ELECTRONICS WORLD

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Relay evolution

Calculating SNR of RIAA-equalised pre-amp

Tried and Tested:

Tektronix WFM700 analyser

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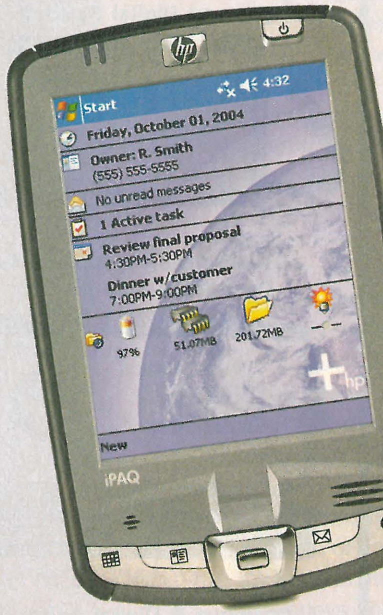

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Consumer leads the way

Ten million Apple iPod MP3 players, 680 million mobile phones, 60 million digital still cameras and over 50 million game consoles were sold worldwide in 2004 alone. Other consumer products also selling like hot cakes are widescreen TVs – plasma, LCD or CRT, projectors and home cinema systems. By 2008, IDC research states that some 450 million households will have a DVD player.

What a staggering amount of consumer devices that represents. And yet, despite the overwhelming evidence of the importance and impact of consumer electronics on our industry, some people still refuse to believe that this area of electronics is the key driving force today and obstinately continue to dismiss this vein of the industry as a "fashion fad", not worthy of being even associated with the 'true' electronics of yesteryear.

Things were undoubtedly different in the past. New technologies were created for (more or less) the sake of it: developers proved how well they could push the boundaries of physics. Nowadays, that technology push has been replaced by ever-growing demands from the consumers themselves. There's been a clear change in the way the electronics industry functions compared to the past and that change has been driven by the consumer.

Consumers' demands for convenience (easy connectivity, communication, portability) and low cost are certainly driving innovation in the electronics industry.

Nearly all portable, consumer devices sold on the High Street today have high-resolution colour screens, high energy-density batteries and chips supporting several different types of communication protocols. There are new coding/decoding technologies, lower-cost yet significantly improved microprocessors , DSPs, FPGAs and even new breeds of programmable logic devices (such as structured ASICs). New power and battery management techniques, new interfaces and lower supply voltages driving ever more complex circuits are just some of the innovations being rapidly adopted in this space.

How can anybody refuse to see this as a positive trend: it drives innovation, it drives productivity, it creates jobs and stimulates the imagination?

Anybody who remains insensitive of the consumer gadgetry that surrounds us in every sphere of our daily lives and who continues to dismiss the importance of such gadgetry to driving innovation – is simply out of touch with the industry today.

Svetlana Josifovska
Editor

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Please call us and leave your details if you would like to participate.

EDITOR: Svetlana Josifovska **E-mail:** s.josifovska@highburybiz.com **EDITORIAL E-mail:** EWeditor@highburybiz.com
EDITORIAL ADMINISTRATION: +44 (0)1322 611274 **E-mail:** EWadmin@highburybiz.com
PRODUCTION EDITOR/DESIGNER: Jane Massey **E-mail:** J.Massey@highburybiz.com
SUBSCRIPTIONS: Customer Interface Ltd, Cary Court, Somerton, TA11 7BR **Telephone:** 0870 4287950, **Fax:** 01458 271146
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‘Big is beautiful’ in boards

The embedded board market is ripe for consolidation and acquisitions, according to Jeff Berson, senior analyst with CIBC, a Canadian merchant bank.

The financial community, particularly private equity funds that made their money during the Internet boom, are eyeing the embedded board business, he says after closely tracking the market. “Wall Street likes it and is starting to wake up to the opportunity.”

He points to 37 tier-two companies – all between $20m and $100m capitalisation – that are ripe for consolidation. “That’s where the opportunities are,” he said. “There are not a lot of acquisitions of a meaningful size.” The remainder of the market is made up of eight large board companies and 455 small companies with revenues of under $20m.

Senior figures for the industry agree. “A fundamental change is taking place today with outsourcing and the market is shifting. There is also going to be more competition from competitors that we haven’t seen in the past, such as Asian manufacturers that do motherboards and embedded boards, and we have to figure out how to differentiate ourselves,” said Scott McGowan, chief executive of Artesyn Technologies, which makes boards and power supplies.

“We do think that it is very, very important to be able to operate at a level where you can offer a range of products – and that takes economies of scale,” said Wendy Vittori, senior vice president at Motorola and general manager of the Embedded Communications Computing Group (ECCG). This was formed late last year after Motorola bought the Force embedded board business from Solectron and merged it with its Computer Group, creating the largest board company in the market.

Wendy Vittori, senior Motorola VP

“Clearly, there is consolidation in the industry and that is going to continue,” added Peter Cavill, chief executive of Radstone Technology, which has just established a new Embedded Computing division. “We’re not interested in doing it just for being big, but, in a way, to help customers with specialist technologies that are complementary to Radstone.”

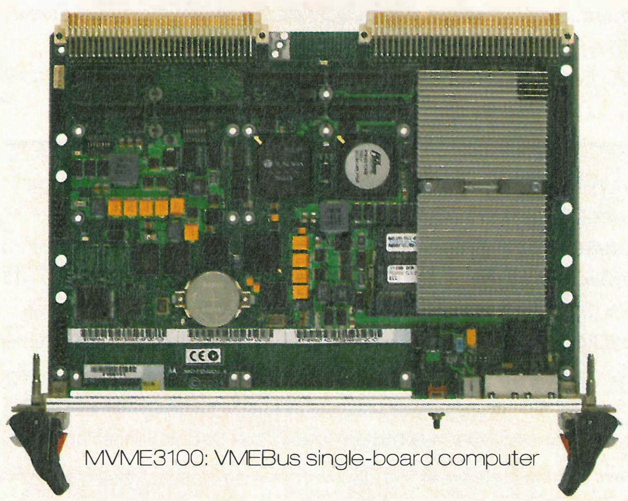
However, some of the smaller board makers such as Pentek, point to the innovation and intellectual property that they own and say they can be faster in meeting the needs of different niches that would not interest the larger companies. The firm has just launched a module that allows a software radio transceiver to be added to a VME card.

The 7140 PMC module uses a Virtex II Pro FPGA and supports the XMC switched Mezzanine card standard.

Motorola backs PCIexpress for VME platform

Motorola’s new Embedded Computing and Communications Group (ECCG) is backing the PCI Express protocol for its VMEbus Switched Serial (VXS) interconnect in a move that gives the technology a significant boost and hits at the competing RapidIO technology. The group is the largest embedded board maker following its takeover of Force Technologies last year.

The new VXS technology (previously called specification 41.4 from the VME Industry Trade Association – VITA) adds switching connectors to existing VME64 board designs but does not specify which protocol should be used. RapidIO had seen it as a natural application area, but has been hit by delays over the last year and board makers such as SBS Technologies supporting Infiniband and now Motorola supporting PCI Express.

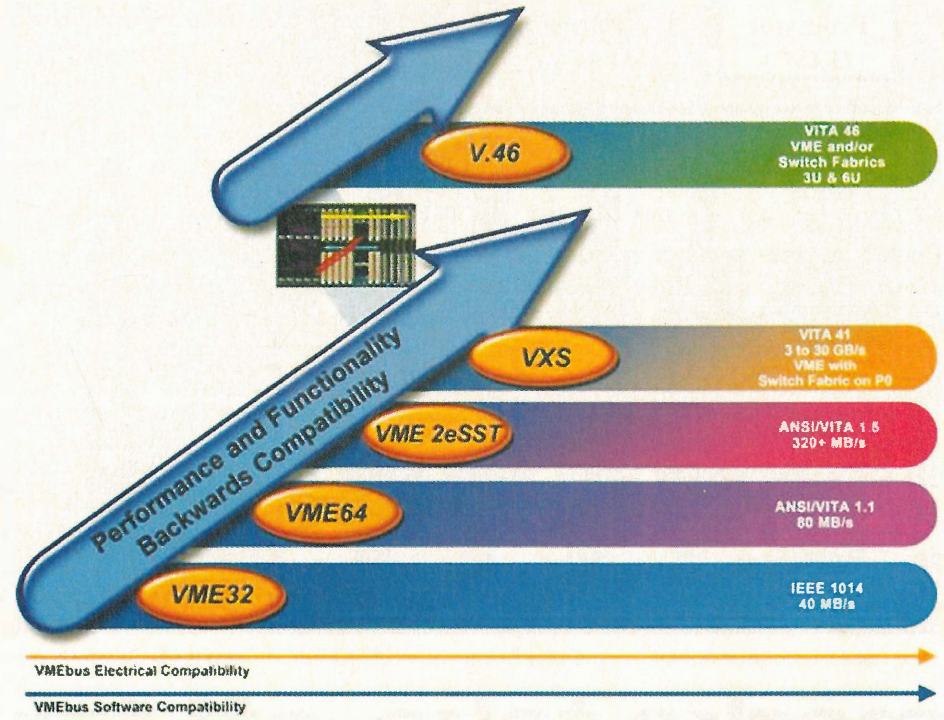


MVME3100: VMEBus single-board computer

“Selecting PCI Express as our VXS (VITA 41.4) implementation is an important extension of the application of PCI Express,” said Wendy Vittori, Motorola senior vice president and general manager of ECCG. “We are bringing the benefits of this standard, broadly-available technology to the new embedded communications computing segment, creating more cost-effective, highly integrated platforms upon which our customers can quickly build their applications.”

“PCI Express is also an excellent fit for the distributed computing applications that many of our customers are building,” added Vittori.

New technologies push VME roadmap



Roadmap of the VME technology

Following the success of the high-speed variant of 64-bit VME, there are new specifications emerging for different parts of the embedded market. While the VITA41 (VME Industry Trade Association) specification, VXS, provides a limited amount of switching between VME cards in an existing VME rack, the VITA46 specification aims to provide significantly more switching via dozens of serial links, with enough combined bandwidth to make distributed switching viable for high-performance applications.

VXS is set to be a general purpose specification, while, at this point, VITA46 is aimed more at the military and aerospace applications. The problem is that not entirely backward-compatible with VME64, as it has to use a hybrid chassis with separate connectors for VME64 and VITA46 cards. This has a series of VITA46 connectors and a series of VME64 connectors, and cards for one specification will not fit in the connectors for the other. The backplane then consists of both the VME64 lines and the VITA46 lines, making this more complex to produce.

This means that there isn’t the traditional flexibility of any card in any slot, but system developers see the VITA46 systems as being custom developments with a set number of each slot for a particular application.

The strength is that existing VME cards, especially custom I/O cards, can still be used in the system, preserving the previous investments and cutting the cost of the development. The VITA46 specification also includes a 3U format for more compact systems that are being demanded in military and aerospace applications, rather than the existing 6U VME systems. It also provides I/O connectors at the rear of the cards so that I/O can be run over the backplane, rather than having to come out in cables from the front of the card, making the systems more rugged.

Yet another variant, VITA48, is coming through as critical for providing the thermal management to take full advantage of the next generation of hot processors, many with dual cores.

VITA41 VXS systems are emerging this year from manufacturers such as Motorola, while VITA46 and VITA48 are emerging in systems from companies such as Mercury Computer Systems by the end of the year.

Datalink Electronics, Leicestershire-based contract electronics manufacturer went to Poland to recruit engineering staff. The firm says this is due to a lack of skilled people in the UK. “Datalink has had problems recruiting skilled staff from this country. The telecoms industry made many workers redundant in the 1990s so many skilled technicians either retrained or settled abroad, leaving a skills gap in the UK,” said Ian Wilson, Datalink director. Datalink also took on students from Loughborough College under the Modern Apprenticeship scheme to train them.

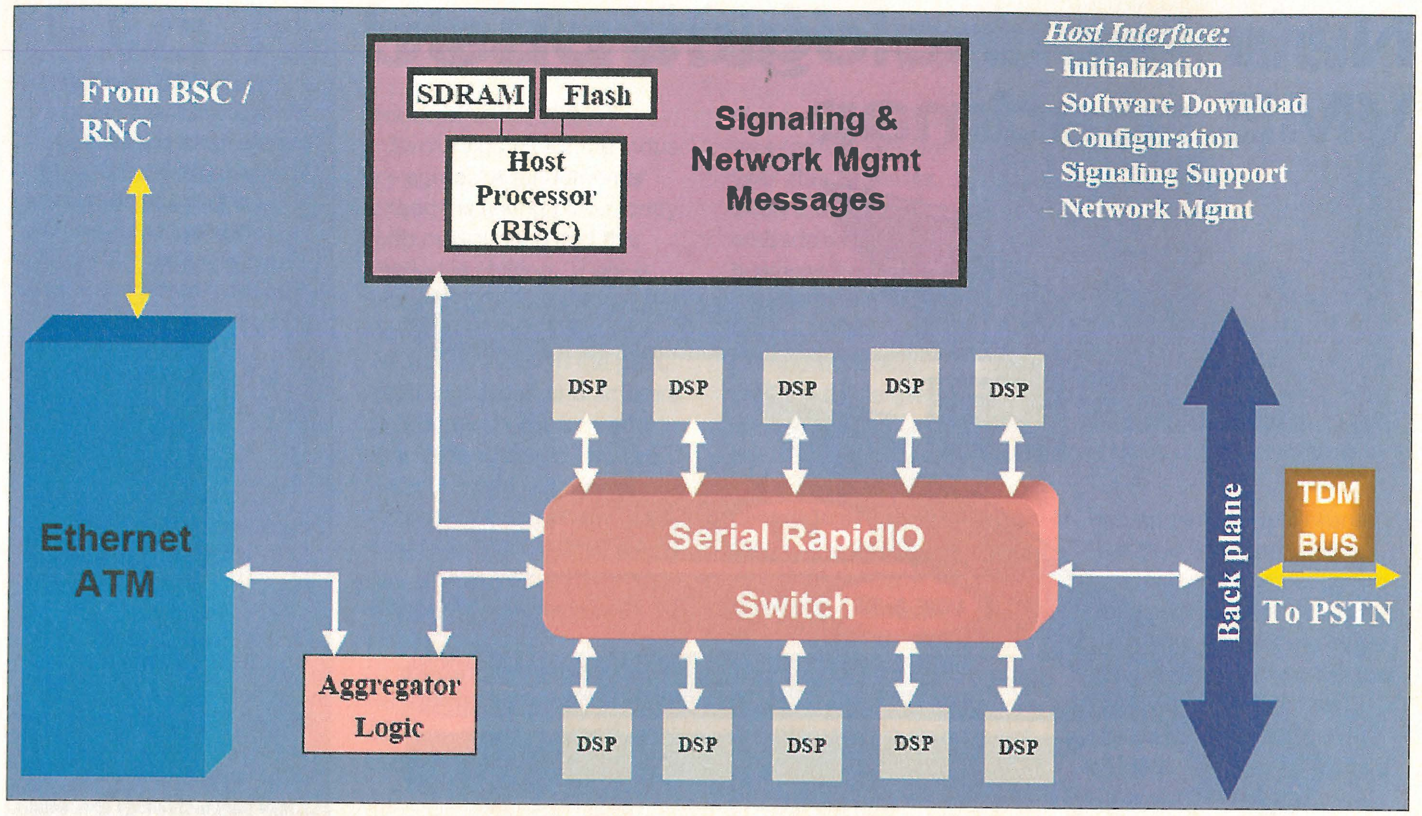
Ω

A multi-disciplinary team of scientists from the Universities of Sheffield, Nottingham, Manchester and Glasgow has been awarded a £3m research grant to develop a new nanotechnology tool, which they have called the ‘Snomipede’. The Snomipede will be used in a diversity of applications including understanding the origins of diseases, low-cost manufacture of plastic electronic circuits and the creation of 13nm molecular structures. The team is led by Professor Graham Leggett from the University of Sheffield.

Ω

Barclays Bank has announcing £500m of lending to support growing businesses within the UK manufacturing sector. “Working on a daily basis with many UK manufacturers, I see a large number of well-managed companies, which have both the desire and the ability to expand and grow if the right finance is available,” said Andy Martin, Barclays’s national director for manufacturing. Barclays predicts that the UK manufacturing sector will grow by up to 2% this year, driven by gradual improvements in order books and the growing investment in R&D.

Ω



Roadmap of the RapidIO future developments

Switch marks take-off for RapidIO infrastructure

Tundra Semiconductor has launched the first RapidIO switch chip that marks the start of the real development of this standard's infrastructure.

While there have been some chips with RapidIO interfaces, linking them together has required FPGAs or custom ASICs. The Tsi568a serial switch chip is being used to provide RapidIO switching on different platforms, from VME to Advanced TCA, with an aggregate bandwidth of 80Gbit/s. The non-blocking switch buffers at the output and so can stream a packet directly through the switch – packet cut-through – to reduce system latency. It supports up to eight 4x links or sixteen 1x links through a SerDes interface.

"The Tundra switch marks the beginning of a significant year for RapidIO, with more than 20 RapidIO-based products scheduled for introduction including switches, processors, bridges, FPGAs, silicon IP, boards, software and tools," said Iain Scott, the new executive director of the RapidIO trade association. "The debut of these products throughout the year will ensure OEMs have the devices they need to speed development of RapidIO-based solutions for the embedded marketplace."

The Association points out that it is ahead of other technologies such as the ASI (Advanced Switching Interconnect). "The release of Tundra Semiconductor's Tsi568A Serial RapidIO Switch provides RapidIO a significant head-start over ASI, which is not expected to be releasing first silicon until the third quarter of this year," said Eric Mantion, senior analyst at market researcher In-Stat.

The RapidIO technology is an open standard and is already included as an interface on some PowerPC-based processors from Motorola, such as the dual core MPC8641D. This is aimed at the networking, telecom, military, storage and pervasive computing applications, with two PowerPC e600 cores, each with the Altivec DSP coprocessor.

Texas Instruments has also launched a digital signal processor with built-in RapidIO interface, the TMS320TCI6482. This supports four serial 1x links that can be combined to form a single 4x link, allowing connectivity to multiple RapidIO enabled devices or to one high bandwidth RapidIO device. Link data rates support data bandwidth from 1Gbit/s to 10Gbit/s. "The TMS320TCI6482 is an important component that facilitates higher speed interconnectivity and more reliable performance in the design of advanced communications systems," said Scott.

PCIe moves into embedded

PCI Express is starting to move from the high-end PC and server market into the embedded world, say its supporters.

The COMexpress specification for Computer-On-a-Module is set to be released in April or May this year, with revision 1.1 of the PCIexpress base specification (approved early this year) and compliance testing starting before the summer. The first standard COMexpress products are expected as soon as May, although there are already pre-compliant products from manufacturers such as Kontron and RadiSys.

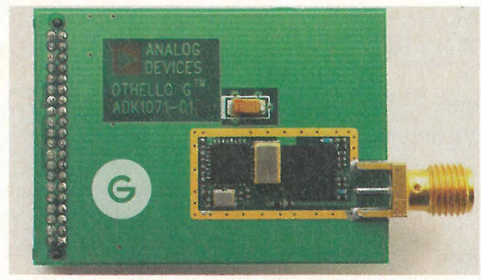
To boost the infrastructure for PCI Express (PCIe) embedded designs, US-based PLX Technology has been sampling a 16-lane switch to customers over the last few months, which it demonstrated in January, and has launched a bridge to link existing PCI systems to PCIexpress.

The PEX 8111 provides both forward and reverse bridging from a single high-speed serial 'lane' of PCI Express to 32-bit PCI bus, and PLX has already sampled the bridge and a development kit to manufacturers in the communications, graphics printing and notebook PC markets. "The PEX 8111 is a key building block for the next wave of PCI Express systems in 2005," said Chris Youman, senior product marketing manager at PLX. "Sampling of the PEX 8111 and the availability of development tools, such as the development kit for the bridge, marks a significant point in the deployment of PCI Express; manufacturers now have the ability to evaluate and design with the world's smallest and the only reversible PCI Express bridge."

It features 8k of shared RAM and consumes less than 500mW of power. It is aimed at small form-factor designs for notebook computers and communication systems, such as the ExpressCard, PCI Express Mini Card, Advanced Mezzanine Card and Switched Mezzanine Card standards.

