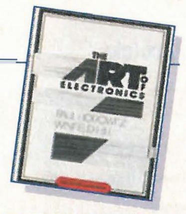

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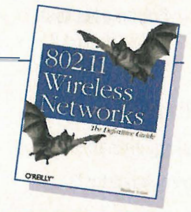

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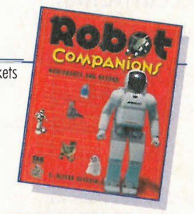

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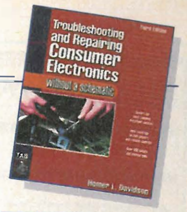

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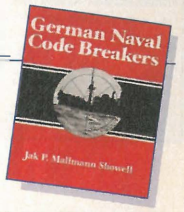

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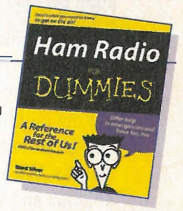

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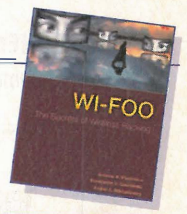

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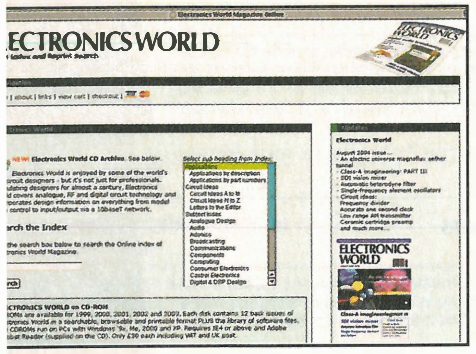

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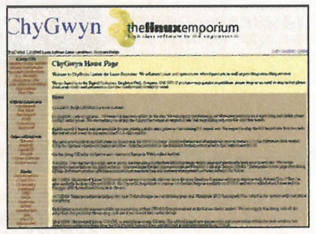

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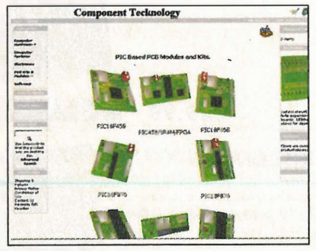

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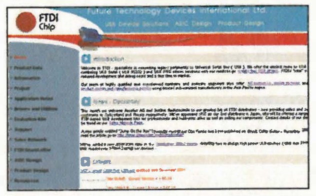

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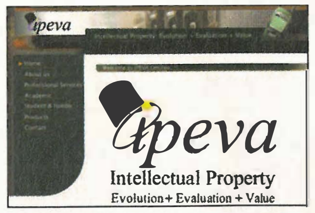

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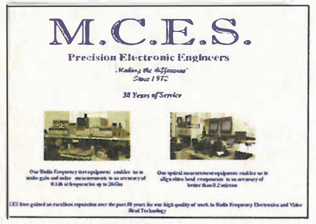

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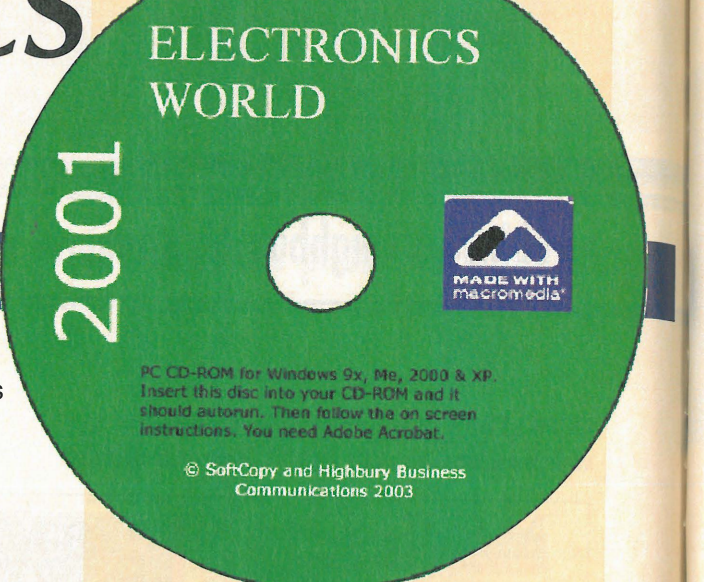