The PEX 8516 switch is the industry's only 16-lane PCIe switch with four flexible ports, two virtual channels and non-transparent bridging. This is the second switch chip from PLX. Both provide key capabilities such as quality of service through the mapping of eight traffic classes on two fully featured virtual channels, with arbitration support for each port, which is not possible with PCI.

ADI technique makes even smaller radio chips



Analog Devices (ADI) showcased its new Othello-G radio chip for GSM/GPRS applications at the 3GSM World Congress. The chip uses 75% fewer components than its previous version. Nevertheless, it supports full quad band operation and integrates nearly all the components for a complete cellular handset radio design onto the single chip with a sensitivity of around -109dBm. The only components that are required are four non-critical decoupling capacitors, SAW filters and matching components, and a power amplifier.

The radio uses direct conversion, zero frequency IF techniques, which ADI pioneered in 1999. Initially, many thought it would impossible to utilise this technique because of the large DC offsets that would appear after amplification. However, by incorporating many new design features, including ADCs and DACs to monitor and compensate for these offsets and the use of differential signal paths, the system has been successfully implemented. A further problem envisaged was that of the mixer breakthrough of the local oscillator signal that would interfere with mobile handsets in the vicinity. This has been overcome using a technique known as a regenerative divider, also pioneered by ADI.

One of the big advantages of using direct conversion techniques is that it is very easy to incorporate multimode operation as well as multiple bands because filtering is easier. As a result, it is possible to construct the complete radio section of a quad band mobile handset including the synthesiser, RF section, PA and all the filtering within a board area of 1.5cm^2.

New touch control system

Atrua's "Wings" system controls the phone

US firm Atrua Technologies has demonstrated an innovative control system for use in mobile phones. With the man-machine interface on handsets becoming more important as their functionality increases, new ways are required to be able to control them easily. Atrua has developed the "Wings" intelligent touch-processing system, which converts finger movements easily into commands for the phone. The system is based on a small, thin sensor (typically less than 15x5mm in size) and specialised processing software.

By wiping a finger over the sensor, the phone is able to assess the owner's fingerprint. This can be used to unlock the phone and other security features. Using the prints from different fingers on the hand or twisting the fingers, for example, can control different functions of the phone.

Atrua's device is already being used in a smart phone developed by Yulong, a subsidiary of China Wireless Technologies based in Hong Kong.

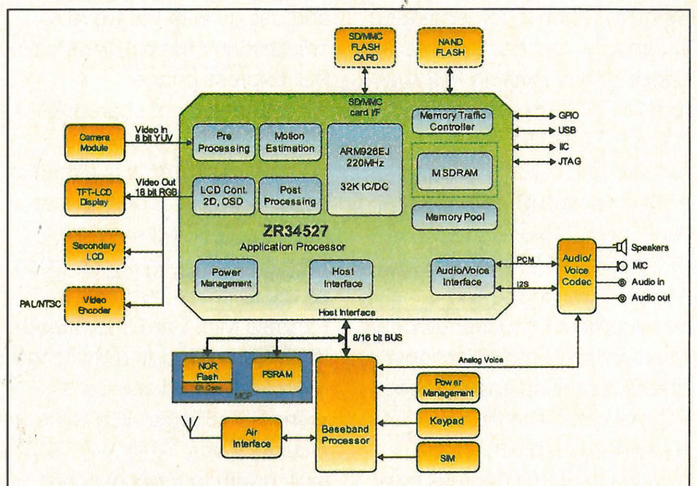
Zoran moves to Approach 4c

US-based Zoran Corporation has launched its second-generation multimedia application processor – Approach 4c – with integrated mobile-SDRAM to provide comprehensive multimedia solutions to phone makers.

Based on the already successful ZR34525, the new ZR34527 improves system aspects such as power consumption, board space and cost, all of which are crucial in the design of mobile phones. The processor provides integrated SDRAM, MPEG-4 video capture and playback, H.264 video decoding, 3Mpixel camera capability, 3D games and 3D audio effects, MP3 and AAC+ playback.

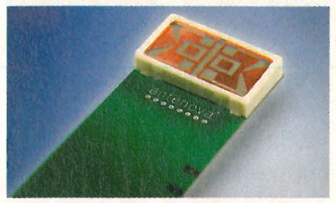
For these capabilities, Zoran used advanced imaging, video and graphics hardware accelerators and a comprehensive set of interfaces. Among them are LCD interfaces with an 18-bit video RGB data bus, 16-bit CPU interface format for up to 18 bits/pixels and an image sensor interface with 8/10-bit CMOS/CCD camera module input port and up to 3Megapixel 15/30 fps input resolution. There are also a USB device interface, JTAG emulation interface, two Universal Synchronous Serial Ports and a variety of other interfaces to enable the device to operate as a full multimedia application co-processor. All of this is built into a 176-pin fine-pitch BGA package, measuring 12x12mm.

The IC is manufactured using a 0.13μm low leakage CMOS process.



Block diagram of the ZR34527 multimedia processor

Better phone efficiencies promised by a dipole



Antenova, the Cambridge-based developer of high-dielectric antennas, has created a drop-in antenna module for mobile phones that offers higher efficiency under torque and an improved specific absorption rate (SAR).

The firm has joined two horizontal unbalanced antennas (monopoles) to create a balanced dipole. "With unbalanced antennas – or monopoles – you have to redesign the antenna because when you put it into torque (when the phone is held in hand), they de-tune and that makes them inefficient," said Simon Kingsley, Antenova's chief scientist and lecturer at Sheffield University. "With our two-halves antenna, we have a balanced dipole, or two carefully balanced, unbalanced antennas."

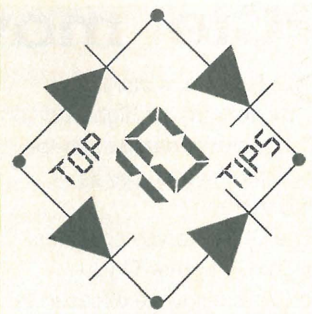
Kingsley said that the torque efficiency would be up by at least 30%. This could lead to a 50% longer talk time.

Mobile phones typically use monopole-type antennas, which use the phone's chassis as a ground plane. But once the phone is gripped, or the chassis redesigned, its resistance changes, which, in turn, de-tunes the antenna. Since Antenova's solution is a balanced self-complimentary two-part antenna, or a dipole, the impedance is virtually independent of the ground plane.

Additionally, being placed into a single module, the transmission line between the antenna and the radio is a lot shorter, too.

The module that also contains the radio, baseband and transceiver, sits on top of electric 'bays'. This requires less PCB real estate as the antenna works over the top of the other components.

The module itself consists of an upper and lower part. The upper part carries the antenna and, being made or plastic, it typically 'snaps' into position on top of the lower module, which contains the radio. The lower part is reflowed onto a PCB and allows for easier testing.



ElectroMagnetic Compatibility

- Consider EMC at the design stage to stop interference at
- When designing PCBs, avoid long tracks, use consistent and unbroken ground planes and decoupling capacitors
- Shield the PCB wherever possible
- Shield the enclosure wherever possible
- Use shielded cables where necessary and terminate the shield at both ends to chassis/ground
- Do not group noisy cables with other cables in a loom
- Avoid large apertures and holes in the enclosure
- Remove the paint from unwelded joints in enclosures, i.e. lids
- Use EMC gaskets for uneven joints
- Ensure all input/output metallic connectors have good all-round contact with the chassis of the host unit

This month's Top Ten Tips list was supplied by Andy Kotas, Marketing Manager at Schaffner Limited.

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

Structured/platform ASICs have arrived

Structured/platform ASICs are not just a buzz word, but a technology offering real benefits , says Gary Meyers

With the current buzz going on about structured/platform ASICs, the question many have been asking is, "Will this new breed of ASIC be successful?" The answer is, "Absolutely." The era of structured/platform ASICs is here with a growing number of customer success stories across the globe, major system customers engaging multiple designs and new vendors entering the field each year. This middle ground between FPGAs and standard cells has become the semi-custom IC of choice for applications not previoúsly anticipated.

Structured/platform ASICs began as the ASIC vendor's answer to the dilemma of deep submicron ASIC design. Smaller semiconductor geometries result in smaller die area and therefore less cost, higher performance and lower power consumption. On the other hand, the era of 130nm design and below hit a wall of complex manufacturing, physics and timing problems that have resulted in expensive tooling charges and lengthier and less predictable design cycles.

Through a combination of device architecture and customised design software, structured/platform ASICs solve these issues and seem a natural fit for ASIC designers who must get to market quickly and are able to relinquish a modest amount of the extreme performance and aggressive unit cost of a standard cell ASIC. The up-front structured ASIC NRE charges are $200k or less compared with 3x to 10x this amount for cell-based semiconductors at equivalent technology nodes. This cost savings alone makes structured/platform ASICs a very attractive alternative for many design teams.

Customised design tools that directly target and understand each unique structured/platform ASIC, typically enable 15-20% better speed and area improvements over conventional design-flows and, thereby, bring results much closer to that of standard cell ASICs. They also solve the timing closure problem through the use of physical synthesis techniques that are tightly correlated to the final place-and-route timing. In addition, they ensure that the designer obeys vendor-specific design rules, which requires extensive signal integrity checking. High performance, low cost and shorter time-to-market with greater schedule predictability cannot be provided by generic tools. This is why all major structured/platform ASIC vendors have ensured that customised physical synthesis tools are available for their architectures.

Early on, it was predicted that structured and platform ASICs could resuscitate the ailing ASIC business by making deep submicron ASIC technology available to smaller companies which, by necessity, have largely shifted from ASIC design to FPGA design. So, was the prediction correct? Structured and platform devices have indeed found themselves in smaller companies, such as Spidcom Technologies in France or WhiteRock Networks in Texas. Such companies that need to tightly manage venture funding can enjoy the performance, low power and unit cost advantages of ASIC technology, while getting to market quickly at a reasonable project cost.

The untold story, however, is the emergence of structured/platform technology in larger companies such as Cisco Systems, Hewlett-Packard, Nortel Networks, Raytheon, EMC, Alcatel, SGI and Seagate that have traditionally only engaged in standard cell or FPGA design.

Trimble Navigation, for example, needed to get its large 3.5m-gate GPS design to market fast and as economically as possible. By choosing to use LSI Logic's RapidChip platform architecture, its NRE cost was about a quarter of what it would have been using a cell-based ASIC. The firm now estimates a saving of 50% on engineering time.

"It was predicted that structured and platform ASICs could resuscitate the ailing ASIC business by making deep submicron ASIC technology available to smaller companies"

Structured/platform ASICs are also benefiting from a major shift in semiconductor end markets. The Semiconductor Industry Association (SIA) states that 50% of semiconductors shipped in 2004 will end up in the hands of individual consumers: from digital cameras to DVD players to increasingly cheap storage devices and cable modems.

And in the consumer markets, performance, low bill of materials, small form-factor and long battery life of the end device are vital. Structured/platform ASICs have indeed arrived.

Gary Meyers is President and CEO of Synplicity, based in the US.

The silicon path of relay technology

Richard Thornton, senior general manager at Matsushita Electric Works in the UK, discusses the development and features of modern switching solutions

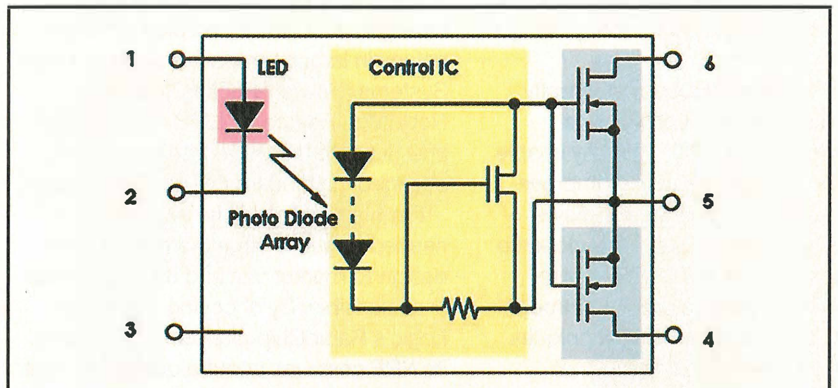


Figure 1: Electrical circuit of a PhotoMOS relay

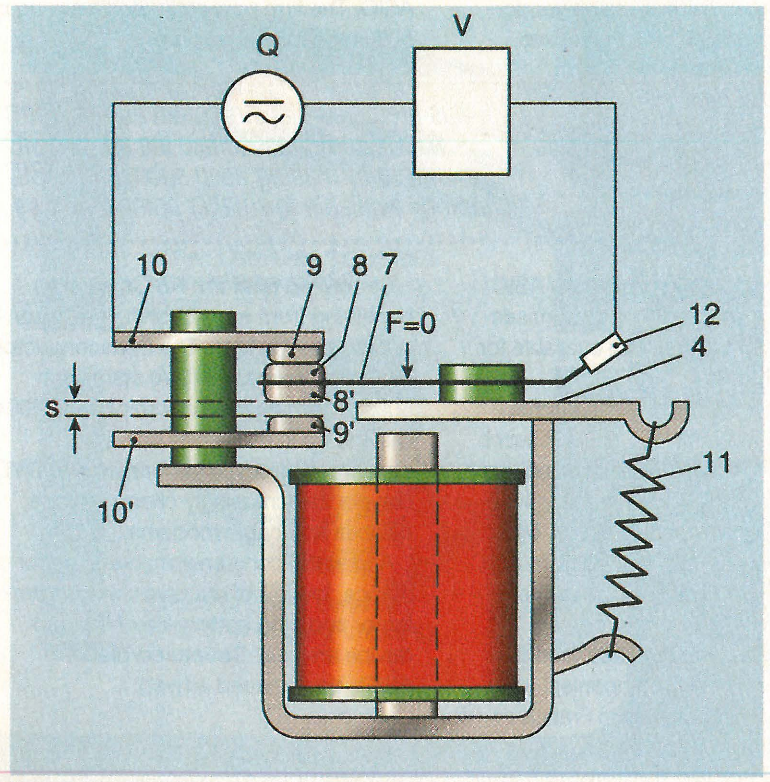


Figure 2: Construction of a non-polarised electromechanical relay

Many engineers believe that in an age of the microchip and its modern electronic circuits, relays no longer have a role to play. But, this is not the case, since electrically-controlled switches are still used in many applications due to their relative simplicity, long life and reliability. Moreover, recent semiconductor technology has provided significant changes to the switching output circuits. This article discusses the development and features of different switching solutions and explains in-depth two different semiconductor-based relay types: the MOSFET-based (PhotoMOS) and triac-based (SSR) relays.

An indispensable part

A relay is an electrical component which output circuit(s) is closed and/or opened depending on application or removal of a suitable voltage to the electrically insulated input circuit.

Relays are, in fact, the optimal switching solution for a wide variety of applications in industrial, consumer, telecommunications, measurement, automotive and other sectors. Many industry applications are completely based on the use of the ubiquitous electromechanical relay. Telecommunication line switching for instance is an area that, against all predictions, has continued to rely on the 2-pole changeover electromechanical relay to make and break line circuits reliably. Admittedly, the size of the relay has dramatically reduced from the old PO3000 design that was the mainstay of the BT network (until the introduction of System X in the mid-1980s that used miniature BT47 relays), to the current micro relays that allow 64 lines per switching card. However, the relatively low unit-cost, reliability of contact resistance, electrical and mechanical life factors, durability under overload conditions and ease of supplying the necessary control factors have made the electromechanical relay an indispensable part of the modern telephone exchange.

Modern test equipment requires many of these features, along with the added qualities of reliable low-level signal switching and electrical isolation, in order to allow distortion-free paths to the measuring circuits. For many years, the electromechanical relay was the only choice for realising such a switching function for an electrical output circuit, which results from the relative movement of mechanical parts.

Semiconductor technology has, however, started to catch up with its electromechanical counterpart. During the last two decades, thanks to the emergence of semiconductor technologies, switching output circuits with an electrical control signal have also been realised by electronic, magnetic, optical and other means that require no mechanical movement.

Non-polarised power relay

The basic function of a non-polarised power relay can be described quite easily: voltage applied to the coil produces coil current that leads to a magnetic flux. Since the armature is mounted near the coil, there is no significant stray flux and the excitation flux encloses the system. Since the yoke is moving, the corresponding contact system is actuated and the contact is opened or closed accordingly. While the relay is excited, the tension of a reset spring increases, leading to a reservoir of stored energy. When the coil applied voltage decreases, this stored energy causes the armature and the contact spring to return to the rest state. This is a simple example of a non-polarised relay.

Today, non-polarised relays employ an increased number of design details in order to offer advanced features. By employing permanent magnets in the magnetic circuit of the relay, efficient polarised relays offer increased advantages, such as reduced coil power consumption, higher contact force and bistable behaviour.

Due to arcs created during switching and mechanical effects, the electromechanical relay suffers wear during its lifetime. In order to prevent this, much consideration was given to the design of

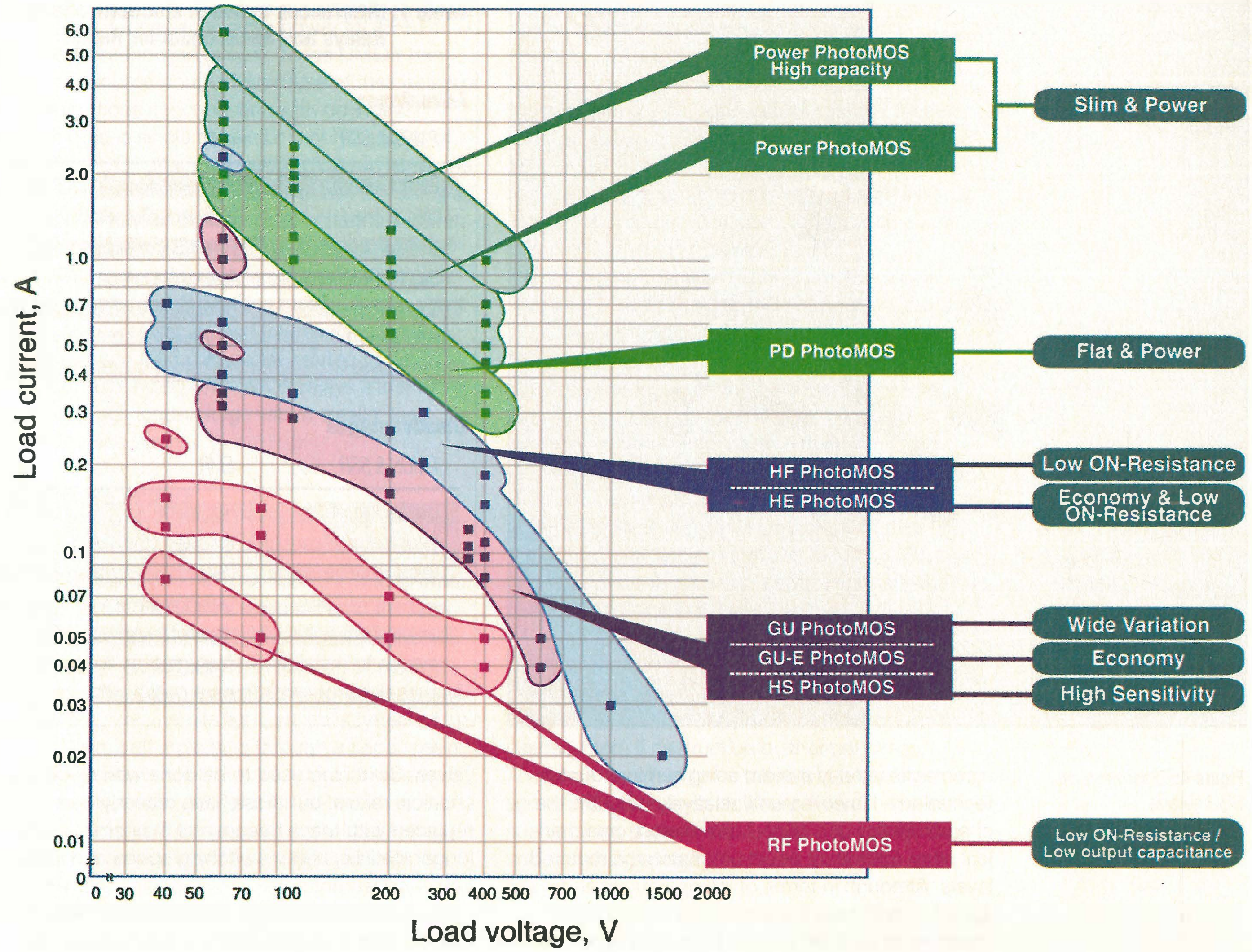


Figure 3: PhotoMOS selector guide

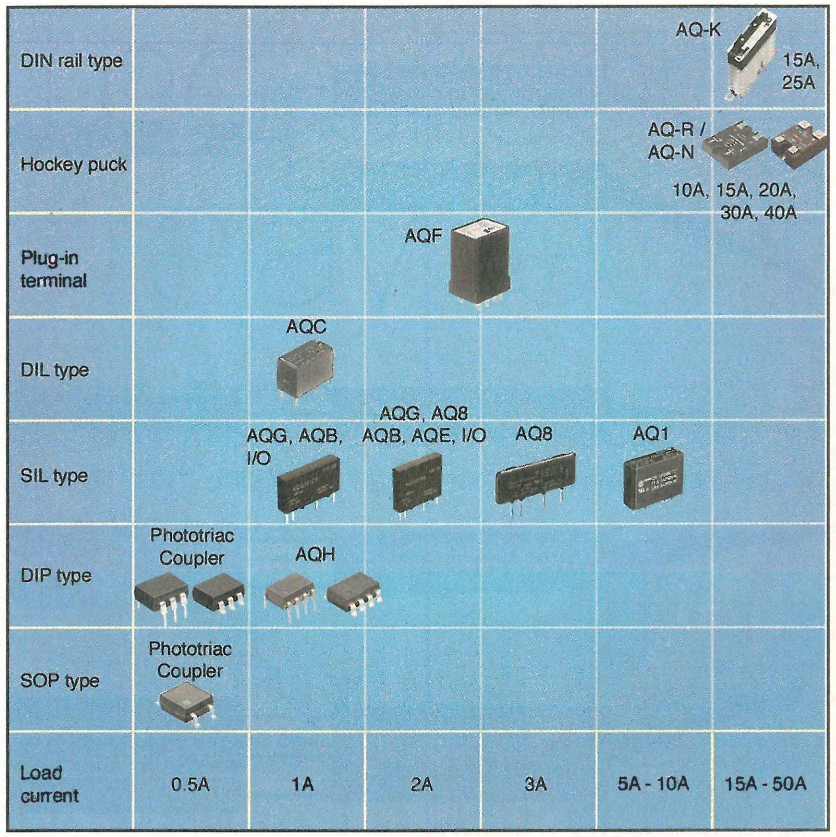


Figure 4: Overview of SSR relays

a contactless relay system using semiconductor technology. However, until relatively recently, the characteristics of a silicon-based electromechanical relay-equivalent could not match the required levels. Although in terms of life operations and speed of switching the silicon relay could offer improvements, it fell short in the critical areas of isolation, overload characteristics, contact arrangements and cost.

There are many circuit applications where older designs of silicon-based relays were ideal – forecourt petrol pumps, where intrinsically safe (no arcing) switching was needed as a prerequisite, generalised motor control encountered in a multitude of industrial devices and non-maintenance applications are just a few. Unfortunately, once moved away from these core applications, semiconductor relays could not be considered as generalised in uses as the electromechanical counterparts.

Triac-based and MOSFET-based models

Modern applications use complex controls to enhance safety, implement convenient features and save energy. Control units use switches to control the sensors and actuators in a system. Since most applications are powered from the AC mains network, several AC voltage loads have to be controlled, e.g. heaters, lamps, motors, fans or valves. Switching used to be done with electromechanical relays, but these have recently been replaced with triacs because of their smaller size, longer lifetime, better switching speed and lower power consumption.

Table 1: Differences between Electromechanical Relays and Semiconductor Relays

Advantages

PMOS & SSR	EMR
Contact reliability	High breakdown voltage
Long lifetime	Surge and noise resistant
Low control current	Form A/B/C contacts
Switching frequency	Load current: microA to A
Noiseless operation	Galvanic isolation of open output
No contact arc	No leakage current
Shock resistant	

Disadvantages

PMOS & SSR	EMR
Leakage current	High volume
Weak against voltage surges	Coil energy consumption
Higher contact resistance	Unstable contact resistance
	Contact wears out
	Operation creates noise
	Contact bounce
	Creates contact arc

Several manufacturers, including Matsushita Electric Works, pursued various paths during the evolution of semiconductor relays and came up with two distinct product groups: MOSFET-based (PhotoMOS) and triac-based (solid state relays, or SSR). One system's strength is the other's weakness. Although based on different working methods, both types of semiconductor relays have galvanically isolated input and output circuits, whereby the output side optically detects the control signal from the input side, hence triggering the switching operation.

However, different technologies can be found in the semiconductor device for switching the output. PhotoMOS relays employ two MOSFETs. The construction of a PhotoMOS relay is, in principle, based on a light transmitting construction. The input pins are connected to a light emitting diode (LED). This LED is located on the upper part of the relay and if a current flows through it, it starts emitting infrared light. Below the LED is an array of solar cells integrated into an optoelectronic device, located at least 0.4mm from the LED to offer suitable isolation characteristics.

The optoelectronic device, in turn, serves as a control circuit for switching the power MOSFETs (and therefore the load circuit). These DMOS transistors are source-coupled, because of their intrinsic bulk-drain-diode in connection with drain and source. Thus, a single transistor is only capable of switching a DC voltage, since the diode will become forward-biased if load polarity reverses. So, using a PhotoMOS relay for switching AC voltages requires two source-coupled DMOSFETs. The output MOSFET's on-resistance and maximum load voltage are a trade-off. For this reason, load current (limited by on-resistance and the resulting power dissipation) and load voltage are related to each other. Corresponding PhotoMOS relays either have a relatively high load-voltage with a smaller load current, or vice versa.

Solid state relays

When it comes to switching main network voltages and high currents, SSRs surpass PhotoMOS relays. The SSR is composed of a low current control input side (typical 5mA to 20mA, depending on the type of SSR) and a high current load side, whereby the relay provides an electrical I/O isolation of several thousand volts. When current flows through the LED on the input side, it emits light, which is detected by a trigger circuit after passing through a silicon resin. The trigger circuit acts like a small triac device and is used to trigger the gate of a larger triac that switches the load in the presence of a load voltage across the triac's output. Once triggered to an 'on' state, the triac maintains this state until the load current crosses zero and the trigger pulse on the input is absent. Upon activation of the input signal, the output is activated in one of two ways: zero-crossing and non zero-crossing.

➢ Zero-crossing: when the input signal is activated, the internal zero-crossing detector circuit triggers the triac to turn on as the AC load voltage crosses zero.

➢ Non zero-crossing: when the input signal is activated, the output immediately turns on, since there is no zero-crossing detector circuit.

Care has to be taken when inductive loads are involved. Voltage spikes may appear across the output when switching to the 'off' state, as the SSR turns off when the load current is zero (which is not necessarily the case for the load voltage due to the phase difference of inductive loads). The generated voltage spike must not exceed the maximum load voltage rating or the dV/dt rating, which is the ascending slope of the voltage spike. The constructional distinction of the output element of PhotoMOS and SSR causes different preferred applications for the two semiconductor relay types.

Nevertheless, there are also common characteristics between the two types of semiconductor relays. Both are sensitive to over-voltages and excessive currents, which leads to power dissipation and causes internal destruction by thermal stress. Therefore, care has to be taken when implementing semiconductor relays. However, if requirements such as long lifetime, stable behaviour, small size and switching speed are critical, semiconductor relays are the best option.

Table 2: Differences between PhotoMOS and Solid State Relays

Advantages

PMOS	SSR
Controls small analogue signals	Best at control of 100/200VAC and 50Hz
Low leakage current	High capacity control (up to 40A)
AC and DC loads	High switching speed
Form A / B contacts	
Small size	

Disadvantages

PMOS	SSR
Output capacity	High leakage current
	Protection circuit necessary
	1 Form A only
	Heat sink

The triac driver

A characteristic that is singular to the semiconductor relay is the possibility that the phototriac may be triggered to 'on' state accidentally. This can happen by exceeding the maximum blocking voltage or by applying very steep rising signals to the output. Such transient signals or noise may exceed the dV/dt rating of the triac driver and, hence, cause the device to proceed into 'on' state.

The dV/dt ratings of the triac and its driver are very important when switching inductive loads, since load voltage and current are not necessary in phase. Since a triac turns off when the load current is zero, load voltage is not necessarily zero. Due to this, the triac may produce a sudden rise in load voltage to its own output, which may exceed its dV/dt rating. In order to increase voltage rise-time, a snubber circuit can be used. In most cases, one snubber circuit will protect the main triac and the phototriac.

It is helpful to look at designing a snubber circuit for a non zero-crossing phototriac (e.g. APT1221), which also protects the main triac in most cases (see **Figure 1**). When using a zero-crossing phototriac (e.g. APT1211), the snubber network may be designed to meet the needs of the main triac, since the phototriac will only switch to 'on' state when the voltage across its output is nearly zero.

When designing the RC snubber network for non zero-crossing triac drivers, detailed knowledge about the load is necessary. By knowing the power factor PF, one can easily calculate the maximum turn-off voltage that may appear across the output. Consequently, a more sensitive triac will require a lower gate current and a higher resistor value. This will force the value of the capacity to increase.

The snubber circuit in this example is designed to meet the dV/dt rating of the phototriac. If the dV/dt rating of the main triac is different, the worst-case value has to be chosen for designing the snubber network.

As can be seen above, there is no easy method for selecting the parts and their values for a snubber network. In particular, detailed knowledge about the load circuit and the power factor is required. These facts make snubber design empirical and result in detailed measurements to verify the parameters calculated. If the user wants to save work when designing the circuit, or have fewer parts and more space on his PCB board, they can choose an SSR.

Besides the phototriac and a main triac, these relays may have an input protection circuit, integrated snubber circuits and a varistor inside. It is possible to choose from various alternatives, based on particular design needs, e.g. space, number of parts, costs, input/output conditions etc.

Silicon supports relays

In summary, the advances in silicon technology achieved during the past decade have allowed a range of semiconductor relays to be manufactured that start to offer both, replacement and complementary product to existing electromechanical product. Only in one area – that of contact configurations – have designs still to be qualified in order that a comprehensive alternative can be offered in the majority of relay switching applications.

Pb free – or not Pb free?

...asks the US military

By Keith Gurnett and Tom Adams

The US military looks – cautiously – at lead-free solders

While the world of electronics manufacturing is turning its attention – if not its enthusiasm – to lead-free processing, the US military is taking a somewhat different view. The US military establishment may, at some point, begin accepting Pb-free as a fact of life, but that time is not likely to arrive soon.

In terms of technology, the military is concerned with the same three Pb-free items that the rest of the world is focused on: the finish on lead frames, the joints between the component and the board, and the plating on the board itself.

The Defense Supply Center in Columbus, Ohio, known as DSCC, has responsibility for specifying parts, taking delivery from suppliers and stockpiling parts for use, as needed. The military perspective, though, is far more conservative than the consumer perspective. New consumer products have radically new designs appear daily, while the military, and DSCC in particular, is responsible for maintaining military electronics systems over periods of decades. A replacement for a navigation system for a helicopter, for example, needs to be available at any time during the service life of the helicopter and the replacement cannot incorporate any changes, however subtle, that make it unusable in the field.

Unlike Europe, the US currently has no federal guidelines mandating the use of Pb-free solders in electronics, so the US military is under no legislative pressure to make the transition. That pressure is more likely to come indirectly from world markets. DSCC has hundreds of suppliers of components, subsystems and systems. Many of these suppliers also manufacture electronics systems that are marketed globally and for these suppliers the switch to Pb-free solders is a necessary element in maintaining their global competitiveness. For example, the great majority of US component manufacturers are currently involved in the research and pilot production needed to begin full-scale Pb-free component production. For DSCC, this broad move toward Pb-free processing means that the supplier of a particular component may one day be able to supply that component only in a Pb-free version.

Part of the current research by component manufacturers involves finding new non-Pb finishes for component lead frames and new molding compounds that will both adhere strongly to the new finishes and survive the higher reflow temperatures of Pb-free processing. As in Europe, US component manufacturers guarantee their components as long as they are reflowed under specified conditions. The critical temperature is 260°C, the temperature above which component damage becomes far more likely. Since reflow temperature is not uniform across a board, a small component in an exposed location might experience 260°C, even during conventional reflow using leaded solder. Manufacturers' guarantees typically account for this possibility by permitting exposure to 260°C for a time of four seconds. But during Pb-free reflow, the same component might reach 260°C for 30 seconds.

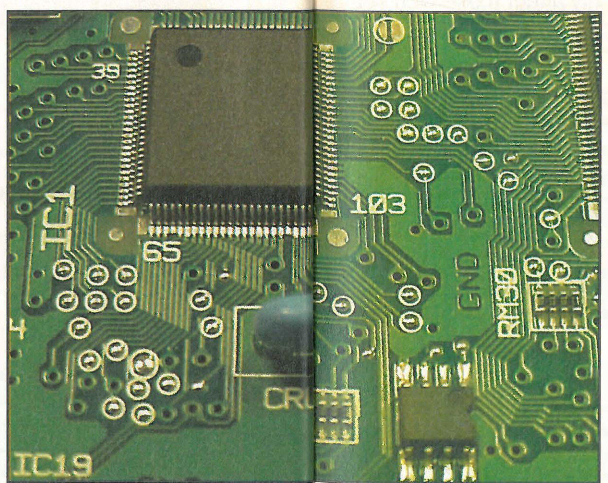
> *"We expect to see the push for Pb-free to come first in the surface mount area – chip resistors, chip capacitors and ICs."*
> Dan Moore, chief of document standardisation, DSCC

Dan Moore is the chief of document standardisation at DSCC. Every new part that is supplied to DSCC must meet carefully defined standards. He notes that no manufacturer has yet applied for approval of a Pb-free component, although he expects such requests sometime in the future. "We cover both surface mount and leaded technology," said Moore. "We expect to see the push for Pb-free to come first in the surface mount area – probably in chip resistors, chip capacitors and ICs."

But Moore points out that a Pb-free component will be handled by DSCC as a new component and that it will have to pass the same battery of qualification tests that would be required of any new or redesigned component. "These are the tests that a manufacturer must perform when there is a design change, so that we are assured that the risk is low," he notes.

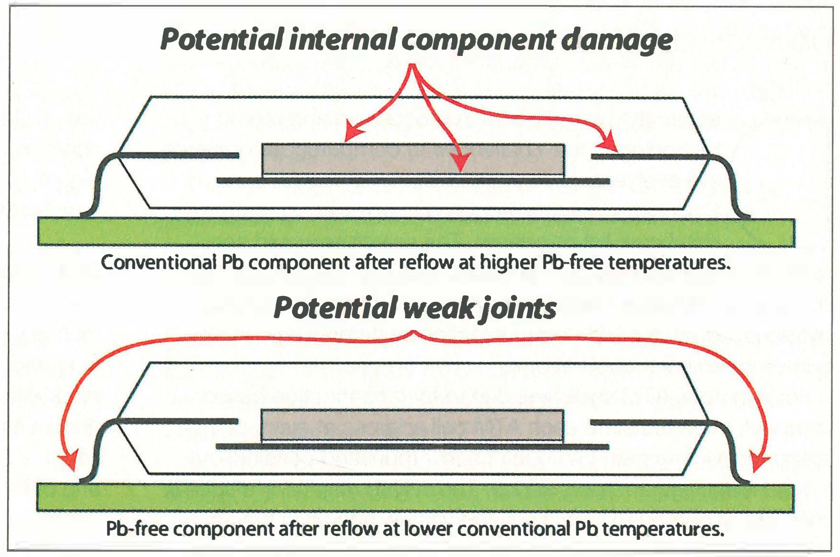
A lead-free component coming into DSCC will also have its own part number, inscribed on the component by the manufacturer. This is what DSCC requires for all components except for those that are physically too small to be labelled – some resistors, for example.

However, the unambiguous labelling of Pb-free components has not met with unanimous approval from US component manufacturers. Although nearly all US component manufacturers are planning to introduce Pb-free components, only slightly more than half of the component manufacturers plan to give those components new part numbers. Instead, they may label the box as Pb-free, or they may refer the user to the manufacturing date range to determine whether a component is Pb-free or not.



Most Pb-free processing is currently being performed on conventional FR4 boards designed for lower temperatures. The higher Pb-free reflow temperatures may warp or delaminate the boards

The situation differs markedly from Europe, where ISO 9000 standards and quality controls govern labelling and traceability of components. What DSCC wants to avoid, of course, is the situation in which a conventional leaded component winds up on a Pb-free board, or the reverse, a Pb-free component sitting on a leaded board. In the first case, the component might suffer damage, but might not fail until it is in the field – the sort of mishap that it is DSCC's mission to avoid. In the second case, the Pb-free component might be only loosely connected to the board – able to pass initial electrical tests, but likely to fail at some unknown point in the future.



Potential damage of Pb-free component after reflow, at higher and lower temperatures

Various industry observers point out that a situation in which the wrong type of component winds up on the wrong board is certain to occur occasionally and that it is much more likely to occur if labelling is less than precise. Other problems also present themselves. For example, assemblers normally return a percentage of components to the component supplier, often without the original package. If only the package bore the Pb-free identification, how will these components be identified? What happens if they are re-sold?

DSCC has been encouraged, but not made less conservative, by scattered reports of tests in which Pb-free components have shown greater reliability than leaded components. Eventually, DSCC will begin qualifying and using Pb-free components. But in military applications in the US, conventional leaded solders will not disappear any time soon and DSCC anticipates having suppliers of leaded components and systems well into the future.

Data manipulation co-processor

Gamal Ali Labib introduces his own design of a co-processor dedicated for data manipulation

Despite the recent boom in processors and memory technology, new challenges to computer performance still evolve.

Some applications require wire speed searches of a database, list or pattern. The searches would normally involve simultaneous comparison of the desired information against the entire list of prestored entries. Image or voice systems, computer and communication systems are possible platforms for such applications.

For example, ATM switches, due to their connection based protocol, must translate each ATM cell address at every point along the routing path into one of a few thousand possible outbound identifiers and port values. The switch maintains a table in memory of outbound identifiers and values, and uses the translated cell address as an index for that table. Cell address translation poses a challenge to hardware performance in order to maintain switch throughput.

On the other hand, manipulating user-defined data complex types and objects in modern programming languages and the increasing reliance of web-enabled and legacy applications on large databases sight additional challenges to hardware performance to cope with software demands.

In this article, I review different processor architectures and introduce my design of a co-processor dedicated for data manipulation. The co-processor hits the key performance issues indicated above and simplifies the manipulation of complex data objects.

Associative memory vs conventional memory

There is a fundamental distinction between associative memory (AM), also called content-addressable memory (CAM), and conventional memory. Associative memory is content addressable, allowing parallel access of multiple memory words. Some implementations of CAM accept search predicate data as input and produce the address of qualifying words as output (see **Figure 1**).

By comparing the input predicate data against the data in memory, a CAM determines if an input value matches one or more values stored in the array. If the comparison is done simultaneously, the CAM is said to be performing at maximum efficiency. On the contrary, conventional memory such as RAM, must be accessed sequentially by specifying the word addresses. The output of RAM is normally data contained in the addressed location. A CAM, on the other hand, has the ability to signal the absence of a piece of data (indicated by the 'Match' output line in Figure 1), unlike an explicitly addressed memory, where some data is always read, whether or not it is what is wanted.