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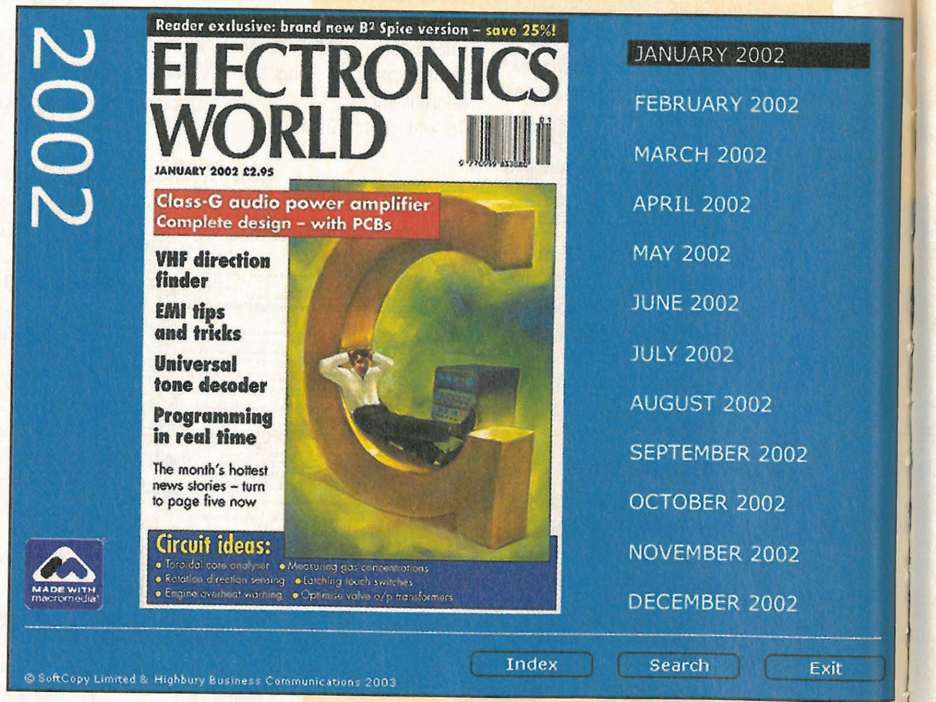

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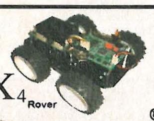

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AT/HP 5350B/010 20GHz Frequency Counter	1995	72
AT/HP 5370A 100MHz Universal Time Interval Counter	1250	50
AT/HP 5372A 500MHz Frequency/Time Interval Analyser	1995	82
Racal 1992 1.3GHz Frequency Counter	950	30
FUNCTION GENERATORS		
AT/HP 3314A 20MHz Function Generator	1250	50
AT/HP 3324A 21MHz Function Generator	1350	54
AT/HP 3325B 21MHz Function Generator	2050	62
AT/HP 3335A 81MHz Function Generator	1850	74
AT/HP 8111A 20MHz Function Generator	1150	46
AT/HP 8116A 50MHz Function Generator	1895	76
AT/HP 8165A 50MHz Function Generator	1350	54
AT/HP 8904A/001/002/003/004 600kHz Function Generator	2950	91
Tek AWG610 2.6 Gs/s Arbitary Waveform Generator	16950	698
LOGIC ANALYSERS		
AT/HP 1652B 80 Channel Logic Analyser	2150	108
AT/HP 1660A 500MHz Timing 100MHz State 136 Ch Log An	2950	89
AT/HP 1662A 500MHz Timing 100MHz State 68 Ch Log An	2550	77
AT/HP 1670G 500MHz Timing 150MHz State 136 Ch Log An	6550	328
AT/HP E2423A SCSI Bus Preprocessor	100	10
NETWORK ANALYSERS		
AT/HP 3575A Gain/Phase Meter	1350	56
AT/HP 3577A 5Hz-200MHz Vector Network Analyser	4750	190
AT/HP 41952A 500MHz Transmission/Reflection Test Set	1950	58
AT/HP 4195A 500MHz Vector Network/Spectrum Analyser	6950	209
AT/HP 8720B 20GHz Vector Network Analyser	20950	825
AT/HP 8752C 1.3GHz Network Analyser	7250	261
AT/HP 8753C 3GHz Vector Network Analyser	6950	285
AT/HP 8753D/1D5 3GHz Vector Network Ana c/w S Param	10250	308
AT/HP 8753E/010 3GHz Vector Network Ana c/w S Param	14000	504
AT/HP 8753ES/002/006/010 6GHz Vector Network Analyser	19500	585
AT/HP 89441A-Various option sets available - prices from	11950	486
Anritsu MS4624B 9GHz Vector Network Analyser	18450	743
Anritsu S331A 3.3GHz Sitemaster Scalar Network Analyser	3950	170
Anritsu S331B 3.3GHz Sitemaster Scalar Network Analyser	4950	213
Anritsu S400A/05 4GHz Sitemaster Scalar Network Analyser	5250	189