Associative memory architectures

The basic associative memory is a two-dimensional array of identical processing cells. The cell unit of the AM is several bits long and is capable of performing the standard functions of read/write like a RAM cell, but also contains sufficient logic to enable its bit content to be compared with the corresponding bits in a Comparand Register, or ignored depending on the setting of the corresponding bits of a Mask Register (see **Figure 2**). Information and commands are broadcast from the Central Control Unit (CCU) to all cells of memory in parallel. Each cell unit has associated with it a tag bit (response store). A matching cell unit for a compare command issued by the CUU will set its tag bit, while a non-matching cell unit will reset that bit. As commands issued to memory cell units will only affect those with set

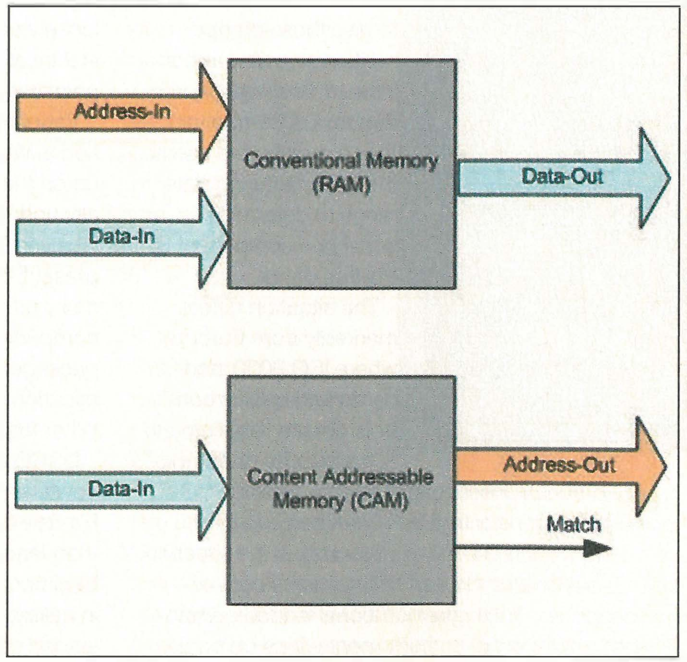


Figure 1: Comparison of CAM and RAM functionality

tag bits, additional capability can be introduced to the AM by linking each tag bit to its immediate neighbours so that transferring (shifting) the activity from one cell unit to its neighbour becomes possible. The Global Tag Operations Unit (GTOU) controls tag bit activities, according to commands issued by the CCU. It also informs the CCU with Response Store status.

The previous features were realised in different implementations of the AM. For example, there is a design capable of performing associative operations on data extending over eight successive cell units. Other design supports forward linking of tag bits, for unlimited number of cell units.

AM organisation may be categorised into four different types, based on how bit/word slices are involved in the operation:

The bit serial: operates with one bit slice at a time across all the words. The time required for an operation to complete (also called the cycle time) using devices of this type is a linear function of the number of bits involved in the operation (except possibly for read and write).

The word serial: operates with all bits of one word slice at a time. The speed of operation in such devices depends on the depth of their memory array.

The fully-parallel: operates with all bits of all word slices simultaneously. The speed of devices of this type depends on the operations implemented in hardware and on the hardware elements used. The cycle time of such devices increases as more complex search and arithmetic operations are to be supported because of carry or borrow propagation.

The block-oriented: operates on mass storage as data is being read (i.e. on-the-fly). The speed of this type depends mainly on the access time of the storage device involved and the used search criteria.

There should be a trade-off between storage capacity, speed and cost when choosing CAM organisation. For example, comparing these four organisations suggests that fully-parallel CAM provides the highest speed (least cycle time) and the least storage capacity.

We may improve the computer performance even further if the processor is designed to perform navigational as well as the pattern-matching operations on structures and objects of business data.

The principles of the co-processor

In this proposal, I follow the direction of adopting associative memories (AM) in supporting querying and manipulating data structures. The proposed co-processor, which I call Associative Co-Processor (ACP), is not a stand-alone back-end structure, but is intended for integration in processor nodes of multiprocessor machines, or with the CPU in single-processor machines (see **Figure 3**).

The co-processor receives data blocks (or data pages) to be processed alongside user-queries or operations to be performed. The CPU is then freed to execute other tasks while the co-processor crunches cashed data. The co-processor module would have direct memory access (DMA) to the node's/computer's local memory and have access to the secondary storage via the node's/computer's I/O controller. Such architecture accelerates data movement to/from the co-processor without posing an overhead on the CPU.

Some AM designs impose a restriction on data by reserving a specific bit pattern for data element headers. Others limit the movement of activity to one direction. The proposed co-processor design presents a solution to those limitations as I will explain in the following sections.

The co-processor architecture and operation

The main functional blocks of the co-processor are similar to t

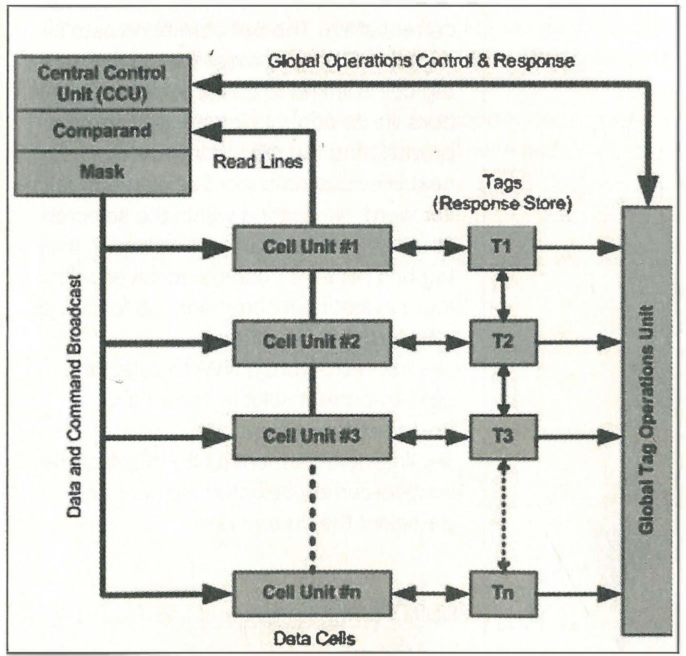


Figure 2: The conventional AM organisation

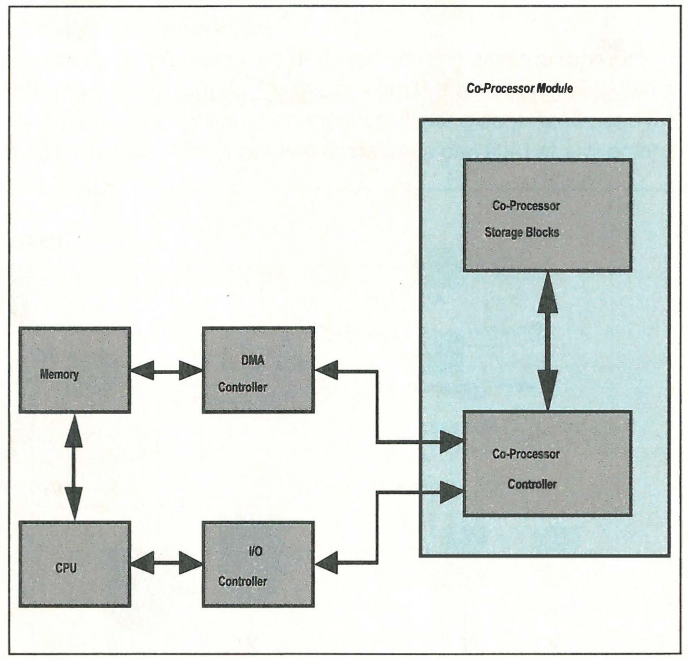


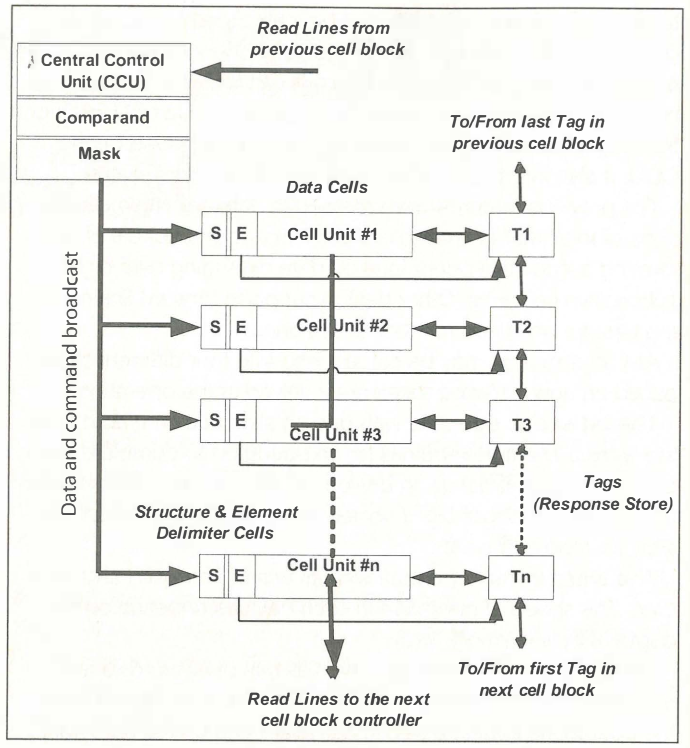
Figure 3: Modified processing node structure

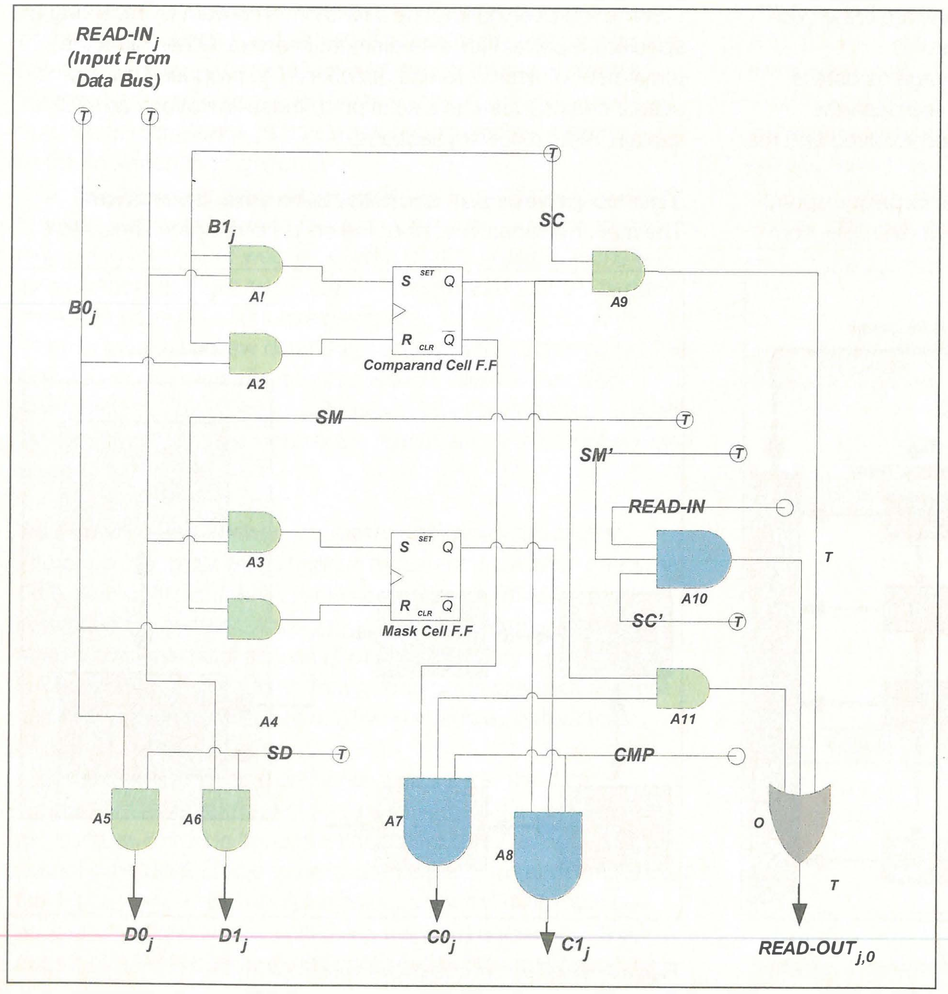
Figure 4: The Co-processor organisation

those of the basic AM, namely: the Comparand, the Mask, the control unit and the associative words (see **Figure 4**). Directing input commands to Data words, the Mask, or the Comparator is achieved by issuing the proper selection command to the co-processor device(s).

The co-processor incorporates in each data word/cell unit (which is basically 8-bit long) additional associative cells of two types: the structure-delimiter type, used to mark the first word of structure header (and optionally its trailer) and the element-delimiter type, used to mark the first word of each element and to navigate throughout structures.

The structure and element-delimiter cells can be manipulated as normal data cells. However, the element-delimiter cell has additional feature of combining its state outputs in the word control circuitry that incorporates the tag bit. A memory word may have one element-delimiter cell at the most, but may have more than one structure-delimiter cell. Allocating a structure-delimiter cell to each constituent-structure would provide optimum performance for accessing complex-structure's components. However, a single structure-delimiter cell per word would suffice to minimise the overhead of control gates per associative word, but with increased navigation overhead.





Selecting a memory word is accomplished by setting its tag bit to '1'. Two commands affect the setting of this cell: Compare and Set. The Compare command matches the contents of each of the selected words with the Comparand according to the Mask setting and, if no match is found, the corresponding tag bit is reset to '0', or otherwise it is left at its current state. The Set command sets all tag bits in the co-processor to '1'. Each tag cell is linked to its immediate neighbors via its control circuitry that permits propagating the tag setting to the next/previous data word or element delimiter word. Navigating within the selected structures, those having words with their tag bits set to '1', can be achieved with four navigational command, as following:

Forward navigation:

➢ link-next-word (LNW) to select the next-to-current selected word and de-select the current one.

➢ link-next-element (LNE) to select the next-to-current selected element and de-select the current one.

Figure 5 (Left): Comparand and mask cell circuitry

Figure 6 (Right): Associative data/delimiter cell circuitry

Backward navigation:

➢ link-previous-word (LPW) to select the previous-to-current selected word and de-select the current one.

➢ link-previous-element (LPE) to select the previous-to-current selected element and de-select the current one.

With such flexibility of navigation within the stored structures in the forward/backward direction, the predicates in a multiple-element search condition can be evaluated in any order, irrespective of their physical locations within structures.

The co-processor has two modes of operation that determine how the associative words are affected by the launched operations (either navigational or data manipulation). The sequential mode causes only the top-most selected word in the co-processor to be affected; the parallel mode affects all selected words, simultaneously. Controlling the mode of operation is realised via the Mode line input to the co-processor. Intermixing sequential and parallel modes of operation is supported within the same transaction.

Circuit design

Figures 5 and **6** show the circuit design of the Comparand, Mask and Data cells mentioned earlier. The data cell is composed of nine gates, which can be reduced to seven (as opposed to five in RAM) if I allow gates O_1 and O_2 to be implemented as wired-ORs. As I indicated before, the co-processor also incorporates in each memory word additional associative cells of two types: the structure-delimiter type, used to mark the first and the last words in the data structure, and the element-delimiter type, used to mark the first word of each structure-element.

Since delimiter words (those having either of their delimiter cells set to '1') are likely to be separated by a number of data words (non-delimiter words), i.e. a structure-element is likely to occupy more than one word, so I introduce a minimised version of those cells that comprises none or a single gate (see **Figure 7**) depending on the word type, that is: structure/element-delimiter or data word.

The built-in control unit of the co-processor device decodes input commands into nine control signals. These are: Compare (CMP), Select Data (SD), Select Mask (SM), Select Comparand (SC), and Set, Link Next Word (LNW), Link Previous Word (LPW), Link Next Element (LNE), Link Previous Element (LPE).

The tag bits manipulate some of the decoded control signals as well as some internal control signals which link the associative words together. **Table 1** describes the functionality of each signal and its source.

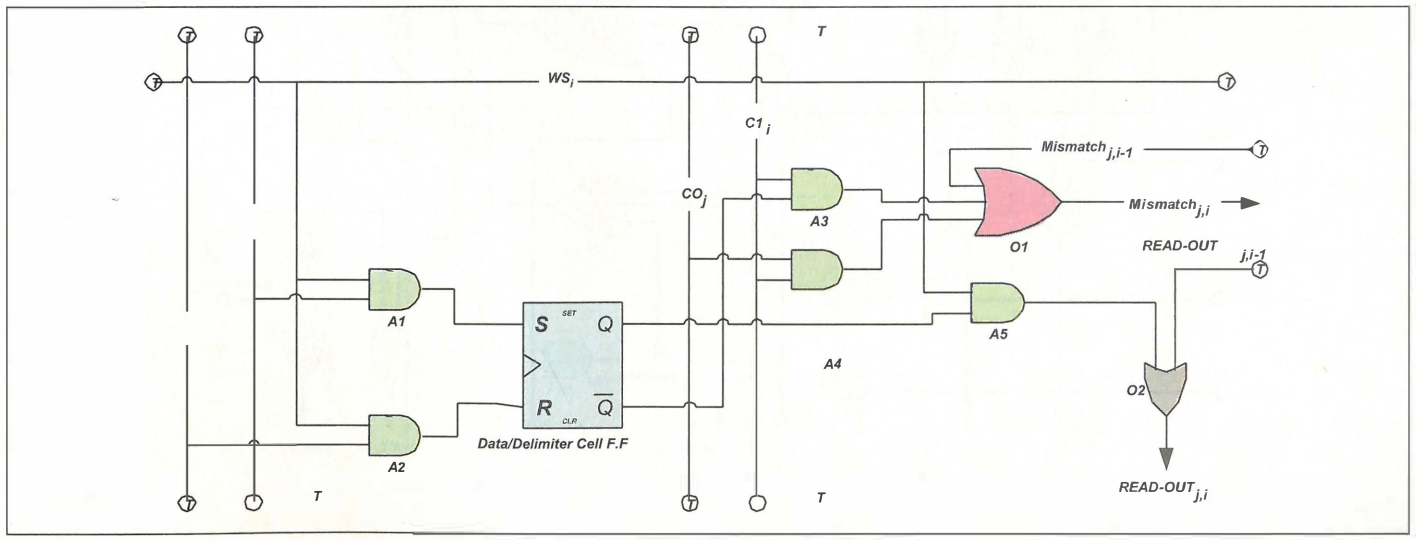
The Delimiter minimisation concept also applies to the tag bits, resulting in two versions comprising 18 and 13 gates (see **Figures 8, 9**). Note that gate O_4 is counted as three 2-input OR gates in Figure 8 with inputs from A1 and A8 being wired-ORed, and is counted for two 2-input OR gates in Figure 9. Gate O_5 is also counted for two 2-input OR gates. Gate O_6 can be implemented as wired-OR to improve cycle time so that RESULT line can convey the tag setting to the chip output as fast as possible. Mentioning the RESULT line, the NONE/SOME line (denoted by N/S) does the same function of the former and in addition it controls word selection in Sequential Mode. This incurs a propagation delay of one gate per associative word making the NONE/SOME line much slower to rely upon for checking comparison results.

Based on the previous optimisations, the co-processor can be manufactured with four intermixed types of words as shown in **Table 2.** Depending on the distribution of those types of words in the co-processor, the average control gates overhead (ACGO) per associative memory word and the maximum number of unused words (MNUW) - fragmentation between structures or structure-elements) - can be determined. For example, choosing an organisation pattern of one type-I word followed by seven type-IV words gives an ACGO of 16 and a MNUW of 7. Thus, tailoring the organisation of the co-processor may be required to suit a particular application.

Operating the co-processor

➢ Retrieval operation

Qualifying structures are retrieved starting with the topmost structure and according to the designated direction (i.e. forward or backward) depending on the word-linking command used (i.e. LNW or LPW). Also, the retrieval process can start at any point



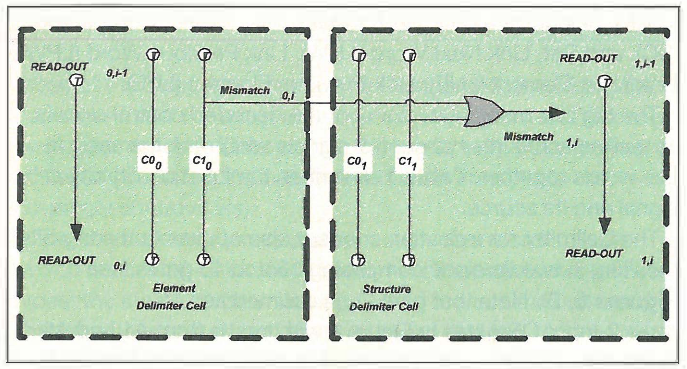


Figure 7: Modified delimiter cell circuitry of a non-delimiter word (type IV)

within selected structures, depending on the requirement of the application and may proceed in either direction as indicated above. The output read lines of the co-processor (READ-OUT) carry the contents of the topmost selected word, while the NONE/SOME line enforces this action.

However, the NONE/SOME line has the potential of elongating the retrieval of selected structures due to its incurred delay of activating the next to the topmost selected structure. Such delays vary according to the distance (counted by associative words) separating both structures. So, instead of accessing structures at fixed intervals (equal to the maximum possible delay), the co-processor controller may sense the setting of the next structure-delimiter at the output lines, then resumes its activities. This mechanism achieves better performance for a large number of selected structures.

Update operation

The co-processor has two modes for the write operation: single-word (Sequential Mode) and multi-word (Parallel Mode). The first mode is realised while the Mode line is reset to '0' during the write operation. In this case, only the topmost selected word will be affected as the N/Si-1 line is reset to '0'. By activating the Mode line (setting it to '1'), the second mode comes in effect. Depending on the control command issued, namely SD, SM or SC, the write operation is directed to the required cells.

Loading the co-processor with a data page is executed by first selecting all associative words using the SET command. While in the Sequential Mode, data is written to the topmost selected word, then the word is de-selected (by comparing it with an illegal value). The latter sequence of operations would be repeated for each word of structure data.

Delete operation

Deleting selected structure(s) can be performed by writing a special bit pattern in the structure header (for example '0's in its first word). Structure freed space can be referenced by the structure's own ID or by replacing it with a special ID introduced specifically for memory management.

Managing free space

The co-processor should be initialised prior to loading it with data. During initialisation, all words are reset to '0's while structure- and element-delimiter cells are set to '1's. So, by selecting the first empty structure-delimiter word (containing '0's in its data cells), while in the sequential-mode, each word of the structure header can be written with SD, followed by a LNW command to select the next empty word. To insert a new element, the LNE command should be issued to select the first available element-delimiter word, and then followed by a SD and LNW to insert each of the element's data words. In this way, the free space is always kept at the bottom of the co-processor as a contiguous area. In update-intensive applications, relocating structures due to their need of acquiring extra space is possible. This would require freeing previous space occupied by the structure. Such mode of operation would cause fragmentation of free space. Reallocating freed structure space to other structures is possible by introducing a management technique for free space. One example of such techniques is the binary buddy system, which was adopted for an object memory. It might also be required to compact free space if memory utilisation falls below a certain threshold while fragments become too small to accommodate any structure. This in turn requires reorganising the structures in the co-processor.

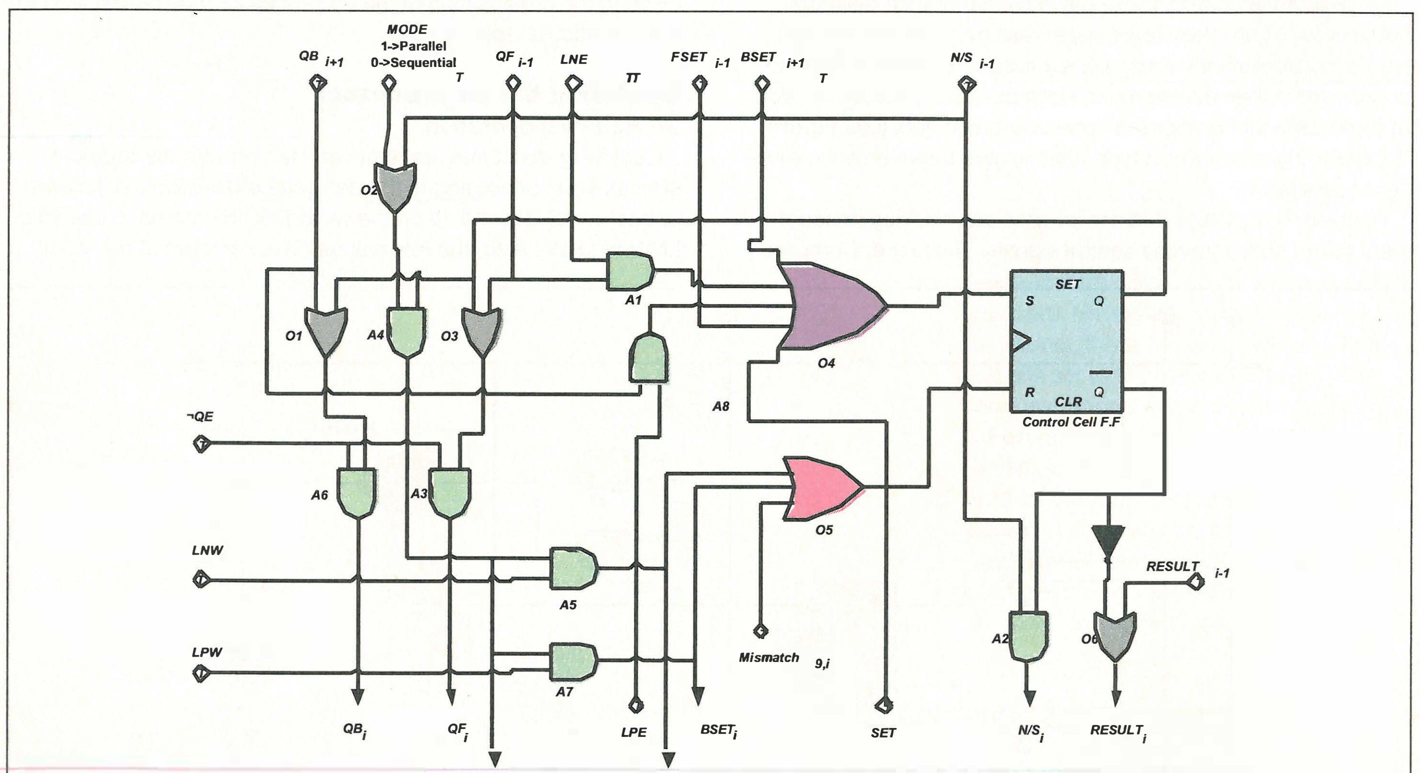


Figure 8: The basic tag control circuitry

Flexible co-processor

In this article, I presented the design of an associative memory based co-processor (ACP) that can perform search and update operations, involving multi-word structure-elements, in parallel or sequentially. Unlike existing associative processors, the co-processor supports bi-directional navigation (forward and backward) within structures and facilitates direct manipulation of structures and their elements with minimal navigation overhead. The co-processor does not impose restriction on structure or element size or reserve any bit patterns to identify data structure or structure-element headers. Co-processor devices can be cascaded to achieve the required cache frame or data-page size. Rather than using separate specialised processors for operations such as data object selection and join operations, the co-processor performs such operations in addition to a variety of logic and mathematical algorithms. Data structures can be relocated in the co-processor without the need to change their references or employ indirection in contrast with RAM-based systems. Supporting navigation between and within structures eliminates the need for storing intermediate query results (in some cases) and provides better performance for nested and complex queries. The associative operation of the co-processor eliminates the need for maintaining multiple indices on objects data in a database.

Such features make the co-processor capable of resolving user queries and manipulating data structures locally instead of transferring them to the host main memory for processing.

The co-processor accelerates data selection and table join operations, a speed-up of several tens-fold can be achieved over typical RAM-based system.

See next page for Table 1.

Table 2: Associative word types (all sizes in gates)

Word Type	Element Cell	Structure Cell	Tag Cell	Data Cell	Total Word Size	Description
Type I	7	7	18	56	88	Fully customisable word
Type II	7	1	18	56	82	Can be an element-delimiter word
Type III	0	7	13	56	76	Can be a structure-delimiter word
Type IV	0	1	13	56	70	Non-delimiter word

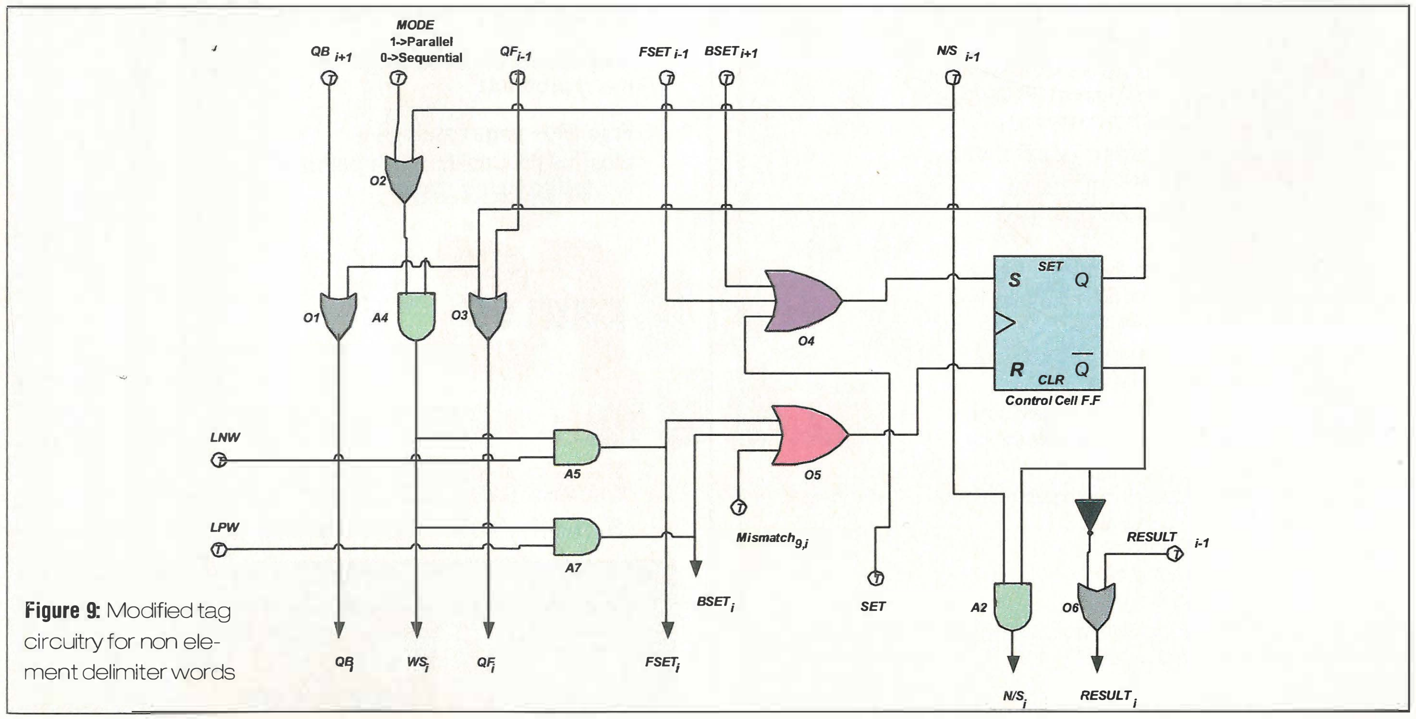


Figure 9: Modified tag circuitry for non element delimiter words

Table 1: Signal legend for the ACP

Signal	Description	external	internal
SET	Set tag bits of all words to 1	√	--
LNW	Link activity to next word	√	--
LPW	Link activity to previous word	√	--
LNE	Link activity to next element	√	--
LPE	Link activity to previous element	√	--
SD	Select input from the data bus as data to associative data cells	√	--
SC	Select input from the data bus as data to Comparand cells	√	--
SM	Select input from the data bus as data to Mask cells	√	--
CMP	Compare data cells with the corresponding unmasked Comparand cells	√	--
QE_i	State of element-delimiter cell of word (i)	--	√
QF_i	State of forward navigation line of word (i) linked to word (i+1) and is used to link activity to the next element-delimiter word. It is disabled if word (i) is an element-delimiter word.	√	√
QB_i	State of backward navigation line of word (i) linked to word (i-1) and is used to link activity to the current element-delimiter word. It is disabled if word (i) is an element-delimiter word.	√	√
WS_i	Select word (i)	--	√
N/S_i	1=no matching found in words (0-i) 0=at least one matching word found in words (0-i)	√	√
$Mismatch_{j,i}$	Accumulated Mismatch results of bits (0-j) in word (i)	--	√
$FSET_i$	Realises forward navigation in conjunction with LNW. Sets Tag cell of next word (i+1) to 1 if Tag (i) is set to 1 and [operating in Parallel Mode (MODE=1) or Tag (i) is the topmost set cell]	√	√
$BSET_i$	Realises backward navigation in conjunction with LPW. Sets Tag cell of previous word (i-1) to 1 if Tag (i) is set to 1 and [operating in Parallel Mode (MODE=1) or Tag (i) is the topmost set cell]	√	√
$RESULT_i$	Accumulated state output of Tag cells of words (0-i) propagated to word (i+1)	√	√
$READ\text{-}OUT_{j,i}$	Accumulated state of delimiter/data cells j of words (0-i)	-- --	√ √
$READ\text{-}IN_j$	Input data to bit j from the data bus. It is split into two adjacent lines: B0j (=1 if READ-INj =0) and B1j (=1 if READ-INj =1)	√	--
$B0_j$, $B1_j$	Input data lines to bit slice j where B0j =1 if bitj =0 and B1j =1 if bitj =1	√	--
$D0_j$, $D1_j$	Input data propagated to cell j of each word (correspond to B0j and B1j when enabled by SD signal)	--	√
$C0_j$, $C1_j$	Unmasked Comparand cell (j) output to delimiter and data cell (j) of each word [0,0] no comparison done [0,1] compare cells (j) with 1 [1,0] compare cells (j) with 0	--	√

Note: (j) refers to bit sequence within the word, where (i) refers to word sequence within the co-processor

Adventure: Noise

How to mathematically outwit the less nice aspects of electronic or mechanical piece of art

By Burkhard Vogel

The design of hum- and noiseless RIAA pre-amplifiers is a kind of art. The existence of a great variety of circuit designs tells many stories of pursuits of high signal-to-noise (SN) ratios, overload matters and fights for precision of the RIAA transfer. Solutions proposed in the past to use – as substitute – resistors or inductors at the input of an RIAA amplifier for noise measurement purposes or to set on mathematical octave-band analysis to get SN results close to the measured ones (with mm-cartridge as input load) do not satisfy. In addition, hum spoils many measurement attempts and the optimal loading capacitance of the mm-cartridge is quite often not taken into account of calculations or measurements.

That's why I wanted to get the answer to the following question: "How can I calculate with relatively high precision the unweighted SN of a RIAA-equalised pre-amp, loaded with a particular mm-cartridge at the input?" In this case, "relatively high precision" means a tolerable difference of 0.5-1.0dB between results of the mathematical approach to find measurement.

Several years ago, in another and much more complex mathematical struggle, I was confronted with a powerful mathematical software called MathCAD (mcd). It's easy to use and offers high speed to find solutions for differential and quadratic equations, integrals, magnitudes etc. So, I thought it might be worth answering my question with the help of such software.

But theory is only one side of the coin, the other side is craftsmanship: all mathematically-generated results have to be confronted with measurement results. Hence, before starting calculations with mcd v11, the whole measurement set-up must be built and tested. Earlier versions of mcd will work equally but mcd11 has one giant advantage over the others – it offers different languages.

Sophisticated piece of equipment

MM-cartridge is a very sophisticated piece of electronic and mechanical elements. Its rather high resistance and inductance values, do not make it easy to develop the right input section for the appropriate amplifier or a good enough mathematical model.

Manufacturers' specifications about cartridges are mostly restricted to DC resistance (*R1*), inductance (*L1*), recommended load capacitance (*C1*) and output voltage (*U*: in most cases given in mV(rms) at 1kHz at 5cm/s peak velocity). Nearly all of this data (**see Table 1**) needs to be questioned since the reality, in many cases, is different to the manufacturer's details (in this study all tested mm-cartridges are made by Shure).

Concerning the data of the M44G cartridge that I've used, the big differences cannot be explained. Because of the many derivatives of this cartridge, it is possible that I have the wrong data.

Unfortunately, it does not end there: the *R1* resistance seems not to have a fixed value. It is claimed that it grows proportional to growing frequencies and, thus, takes an increasing part of the noise creation in the whole input network of a RIAA pre-amplifier, which includes mm-cartridge, *C1*, input resistance *Rin* (= 47kΩ) and input transistor of the pre-amp (**Figure 1**). Fortunately, the influence of the input transistor can be made rather low. With a clever design for the most part, it can be limited to its noise contribution alone.

The frequency generator *Gen1* feeds the mm-cartridge via a high value resistor (2.2MΩ), with that creating a current source. *Gen1*'s output voltage *u(f)* should be 0.5V(rms) and it should be capable of handling the whole frequency range from 10Hz-20kHz. The cartridge is connected to a FET-input op-amp (e.g. OPA604) with low input capacitance (<10pF) and very high input resistance (>10MΩ). The output of the op-amp must be connected to an appropriate measurement system, being capable to measure voltages and phase angles. Here, this is a CLIO40 measuring system that runs very well on an old 133MHz-Pentium computer. It also includes Gen1. To create the trace of the magnitude of the mm-cartridge, the whole frequency range must be fed to the cartridge. The resulting voltage is proportional to the magnitude of $Z1 = |R1+j\omega L1|$ of the cartridge (**Figure 3a**, lower trace, left ordinate [dBV]). It can be transferred into Ohms by calculation with the rule of three. Starting point for *Z1* is 1.01∗R1 at 10Hz which is an empirical value as a result of many performed measurements.

If *R1* and *L1* are a constant value, then the phase angle ϕ (= angle between the magnitude of the impedance of the mm-cartridge and it's real part *R1*, **Figure 3a** upper trace, right ordinate) should become values more and more close to 90° with frequencies above 10kHz (**Figure 3b** = Spice simulation with constant values for the V15V resistance and inductance, transferred into Excel).

But this is not the case as one can see in **Figure 3a** (>3kHz). I guess that not only *R1* is frequency-dependent, *L1* will be too. For example, V15V – right channel: *L1(120Hz) = 338.0mH*, *L1(1kHz) = 331.8mH*. The manufacturers of mm-cartridges don't give much usable information about the substance of their creation. Therefore, any attempts will fail to dive deeper into the physical and chemical secrets by analysing skin effects and permeability. But **Figure 4** shows several interesting looking traces for the V15V MR cartridge, which might give better hints for a mathematical model of a mm-cartridge. Measured with CLIO's 1/3-octave band analyser (RTA) these four traces represent unweighted and RIAA-equalised resistor white noise and V15V noise. You can see that unweighted resistor white noise and V15V noise have the same slope <1kHz. For frequencies >1kHz the slope of the V15V noise becomes +6dB and above, until it reaches the resonance frequency of the input network, whereas the slope of the resistor noise keeps its initial slope (+3dB). The same difference applies to the RIAA-equalised situation. That's why mm-cartridge noise is always stronger than the noise of a resistor alone. Consequently, to get results closer to reality when measuring SNs you'll never find a resistor that is able to replace a mm-cartridge – other approaches have to be found.

A simple mathematical model

In accordance with the findings, it makes sense to start with the simplest mathematical model for a mm-cartridge, which consists of a sequence of a constant value resistor *R1* and a constant value inductance *L1* (**Figure 5**). For calculations of SNs all you need are the exact values of the noise-making components of the RIAA pre-amp and the mm cartridge itself.

To examine the results of the proposed mathematical model for a particular mm-cartridge connected to a particular RIAA pre-amp, it must be possible for all readers to check these results. That's why details for all measurement tools are given. The measurements where carried out with different pieces of equipment, shown in **Figure 6**.