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OSCILLOSCOPES		
AT/HP 54111D 2 Channel 500MHz 2GS/s Digitising Scope	1975	80
AT/HP 54112D 4 Channel 100MHz 100MS/s Digitising Scope	2450	103
AT/HP 54502A 2 Channel 400MHz 400MS/s Digitising Scope	1450	58
AT/HP 54600B 2 Channel 100MHz 20MS/s Digitising Scope	1250	40
AT/HP 54602B 4 Channel 150MHz 20MS/s Digital Scope	1850	81
AT/HP 54622D 2 + 16 Ch 100MHz 200MS/s Digi Scope	2750	115
AT/HP 54650A HPIB Interface Module	155	16
AT/HP 54825A 4 Channel 500MHz 2GS/s Digitising Scope	6250	189
AT/HP 54845A 4 Channel 1.5GHz 8GS/s Infinium Scope	9950	399
Lecroy 9374L 4 Channel 1GHz 2GS/s Digitising Scope	4350	195
Lecroy 9384AL/WP1/2/FD/GP/DDM/PRML/MCI/4 4 Ch 1GHz	4750	199
Tek TDS210 2 Channel 60MHz 1GS/s Digitising Scope	600	30
Tek TDS320/14 2 Channel 100MHz 500MS/s Digitising Scope	1500	45
Tek TDS350 2 Channel 200MHz 1GS/s Digitising Scope	1950	80
Tek TDS420A 4 Channel 200MHz 100MS/s Digitising Scope	3600	155
Tek TDS724A/1M 2 Channel 500MHz 1GS/s Digitising Scope	3800	152
POWER METERS		
AT/HP 11722A 2.6GHz Power Sensor Module	1150	35
AT/HP 437B RF Power Meter	1250	55
AT/HP 438A Dual Channel RF Power Meter	1550	47
AT/HP 8481A 10MHz-18GHz 100mW Power Sensor	500	25
AT/HP 8481H 10MHz-18GHz 3W Power Sensor	650	33
Anristu ML2437A RF Power Meter (Single Channel)	1395	60
Anritsu MA2442A 18GHz Power Sensor (High Accuracy)	695	29
Anritsu MA2444A 10MHz-40GHz Power Sensor	825	42
Anritsu MA2473A 10MHz-32GHz Power Sensor	1200	50
Anritsu ML2438A RF Power Meter (Dual Channel)	1995	80
Gigatronics 80401A 10MHz-18GHz 200mW Mod Pwr Sensor	800	40
Gigatronics 80601A 10MHz-18GHz 200mW Mod Pwr Sensor	950	50
Gigatronics 8542C Dual Channel Power Meter	2350	97
Gigatronics 8652A Dual Channel RF Power Meter	3750	150
POWER SUPPLIES		
Wide Range of AT/HP Programmable DC Supplies .....from	600	30
Keithley 248 5000V 5mA High Voltage Supply	1850	74
Kikusui PLZ-300W 300W Electronic Load	995	50
PULSE GENERATORS		
AT/HP 8011A 20MHz Pulse Generator	995	50
AT/HP 8012A 50MHz Pulse Generator	995	50
AT/HP 8130A 300MHz Pulse Generator	5650	230
AT/HP 8133A 33-3000MHz Pulse Generator	12750	537
AT/HP 8160A 50MHz Pulse Generator	2950	119
RF SWEEP GENERATORS		
AT/HP 8340B 10MHz-26.5GHz Synthesised Sweep Generator	9950	399
AT/HP 83640A/001/004/008 10MHz-40GHz Synth Sweeper	19950	790
AT/HP 83650B 50GHz Synthesised Sweeper	38650	1495
Anritsu 68177B/2C 10MHz-50GHz Synthesised Sweeper	19500	759
Gigatronics 8911 10MHz-20GHz Swept Signal Generator	4950	199