The measurement arrangement consists of:

1) A low-noise measurement pre-amplifier simulates the input stage of a RIAA amplifier. It is not equalised. Its gain is set to

Figure 1: Basic situation

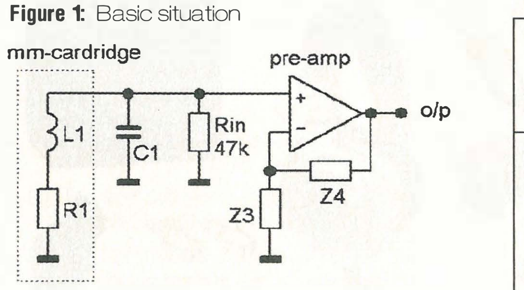


Figure 2: Impedance measurement circuit

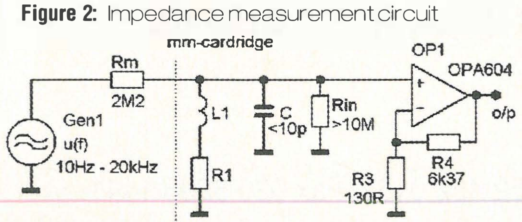


Table 1: Manufacturer data vs measurements

part		Shure MM-cardridges							
		V15V MR		V15IV		V15III *		M44G	
		L	R	L	R	L	R	L	R
R1 [Ω]	manufacturer	815		1380		1350		650	
	measured	791	793	1316	1347	1361	1359	640	641
	delta abs.	24	22	64	33	11	-9	10	9
	delta [%]	0.3	2.7	4.6	2.4	0.8	-0.7	1.5	1.4
L1 [mH]	manufacturer	330.0		500. 0		500.0		650. 0	
	measured	320.3	331.8	519.2	519.7	501.5	504.2	732.7	733.2
	delta abs.	9.7	1.8	19.2	19.7	1.5	4.2	82.7	83.2
	delta [%]	2.9	0.5	3.8	3.9	0.3	0.8	12.7	12.8

* values according to [3]: 1388.8 / 460mH

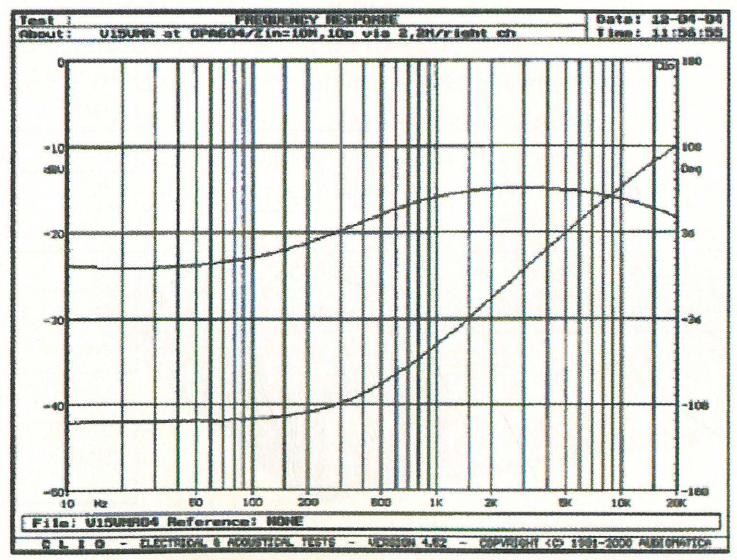
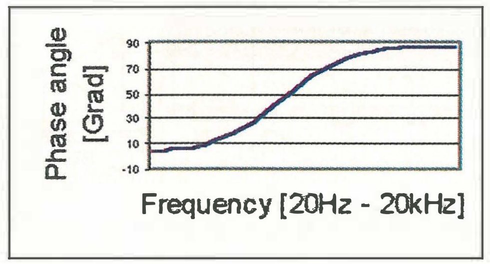


Figure 3a (Left): V15V MR – impedance and phase

Figure 3b (Below): Phase of constant R1 & L1



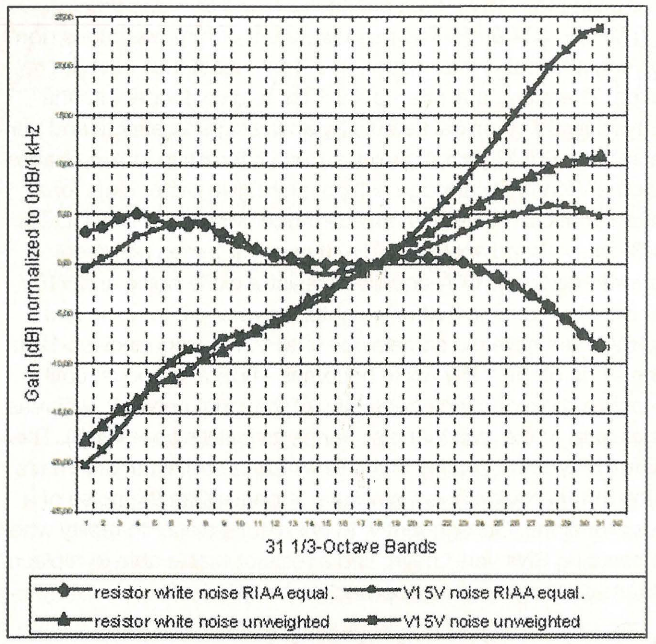


Figure 4: 1/3-octave-band measurements (the numbers underneath the x-axis stand for 31 1/3-octave bands, internationally called bands n. 13 - 43 [5]

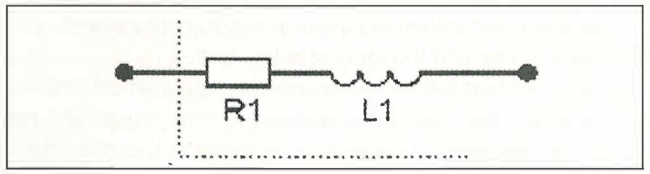


Figure 5: MM-cardridge equivalent-circuit for mathematical modeling

+34dB; input sensitivity is 5mV(rms).

2) A second amplifier stage (AMP) with a gain of +12dB lifts up the output level of the first stage to a typical driving level (0dBV) for power amps. To avoid overload it makes sense to design the output level of the first stage as low as possible (say, 125-300mV(rms)).

3) To enable measurements with RIAA equalisations, a low tolerance (±0.1dB) RIAA equalising stage with a gain of 0dB at 1kHz can be switched to the output of AMP.

4) To lift the very low-level noise signals an extremely low-noise variable gain (0-100dB) stage with 3xLT1028 OPAs follows.

5) A 3-position switch allows the selection of several weighting possibilities:

a) NAB-A-Filter (±0.1dB)

b) 5th order ±0.1dB Chebyshev high-pass filter (f_c = 355Hz), to enable measurements without hum interference. However, the shielding efforts for the whole measurement arrangement should not be underestimated,

c) No weighting.

6) Finally, four different measurement tools show results:

a) CLIO40 is a 16-bit signal generation and measurement system for FFT, frequency response, RTA and much more. It also has a built-in low tolerance NAB-A-Filter,

b) RMS-voltmeter with AD536, followed by an analogue DC-meter,

c) The voltmeter section of a HP 331A distortion analyser,

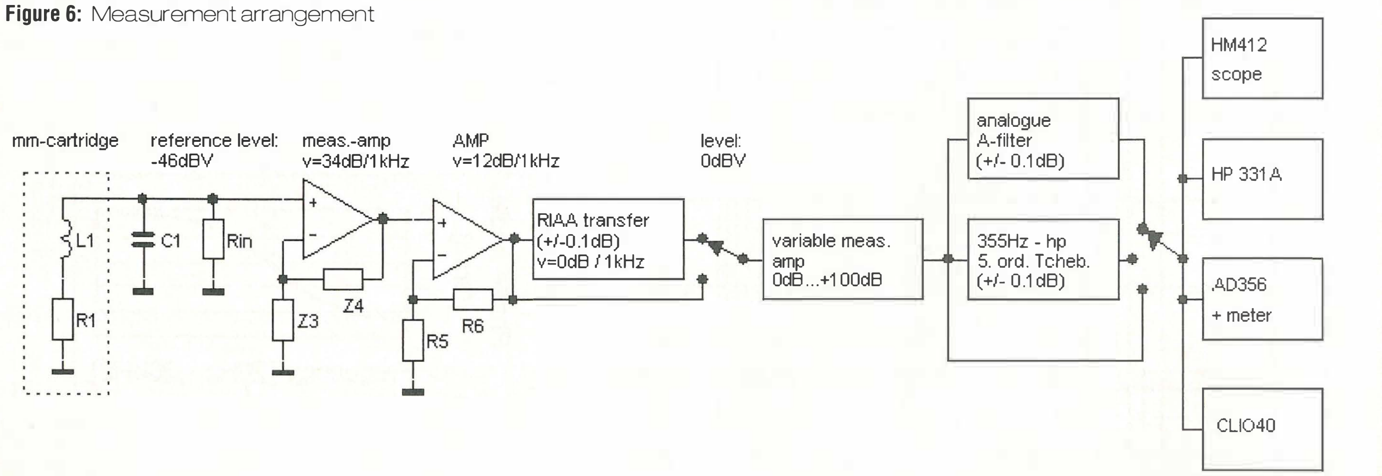
d) Hameg HM 412 scope.

7) All resistors, inductances and capacitors where measured with an 'ELC-131 D' L-C-R-meter (±0.5% tolerance) made by ESCORT.

A Mathcad mathematical model

You can easily calculate impedance networks with Mathcad. In addition, elements once defined on the worksheet keep their value until the end of that worksheet. For example, if the value of *R1* (some lines down this page) got changed to another value, all

Figure 6: Measurement arrangement



following calculations on the worksheet will change accordingly.

The input impedance network *Ztot(f)* shown in **Figure 1** (*mm-cartridge, C1, Rin*) can be written as the sum of admittances, which is in mcd style:

$$Z_{tot}(f) := \left(\frac{1}{R1+2j\pi fL1} + 2j\pi fC1 + \frac{1}{Rin}\right)^{-1}$$

To calculate the magnitude of *Ztot(f)* and its phase angle, all values of the components and the plot frequency range f (e. g. 10Hz steps from 10Hz-20kHz) have to be defined first, in this example case for the Shure V15V MR cartridge. The calculation results can be plotted in diagrams (**Figure 7** and **8**). All values in the diagrams can be read out by applying the mcd-tool "x-y trace". Values (without units) written in mcd style look as follows:

R1=793; L1=0.3318

C1=250∗10^{-12}; Rin=47.5∗103; f=10,20...20000

In Mathcad, phase angles of complex figures are expressed as radians (rad) of the argument (arg). To get "degrees", the results in "rad" have to be divided by "deg" (**Figure 8**). The total noise voltage of *Ztot(f)* consists of the two parts $e_{N1}(f)$ and $e_{N2}(f)$, which, as uncorrelated noise voltages, have to be summed up together with the other amplifier's uncorrelated noise voltages at the +/-input of a noiseless amplifier (**Figure 9**), according to the mathematical rules of the handling of noise voltages and currents. In this case, $e_{N1}(f)$ is the noise voltage of *R1* after it passed through the voltage divider formed by *Z1(f)* and *Z2(f)*, $e_{N2}(f)$ is the noise voltage of *Rin* after it passed through the voltage divider formed by *Rin* and *Z1a(f)*. To continue in mcd style, all physical constants and values (T= 300°Kelvin = absolute (room) temperature, k=1.380651∗10^{-23}= Boltzmann's constant, frequency bandwidth B=19980Hz) have to be written down as well. Application of the Nyquist formula gives the noise voltages of the noise producing components *R1* and *Rin* within *B*:

$e_{NR1}=5.124*10^{-7}$

$e_{NRin}=3.965*10^{-6}$

The impedances that form the input voltage dividers in **Figure 9** are:

$$Z1(f) := R1 + 2j\pi fL1$$

$$Z1a(f) := \left(\frac{1}{Z1(f)} + 2j\pi fC1\right)^{-1}$$

$$Z2(f) := \left(\frac{1}{Rin} + 2j\pi fC1\right)^{-1}$$

Consequently, the equations for $e_{N1}(f)$ and $e_{N2}(f)$ look like:

$$e_{N1}(f) := \sqrt{e_{NR1}^{2}\left|\frac{Z2(f)}{Z1(f)+Z2(f)}\right|^{2}}$$

$$e_{N2}(f) := \sqrt{e_{NRin}^{2}\left|\frac{Z1a(f)}{Z1a(f)+Rin}\right|^{2}}$$

Besides these two noise sources, there are several other equivalent and uncorrelated ones: equal noise voltages and currents $e_{NT1,2}$, $i_{NT1,2}$ of the long-tailed pair T1, T2 ("equal" if both transistors are carefully paired, h_{FE} should be >550) and noise voltage sources from the feedback network itself or in conjunction with i_{NT2} as well as from the total input network in conjunction with i_{NT1} (the measurement amp will be shown in detail later). It is assumed that in the frequency band *B*, the spectral noise densities are "white" in general and that there is no 1/f-noise in *B*. This assumption seems to be valid because the chosen transistors

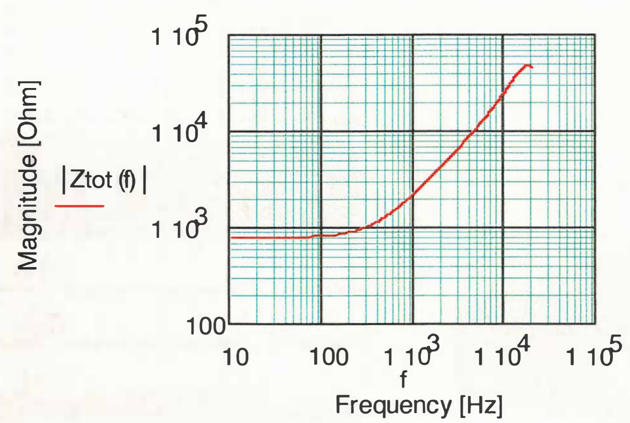


Figure 7: Impedance of input network

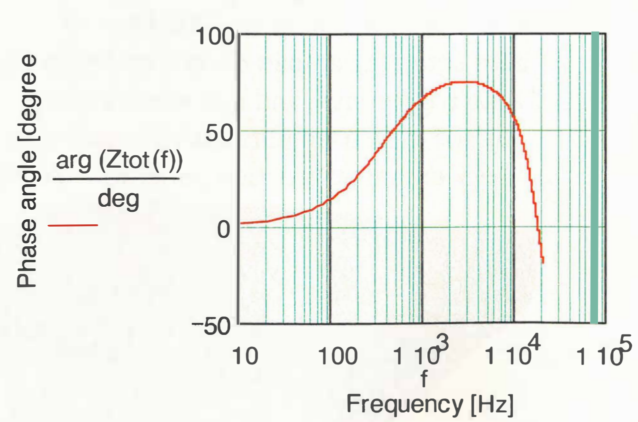


Figure 8: Phase of input network

(2SC2546E) create noise figure traces (**Figure 10-12**) which are very favourable for typical mm-cartridge source resistances in the range of 700R -40k at I_C=100μA.

But these findings do not give an answer to the question from where to get the input transistor noise voltage and noise current at a definite collector current. In the low-noise op-amp case, you can find these figures or traces in the data sheets. The values of e_{NT1}, e_{NT2}, i_{NT1} and i_{NT2} only depend on physical constants (*T, k, q = elementary charge = 1.6022∗10^{-19}*), *IC*, h_{FE} and base resistor R_B (all other internal transistor resistors can be neglected).

$i_{NT1}=3.267*10^{-11}$ $e_{nT1}=2.069*10^{-7}$

To get e_{NT1} (= e_{nT1} + R_B-effect), further steps have to be taken to find the right value for R_B first. Calculations lead to a quadratic equation for e_N^2 that can easily be solved with mcd. The 2SC2546 data sheet figures for the noise voltage e_N at the definite collector current I_K will be the basis for the following calculation:

$I_K=10^{-2}$ A/vHz $e_N=0.5*10^{-9}$V/vHz

Noise voltage and current can be calculated as:

$$i_n(I_K) := \sqrt{\frac{2qI_K}{h_{FE}}}$$

$$e_n(I_K) := kT\sqrt{\frac{2}{qI_K}}$$

The quadratic equation's mcd solution for R_B looks as follows (including the specific mcd-tool "*solve, R$_B$*":

$$e_N^{2} = e_N(I_K)^{2} + (i_n(I_K)R_B)^{2} + 4kTR_B$$

$$solve, R_B \rightarrow (-3115.98 + 13.74)$$

For further calculations only the positive solution for *RB=13.74Ω* makes sense. A check of the calculation approach with LM394 creates a result close to the manufacturer's detail too – 40R3 vs 40R0. Thus, e_{NT1} (*IC = 100μA*) becomes:

$$e_{NT1} := \sqrt{(e_{nT1})^{2} + (i_{NT1}R_B)^{2} + 4kTR_BB}$$

$$e_{NT1} = 2.176*10^{-7}$$

The collection of important noise sources will be completed by inserting the influential factors of *Z3(f)* and *Z4(f)* into the whole calculation course: *Z3(f) = R3 + 1/(j2ωfC3) and Z4(f) = R4 ‖ Z3(f).* i_{NT2} flows through R4 only, thus, $(i_{NT2}*R4)^2$ is a noise voltage source, which is independent of the noise gain of the amplifier. To refer this term to the input it must be divided by the noise gain G = *1+R4/|Z3(f)|*, thus, *R4* divided by *G* leads to the noise voltage $i_{NT2} * |Z4(f)|)^2$.

To get Z3(f) and Z4(f) you have to define the values of R3, C3, R4 first (without units):

R3=130; C3=122∗10^{-6}; R4=6.37∗10^{3};

$$Z3(f) := R3 + \frac{1}{2j\pi fC3}$$

$$Z4(f) := \left(\frac{1}{R4} + \frac{1}{|Z3(f)|}\right)^{-1}$$

$$e_{NZ4}(f) := \sqrt{4kT|Z4(f)|B}$$

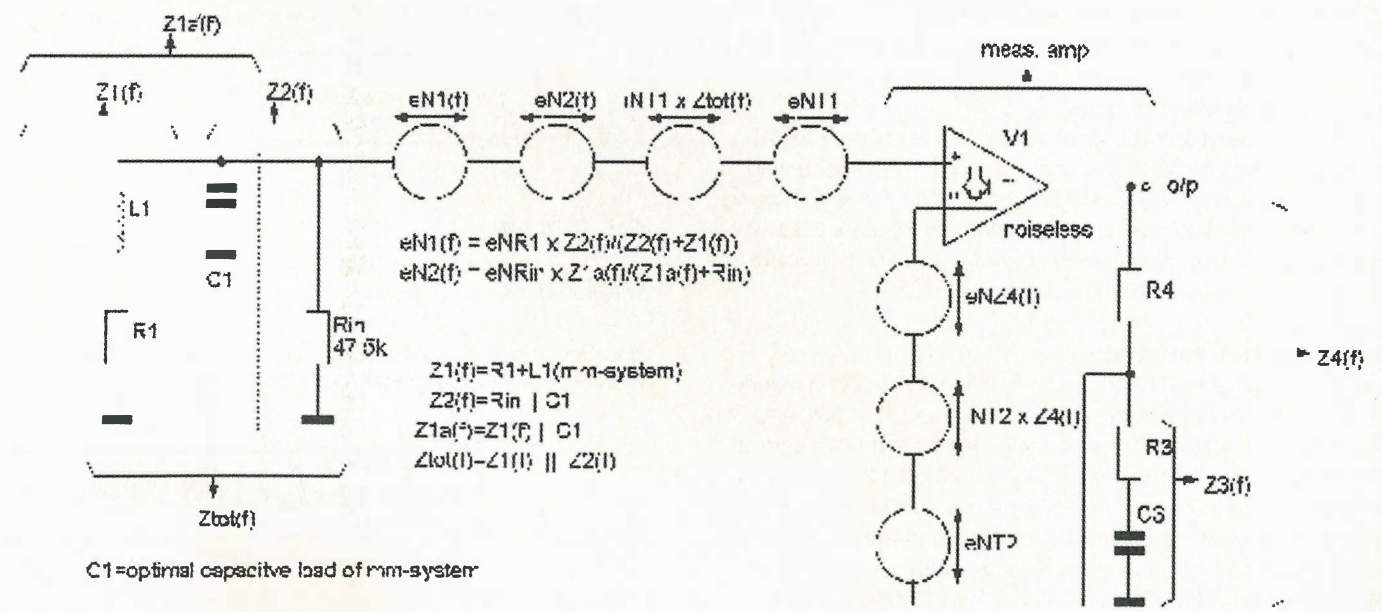


Figure 9: Measurement amplifier including all meaningful noise sources

Equation 12

$$e_{NRot}(f) := \sqrt{2(e_{NT1})^2 + e_{N1}(f)^2 + e_{N2}(f)^2 + (i_{NT1}|Z_{tot}(f)|)^2 + (i_{NT1}|Z4(f)|)^2 + e_{NZ4}(f)^2}$$

The sum of all relevant noise voltages squared will lead to the input referred and frequency dependent noise voltage $e_{Ntot}(f)$. Its rms value is the basis of the signal-to-noise ratio *SN* with reference to an input voltage of 5mV(rms) (-46dBV). Consequently, signal to noise SN_{ne} [dB] can be defined as *SN* of the unweighted and unequalised noise signal (*ne* = non equalised) $e_{Ntot}(f,)$, which includes noise from the cartridge as well as from the pre-amp. SN_{riaa} is the *SN* of $e_{Ntot}(f)$ after equalisation with the RIAA transfer, $SN_{ariaa} = SN_{riaa}$ + *A-Filter weighting*. See **Equation 12** above.

The rms form $e_N(f)$ of a noise voltage $e_{Nxy}(f)$ in a definite frequency bandwidth can be plotted:

$$e_N(f) = \sqrt{\frac{1}{f_{high} - f_{low}} \int_{f_{low}}^{f_{high}} |e_{Nxy}(f)|^2 \, df}$$

Thus, SN_{ne} [dB] referred to 5mV(rms) becomes:

$$SN_{ne} := 20 \log \frac{\sqrt{\frac{1}{B} \int_{20}^{20000} e_{NRot}(f)^2 \, df}}{5mV}$$

$SN_{ne} = -65.1dB$ Measured: SN_{ne} = -67.2dB

Before going further on at this point I have to go back to **Figure 9**: there are two reasons for the inclusion of a hp pole (formed by *R3* and *C3*) into the circuit:

a) Heavy changes of DC voltages at the output can be minimised (caused by impedance changes at the input when measuring with different input loads),

b) This is an additional time constant, simulating the RIAA/IEC roll-off frequency at 20Hz. I've chosen to shift this frequency to 10Hz, because my V15V and V15IV driven RIAA pre-amps sound optimal with this configuration. Generally, this frequency doesn't give any heavy extra disturbance. It is kept at 10Hz throughout the whole calculation and measurement process.

RIAA transfer function

The magnitude of the RIAA transfer function is *R(f)* and is a combination of two low-pass filters (*T1=3180μs* and *T2=75μs*) and one differentiator (*T3=318μs*). To make certain that R(f)'s gain at 1kHz will become 0dB it is necessary to include a 2nd term *R(1000)* into the formula of *R(f)*. This term is nothing else but the reciprocal figure of the original transfer function with *f = 1000Hz*. A plot (**Figure 13**) allows to pick all values with the help of the respective mcd-tool:

e. g. *20Hz = +19.274dB, 20kHz = -19.62dB.*

$$R(f) := \left[\frac{\sqrt{1+(2\pi f T3)^2}}{\sqrt{1+(2\pi f T1)^2}\sqrt{1+(2\pi f T2)^2}} \right] R(1000)^{-1}$$

$$R(1000)^{-1} = 9.898$$

Thus, with the calculation rules for noise voltages passing through a given circuit block the input voltage referred RIAA weighted SN becomes:

$$SN_{riaa} := 20 \log \frac{\sqrt{\frac{1}{B} \int_{20}^{20000} e_{NRot}(f)^2 R(f)^2 \, df}}{5mV}$$

$SN_{riaa} = -78.4dB$

Measured: $SN_{riaa} = -78.6dB$

A-filter transfer function

RMS noise voltages passing through an A-filter according to NAB/ANSI standard (or IEC/CD 1672) with reference to a definite rms voltage level (5mV(rms)) produce the A-weighted *SNa*.

SN_a for $e_{Ntot}(f)$ A-filter weighted becomes:

$$SN_a = 20 \log \frac{\sqrt{\frac{1}{B} \int_{20}^{20000} e_{Ntot}(f)^2 A(f)^2 \, df}}{5mV}$$

$SN_a = -70.1dB$

Measured: $SN_a = -70.9dB$

and SN_{riaa} for $e_{Ntot}(f)$ equalised with RIAA transfer plus A-filter weighting becomes:

$$SN_{ariaa} = 20 \log \frac{\sqrt{\frac{1}{B} \int_{20}^{20000} e_{Ntot}(f)^2 R(f)^2 A(f)^2 \, df}}{5mV}$$

$SN_{ariaa} = -81.9dB$

Measured: $SN_{ariaa} = -81.4dB$

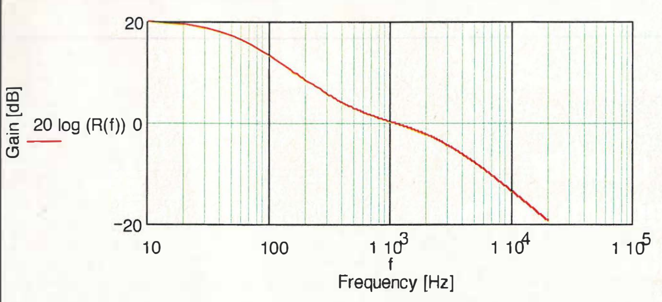


Figure 13: RIAA transfer

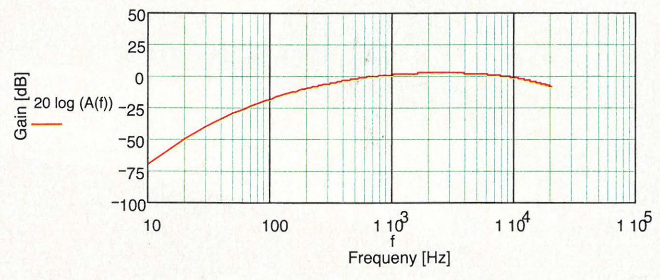


Figure 14: A-weighting filter transfer

It seems that RIAA equalisation "smoothes" the mathematical SN results more towards the measured ones in comparison with the nonequalised cases.

Measurement circuit

The measurement circuit consists of three different blocks. They are all located on one small PCB that is fixed in a shielded Al-box with the dimensions of 170x120x60mm. Block 1 (**Figure 15**) is the adaptation of a RIAA pre-amp circuit design described in National Semiconductor's Application Note An-222. Block 2 (**Figure 16**) is the impedance measurement stage and block 3 (**Figure 17**) is AMP according to **Figure 6**.

To keep noise on the power supply lines as low as possible, the respective circuit looks relatively extensive. VR1 and VR2 stabilise the incoming ±20V, which is fed in from a separate power supply unit through a 1m-shielded cable. Gyrators (T4, T5) form an extra power supply filter. The separate power supply unit (not shown here) consists of one toroidal transformer, two rectifiers and two high-value Cs followed by two additional gyrators with high h_{FE} Darlington transistors BD679 and BD680.

The mm-cartridge is attached to its headshell, fixed by an SME connector to a very short piece of tonearm pipe on the top of a separate shielded Al-box (115x65x55mm). The signal lines go out via BNC connectors. *u(f)* fed through a BNC-L-connector into block 2 and cartridge box (**Figure 2**) enables impedance measurements, while a very short BNC coupler connects block 1 with the cartridge box for *SN* measurements.

The circuit diagram of block 2 is shown in **Figure 16**. For other measurement purposes, S3 switches the input resistance from 10M to 47k5. The 1Hz cut-off frequency of the high-pass filter C3, C4 & R15 is low enough to keep the amp free from gain errors in the 20Hz-20kHz frequency band.

Block 3 (AMP) is a simple low-noise amplifier with its gain setting components. R18 simulates the resistor that might play a role in a two-stage RIAA pre-amp arrangement (75µs low-pass filter, e.g. 750R+100n). This stage's contribution to the overall noise is totally negligible. A rule of thumb says that,"if the input referred SN of an amplifier stage is more than 20dB below the SN at the output of the stage in front of it, then this noise contribution can be neglected" (a calculation gave a 0.0001dB deterioration factor).

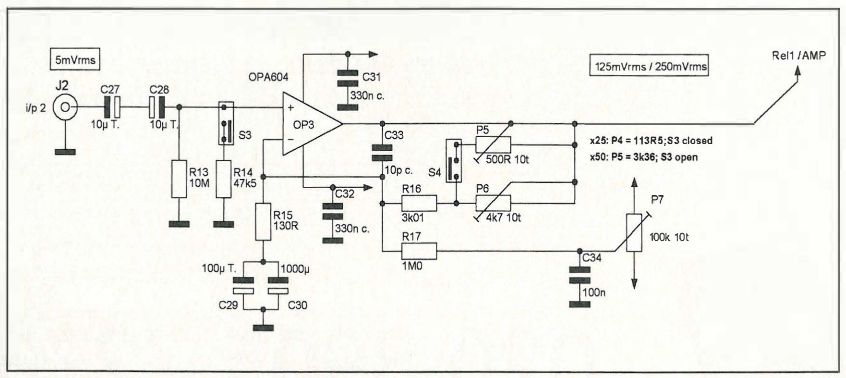
Results

Calculation and measurement results are listed in **Table 2**. The most important lines are number 13 (RIAA-equalised noise: SN_{riaa}) and 16 (RIAA-equalised and A-weighted noise: SN_{ariaa}). These deltas indicate that the claim at the beginning of this article becomes true that a maximum 1.0dB variance between mathematics and measurements could be possible. Another interesting point is that the measured results for the 1k and 12k resistors (lines 6, 9, 12,15) match perfectly with the calculated ones, which is a nice proof of the mathematical model for white noise. The results of the 0R0 and 100R resistors (lines 7, 10) indicate the problems shown in **Figure 10, 11, 12**: very low source resistances and a low collector current (100µA) don't match and will lead to additional noise, which is not reflected in the chosen mathematical approach.

For comparison reasons, column "L" shows the calculated results of a so-called "standard" cartridge, which is used in test magazines to check SNs of RIAA amplifiers (e.g. stereo play"). It consists of a 1k resistor series-connected with a 0.5H inductance (which, of course, is not the same as mm-cartridge inductance of 0.5H with its resistance of 1k. It's nearer to the truth than a resistor alone). But it might not be a good idea to compare test magazine results (with "standard" cartridge) with self-generated ones because there isn't enough information about C1's value in the measurement setup. This capacitor has a great influence on SN, which will be lined out a bit later. The SNs shown in **Table 2** are not the whole truth because each of the tested mm-cartridges has its definite sensitivity *U*, expressed in rms output voltage at 1kHz at 5cm/s peak velocity. Taking this into account, all SNs in **Table 2** will be improved: e. g. U_{V15V} = 3.2mVrms at 5cm/s, on an LP-disc the 0dB level is at 8cm/s peak velocity, therefore, with the rule of three U_{V15V} becomes 5.12mV(rms) and thus, the V15V SNs improve by +0.21dB. The M44G is much better: with it's output voltage of U_{M44G} = 9.6mV(rms)/8cm/s it improves all SNs by the factor of 20*log(9.6mV/5mV) = 5.67dB.

In line four of **Table 2** there are different values of C1. For mm-cartridges its 30pF higher than for resistors because of the addi-

Figure 16: Impedance measurement circuit



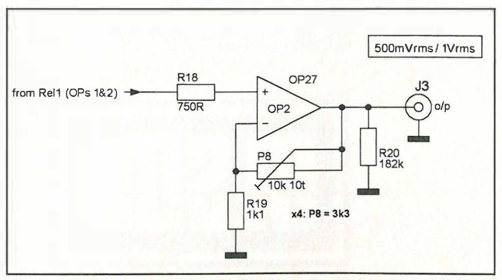


Figure 17: AMP circuit

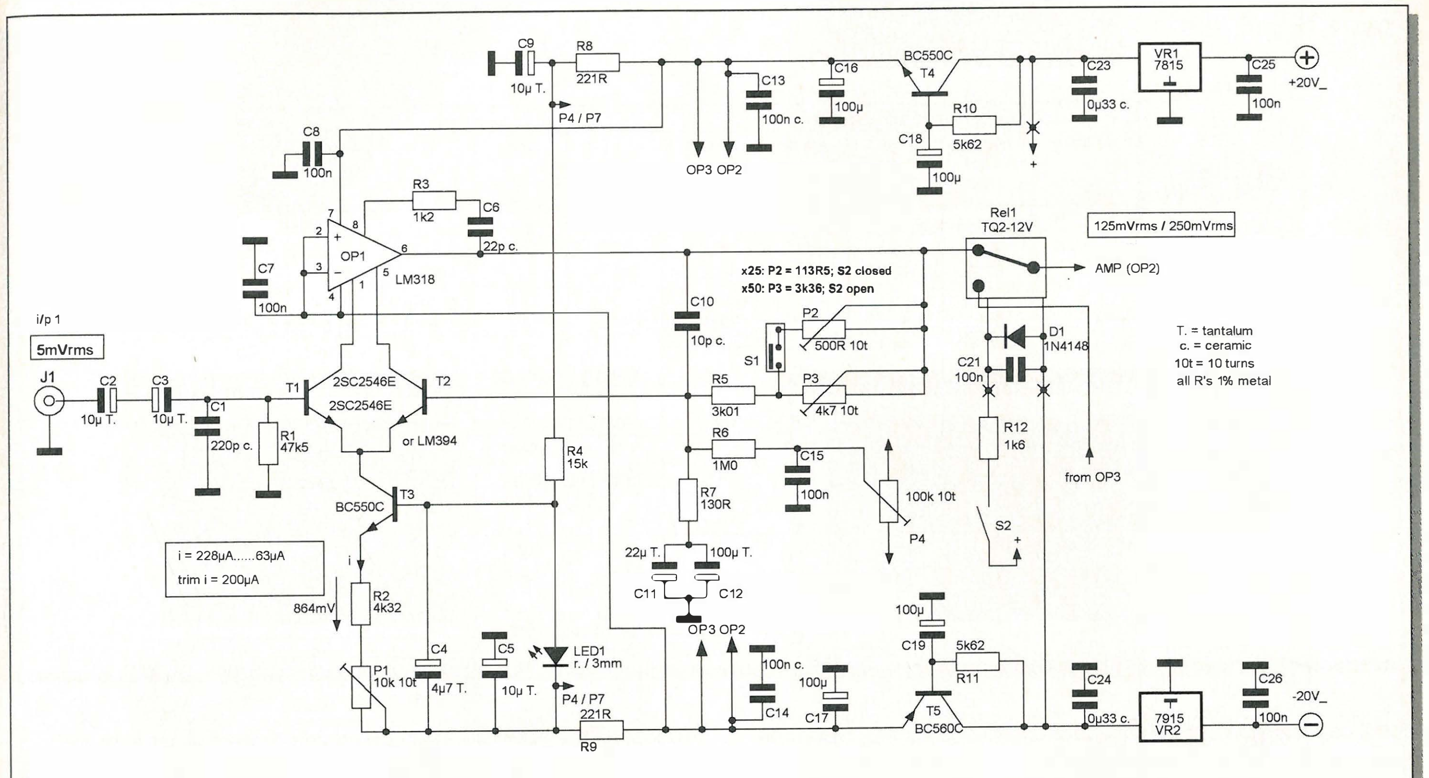


Figure 15: Circuit of measurement pre-amp and power supply for AMP and impedance measurement block

Figures 10, 11 and 12

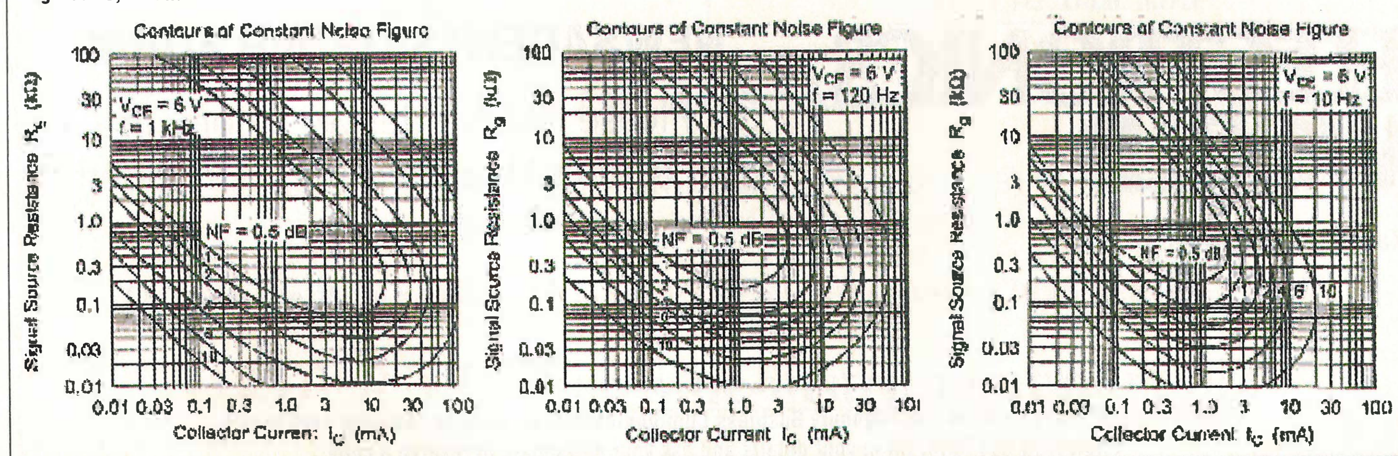


Table 2: Results

1/A	B	C	D	E	F	G	H	I	J	K	L
2			MM-cartridges				resistors				MM
3		input load	V15V MR	V15IV	V15III	M44G	0R	100	1k	12k	standard
4	SN		right channel only, C1 = 250p				C1 = 220p				0.5H + 1k + 250p
5	SNne [dB]	calculated	-65.1	-64.1	-64.2	-63.7	-82.6	-81.7	-77.3	-68.8	-64.2
6		measured	-67.2	-65.7	-65.3	-65.7	-82.1	-81.3	-77.2	-68.8	
7		**delta**	**2.1**	**1.6**	**1.1**	**2.0**	**-0.5**	**-0.4**	**-0.1**	**0.0**	
8	SNa [dB]	calculated	-70.1	-68.1	-68.2	-67.1	-84.7	-83.7	-79.4	-70.8	-68.3
9		measured	-70.9	-69.0	-68.8	-69.0	.84.0	-83.2	-79.2	-70.7	
10		**delta**	**0.8**	**0.9**	**0.6**	**1.9**	**-0.7**	**-0.5**	**-0.2**	**-0.1**	
11	SNriaa [dB]	calculated	-78.4	-76.5	-76.5	-76.2	-86.2	-85.3	-81.0	-72.3	-76.9
12		measured	-78.6	-76.5	-76.5	-67.5	-84.9	.84.2	-80.7	-71.9	
13		**delta**	**0.2**	**0.0**	**0.0**	**0.3**	**-1.3**	**-1.1**	**-0.3**	**-0.4**	
14	SNariaa [dB]	calculated	-81.9	-79.3	-79.4	-78.0	-90.6	-89.6	-85.3	-76.6	-79.7
15		measured	-81.4	-79.2	-79.2	-79.0	-89.9	-89.0	-85.1	-76.5	
16		**delta**	**-0.5**	**-0.1**	**-0.2**	**1.0**	**-0.7**	**-0.6**	**-0.2**	**-0.1**	

tional capacitance of the BNC connectors and cables inside the cartridge box. A test-wise increase to 250pF for resistor measurements didn't change anything except for input loads >15k.

A rather significant effect can be observed if you don't take C1 into account. The SNne of the V15V changes from -65.1dB (250p) to -68.5dB (3p), which is an improvement of +3.4dB, SN_{riaa}'s improvement will be +1.2dB. Similar improvements will come up in the A-Filter case.