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Advantest R3261C 9kHz-2.6GHz Spectrum Analyser	4500	185
Advantest R3365A 100Hz-8GHz Spectrum Analyser c/w TG	9850	391
Advantest R3371A 100Hz-26.5GHz Spectrum Analyser c/w TG	13950	549
Advantest R4131B 3.5GHz Spectrum Analyser	3250	130
AT/HP 3561A 100kHz Dynamic Signal Analyser	2550	108
AT/HP 3585A 40MHz Spectrum Analyser	3500	106
AT/HP 53310A 200MHz Modulation Domain Analyser	2950	90
AT/HP 8560A/002 2.9GHz Spectrum Analyser	6250	250
AT/HP 8562A 22GHz Spectrum Analyser	10950	329
AT/HP 8563A/103/104/H09 22GHz Spectrum Analyser	7950	240
AT/HP 8563E 9kHz-26.5GHz Spectrum Analyser	17500	685
AT/HP 8591A/010/021 1.8GHz Spectrum Analyser With TG	3950	119
AT/HP 8594E 2.9GHz Spectrum Analyser	4650	149
AT/HP 8901B 1.3GHz Modulation Analyser	1950	82
AT/HP 8903B/001/013/051 20Hz-100kHz Audio Analyser	1850	56
Anritsu MS2663C/1/2/4/6 9kHz-8GHz Spectrum Analyser	8350	338
Anritsu MS2665C 21.2GHz Spectrum Analyser	11750	470
Anritsu MS2667C 9kHz-30GHz Spectrum Analyser	14500	596
Anritsu MS2711A 3GHz Handheld Spectrum Analyser	3600	144
IFR 2392 9kHz-2.9GHz Spectrum Analyser	4650	140
R&S FSP7 9kHz-7GHz Spectrum Analyser	11750	423
SIGNAL GENERATORS		
AT/HP 8642A 1GHz Synthesised Signal Generator	1950	78
AT/HP 8643A 1GHz Signal Generator	6975	279
AT/HP 8648A Synthesised Signal Generator	2500	100
AT/HP 8657B/001 2GHz Synthesised Signal Generator	2350	71
AT/HP E4421B 250kHz-3GHz Synthesised Signal Generator	5500	220
AT/HP E4432A/1E5 3GHz Synthesised Signal Generator	6950	278
AT/HP E4433A/1E5 250kHz-4GHz Synthesised Signal Gen	7950	239
Anritsu 68047C 10MHz-20GHz Synthesised Signal Generator	7950	318
Marconi 2031/002 2.7GHz Synthesised Signal Generator	4500	135
Marconi 2041/001 2.7GHz Low Noise Signal Generator	6950	278
TELECOMS		
AT/HP 37722A 2MBPS Digital Telecom Analyser	2650	106
Trend AURORA DUET Basic & Primary Rate ISDN Tester	1950	75
Trend AURORA DUET Basic Rate ISDN Tester	995	50
Trend AURORA PLUS Basic Rate ISDN Tester	350	28
TTC 147 2MBPS Digital Communications Analyser	3500	106
TTC Fireberd Interfaces - many in stock from	395	12
TTC Fireberd 6000A Communication Analyser	3650	110
TTC Fireberd 6000A/5 Communications Analyser	3950	119
TTC Fireberd PR-45 Printer For Fireberd 6000	350	15
TTC ISU 6000-4 Interface Switching Unit For 4 Modules	1650	85
TTC TIMS-45 TIMS Test Set For Fireberd 4000/6000	750	23
W&G PFA-35 2MB/s Digital Communications Analyser	3950	158
TV & VIDEO		
Minolta CA-100 CRT Colour Analyser	2000	80
Philips PM5515T/RGB TV Pattern Gen c/w Teletext + RGB	1750	55
R&S SFQ TV Test Transmitter Various Option sets avail from	17950	646
WIRELESS		
AT/HP 11759C RF Channel Simulator	4750	143
AT/HP 83220E/010 GSM/PCS/DCS1800 (1710-1900) Test Set	1950	59
AT/HP 8920B/1/4/7/13/14 1GHz Radio Comms Test Set	3950	119
AT/HP 8922M/001/006/010 1GHz GSM MS Test Set	3950	158
IFR 2935 GSM 900/1800/1900 Test Head	4950	198
IFR 2967 Radio Comms Test Set with GSM	5950	245
Marconi 2955B 1GHz Radio Comms Test Set	3500	126
Racal 6103/001/002/014 Digital Mobile Radio Test Set	3950	119

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