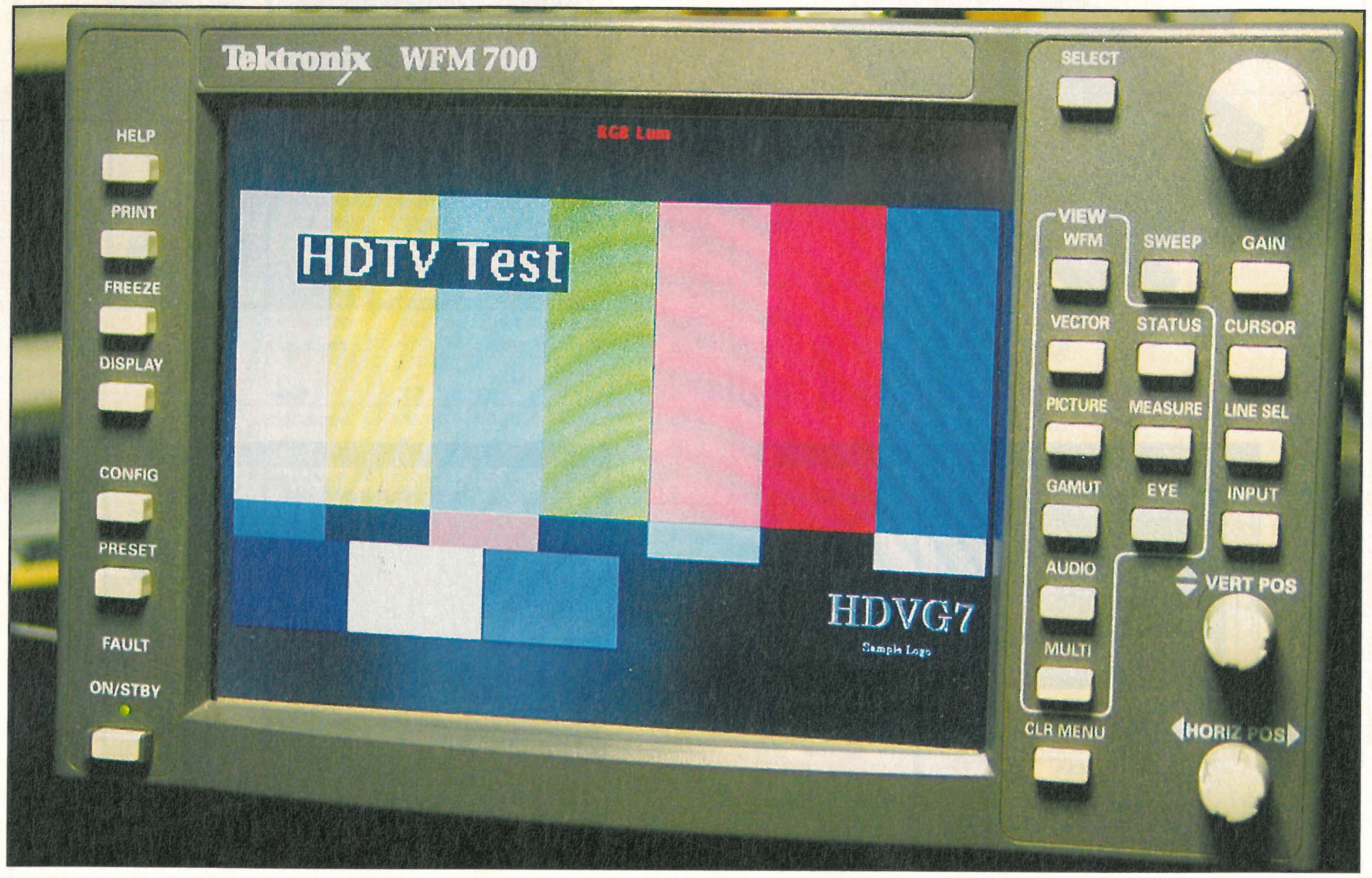
R7 of **Figure 15** has an influence on the SNs too. Provided that C11 and C12 and R5+P3 or P4 have been changed adequately a change from 130R to 10R improves the SN_{riaa} of a V15V cartridge by a factor of +0.2dB, whereas a change to 499R worsens it by a factor of -0.6dB. In the RIAA+A-filter case the respective figures are +0.1dB/-0.5dB.

Cooling of the pre-amp (e. g. down to -18°C = 255.2°K) leads to an SN improvement of only +0.5 dB for SN_{riaa} and SN_{ariaa} because the cartridge can't be cooled down the same way.

With a software like Mathcad and the formulae given in this study to calculate unweighted or weighted Signal-to-Noise ratios of mm-cartridges connected to a RIAA-transfer forming pre-amplifier, you only need seven basic parameters to get very good calculation results that are close to reality: the DC resistance, the inductance, the output voltage and the optimal load capacitance of the cartridge, the preamplifier's input referred noise voltage and noise current and the gain setting components of the feedback network of the pre-amp.

SN measurements with resistors at the input never reflect the mm-cartridge's noise reality and those carried out with values <10k will lead to SNs that are too optimistic.

Doubling of the input transistors or minimising the resistors in the feedback network (e. g. in **Figure 15**: R7 ~ 1R0) does not produce that big difference in noise reduction, at all.



Tektronix WFM700 Waveform Monitor

BY ANDREW BIRT

Whilst the current talk is about a revolution in multimedia – DVDs, widescreen, plasma displays etc. – the real big noise in television and cinema production circles is high definition television (HDTV), even though this has not been an overnight phenomenon. Plans were started back in the early eighties under the European Eureka EU95 project.

Unfortunately, achieving satisfactory resolution for 1250 lines with it resultant bandwidth of around 30MHz, thermionic camera tubes and analogue circuit techniques of the day, HDTV was firmly stuck in the world of laboratory prototypes and demonstration roadshows. Since then, two main factors have lead to HDTV being developed to a sophisticated television and film origination tool. Firstly, solid-state charge-coupled devices (CCD) have now all but replaced the earlier thermionic camera pickup-tubes, leading to smaller, more reliable optical assemblies.

Secondly, the widespread introduction of digital technology has simplified both equipment and studio topologies. Manufacturers are now able to bring to market advanced digital equipment for both the current standard-definition television (SDTV) and HDTV systems.

The Tektronix WFM700 analyser is a good example. It is aimed mainly at practising engineers involved in manufacturing R&D, broadcasting and studio project teams. The last category is one to which I belong. Over the last few months I have been using the WFM700 on a daily basis whilst designing and installing a new high-definition television facility for the University of Surrey, Guildford.

Various international bodies define standards for the digital interchange within studios and broadcast facilities; for HDTV the European ITU defines this serial digital interface (SDI) as recommendation BT709-5. Stated very simply, separate luma and chrominance video signals are multiplexed together with synchronising and control signals (ANC). This then forms an uncompressed 1.485Gb/s serial data signal that can be sent via a low-loss 75Ω coaxial cable.

The complexity of the serialised signal renders conventional oscilloscopes virtually useless. Even when decoded, there is no easy way to observe what is, or not, happening to the actual data stream. The Tektronix WFM700 analyser permits the user to monitor the serial signal and then check the integrity of the various data channels, both in standard and high-definition formats. Optional plug-in cards dictate the level of monitoring, for example the standard base model is suitable for compliance, i.e. video levels, 'illegal' colours and general picture impairments. Further hardware options allow the exact measurement of the HD-SDI signal and digital audio signals conforming to the worldwide AES standard. The model reviewed here features all of these options.

The WFM700 analyser can be used either as a rack mounting or standalone desktop unit. When ordering, it is important to remember that the desktop model is supplied 'bare' and that the portable cabinet is an optional extra. When used on a flat surface, the unit can be angled upwards approximately 9cm by clicking down the two front legs. Personally, I don't find this gives a particularly comfortable viewing angle, although extra height can be added by propping the front legs underneath on a large book. The rear of the analyser houses the various modules with their respective BNC sockets (**Figure 1**).

Other connectors include IEC mains, CAT 5 Ethernet, USB, VGA and 9-pin D-type. Mains operation is from 100V to 240V and, rather inconveniently, the main fuse is non-user serviceable.

The front of the unit consists of a TFT screen (approximately 17cm diagonal), three conventional knob-type controls and a selection of press-buttons. The general layout is quite intuitive, a definite advantage for engineers working in panic-stations scenarios. I regard digital displays a mixed blessing when used for accurate test and measurement. On the one hand, they offer a clear bright image with touch-screen button selection, on the other, I can't sometimes help feeling that sharp transient spikes are lost at certain timebase settings. Although I haven't actually experienced this with the WFM700, it is something I have noticed with some other digital oscilloscopes. My belt-and-braces solution, at least for critical standard-definition TV applications, is to use the WFM700 in conjunction with its earlier CRT incarnation, the WFM601.

Rather than laboriously explain every button and feature in turn, it is perhaps better to describe some real-world example applications. For the purpose of this review, I shall use the WFM700 to analyse a signal arriving down a 50m cable, check its integrity and potential reliability (digital video signals are notorious for the 'cliff-edge' effect, where signals can slowly degrade with no visible picture impairment, until a point is reached where a signal is suddenly completely lost).

Finally, I perform a quick analysis of a Thomson HDTV electronic-cinematography camera.

First, I examine a link, which consists of a colour-bar test signal transmitted via a 50m coaxial cable. Switching to the 'Eye' menu allows you to see the 1.485Gb/s signal directly. In order to determine the quality of the signal, it is necessary to create an eye-diagram that consists of three superimposed bit-cells. Measuring the eye-diagram aperture is a good (but not infallible) indicator of the quality of the signal.

A well-formed eye-pattern indicates a reliable signal; alternatively, if the eye pattern is nearly closed there is a good chance that it will be unreliable. In this example, I can see that the opening is fairly good and, using the onscreen electronic graticule, the peak-to-peak level is to within specification (800mV ±10%) (**Figure 2**). As with a conventional oscilloscope, using the WFM700's 'Cursor' option will enable a direct textual readout of the voltages.

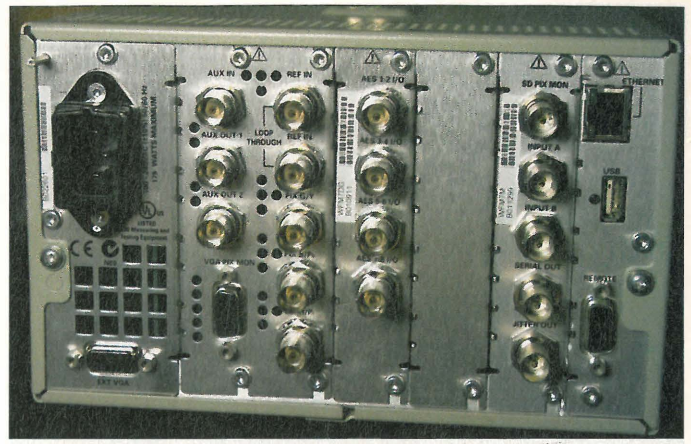
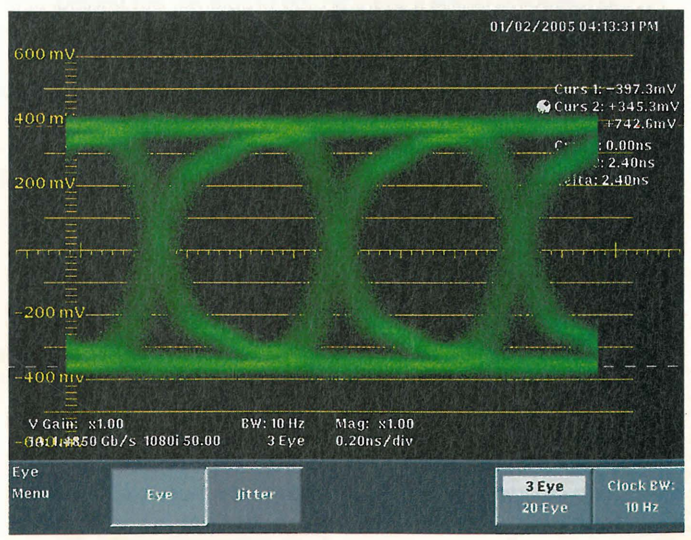


Figure 1: Optional modules may be plugged in at the rear of the unit. This example has additional inputs for AES digital audio.

The HD-SDI signal is self-clocking, therefore, the amount of jitter is critical to the receiver's locking ability. Pressing the 'Jitter' on-screen soft button will give us a direct reading in terms of time. In this case, it was measured to be approximately 250ps and this would be considered quite good, well within specification for HDTV. Very quickly we already can see that this represents a healthy, reliable signal.

Having established the serial signal's integrity, it is now possible to check the individual video, audio and control signals through the analyser's waveform and measurement menus. A direct analogue representation of the video signals can be displayed under the WFM menu. Soft selection buttons allow you to select between luma, red, green and blue channels, either displayed in a row or overlaid. There is also a 'Composite' option that will display the signal as a psuedo old-fashioned PAL colour waveform – very handy for broadcast engineers of a certain age! Signal levels can therefore be directly equated with values similar to those used for analogue television, i.e. 700mV peak white, 0mV black and -300mV for synchronising pulses.

Figure 2: Waveform of HD-SDI signal at the receiving end of a 50m coaxial cable. 'Eye' opening is still good, despite noise.



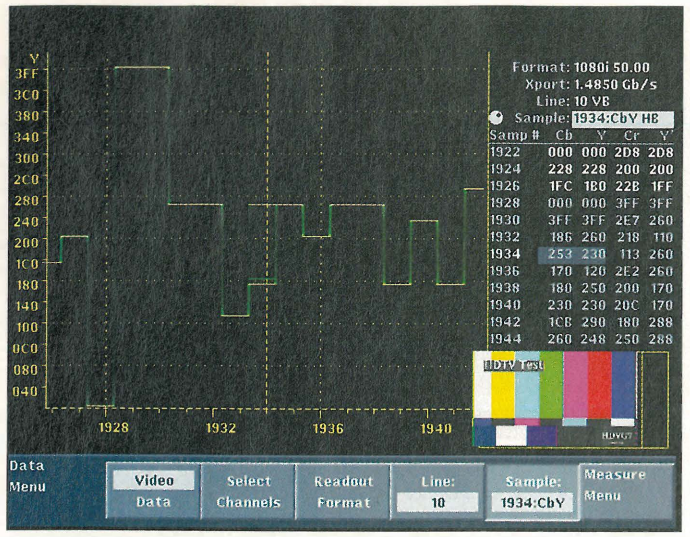


Figure 3: Selecting the correct line and pixel location shows time-code data. Values displayed are selectable hex, decimal or binary notation.

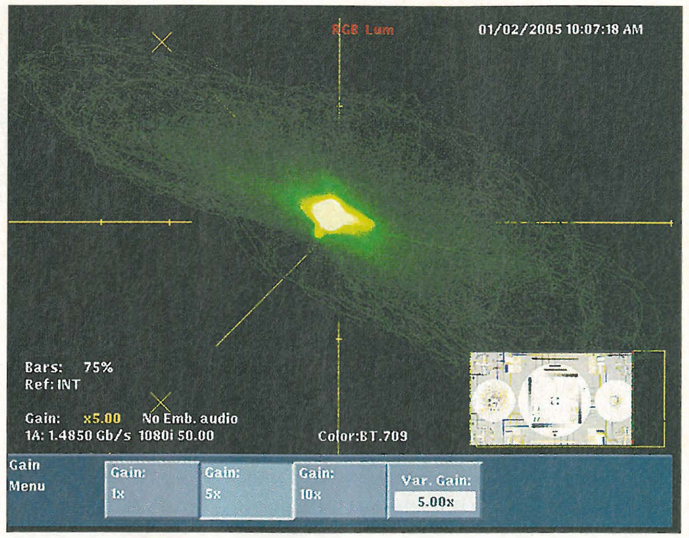


Figure 4: Magnified view of vectorscope display, showing a correctly white-balanced camera.

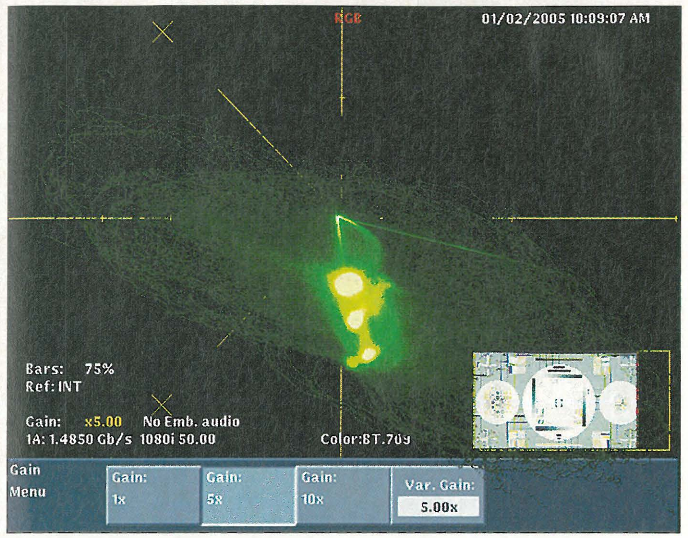


Figure 5: As in Figure 4, but camera gains are unbalanced producing an erroneous tinting of neutral grey areas of the picture. In this case, the display points towards the cyan axis indicating a lower gain red channel.

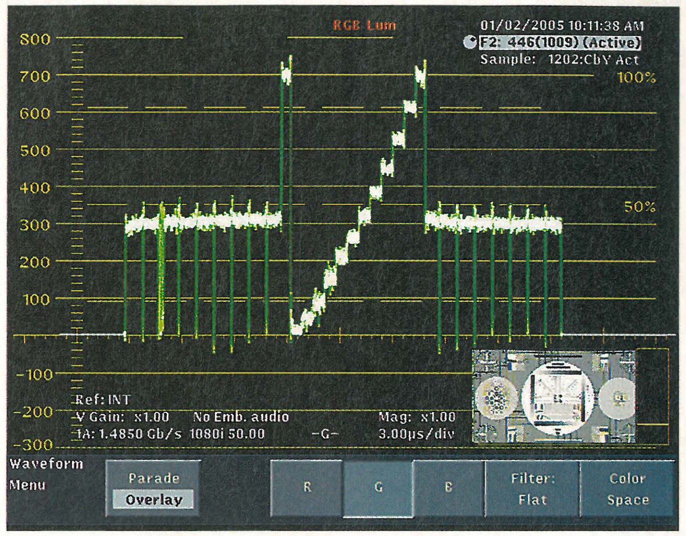


Figure 6: Selection of a suitable line from a test chart enables comparative linearity measurements of the camera's video channels. Timing errors can be measured using the negative-going lines at the edges of the chart.

Here, again, on-screen cursors can be selected for more accurate voltage and timing measurements.

Located at the bottom right of the screen is a very useful picture-in-picture facility showing the incoming signal. This would be too small for proper monitoring so pressing the 'Picture' button will display a full-sized image (16x9 aspect ratio for HDTV), with surprisingly good resolution and colorimetry. Additionally, this picture feed is available through a VGA connector, located at the rear of the unit. Connecting a conventional PC-type monitor here makes for a very economical HDTV display. One caveat, however, is that the video is 'raw' in that the signal is unprocessed, it is unlikely therefore that some monitors will lock to lower frame rates such as 25fps and 24fps.

The WFM screen also contains other important information in textual form. The presence of embedded timecode and audio ANC data are indicated and, most importantly, for checking unknown sources, the HDTV standard is being monitored. There are currently many different HD standards in use worldwide, the WFM700 will detect and display the vast majority of them.

All the foregoing is fine if there are no problems, but finding oddities within such a complex serial stream is very hard. For example, if the embedded timecode were to skip the occasional frame(s), I could view the data words directly by choosing the 'Measure' menu and selecting TV line 10. As it is one of several ancillary signals located within the horizontal blanking period, I have to select the relevant starting pixel, number 1934 in this example. I now have displayed a waveform of timecode data plus text readout of the data words in hex form. The timecode data immediately follows unique data identification words (as defined within the specification) 0000h 3FFh 3FFh 260h 260h 110h (**Figure 3**).

After all that hi-tech, it's then all down to the keen eyes and patience of the engineer to spot the dropped frames.

Basic television camera performance can be measured using just the WFM700 plus suitable lighting and a test chart. Monitoring of video and black level controls is possible, using the WFM function. A check of the cameras' white-balance, i.e. neutral colouration of the picture highlights, can be done by checking for equal peak-white outputs on the respective red, green and blue signals. The 'Vector' display, however, offers a far more accurate method, as the white point is displayed as a clustered 'dot' at the centre of a circular pattern (**Figure 4**). The centre cross represents neutral white; any deviation will literally 'point' in the direction of the colour error (**Figure 5**). A basic check of camera resolution and linearity can be achieved with a suitable test-chart using the WFM700's line selection facility (**Figure 6**). Timebase magnification will reveal any timing/registration errors between each RGB channel as this can cause coloured fringes around an object's edges (yes, it does happen even with modern CCDs!).

It is unfortunate that this can only be a quick tour of the WFM700 and, as such, it only scratches the surface of the equipment itself and video measurement techniques.

On the plus side, the unit is intuitive to use with a logical menu-tree. It offers some highly ingenious measurement graticules to check timing errors and 'illegal' colour levels. In addition, it is possible to have complete remote functionality (**Figure 7**) using nothing more than an Ethernet link and your favourite web browser.

On the negative side, the touch-screen buttons require nimble fingers (the eraser end of a pencil used as a prod can help), and the audio input grouping and mapping menu I found very confusing. The HD-SDI input BNC sockets at the rear are not at the topmost of the frame – a bit frustrating when trying to connect a cable from the front by touch alone.

Overall, this is an essential piece of kit for control-room, projects and maintenance engineers.

For the 'Pros & Cons' table of the WFM700 analyser, see overleaf.

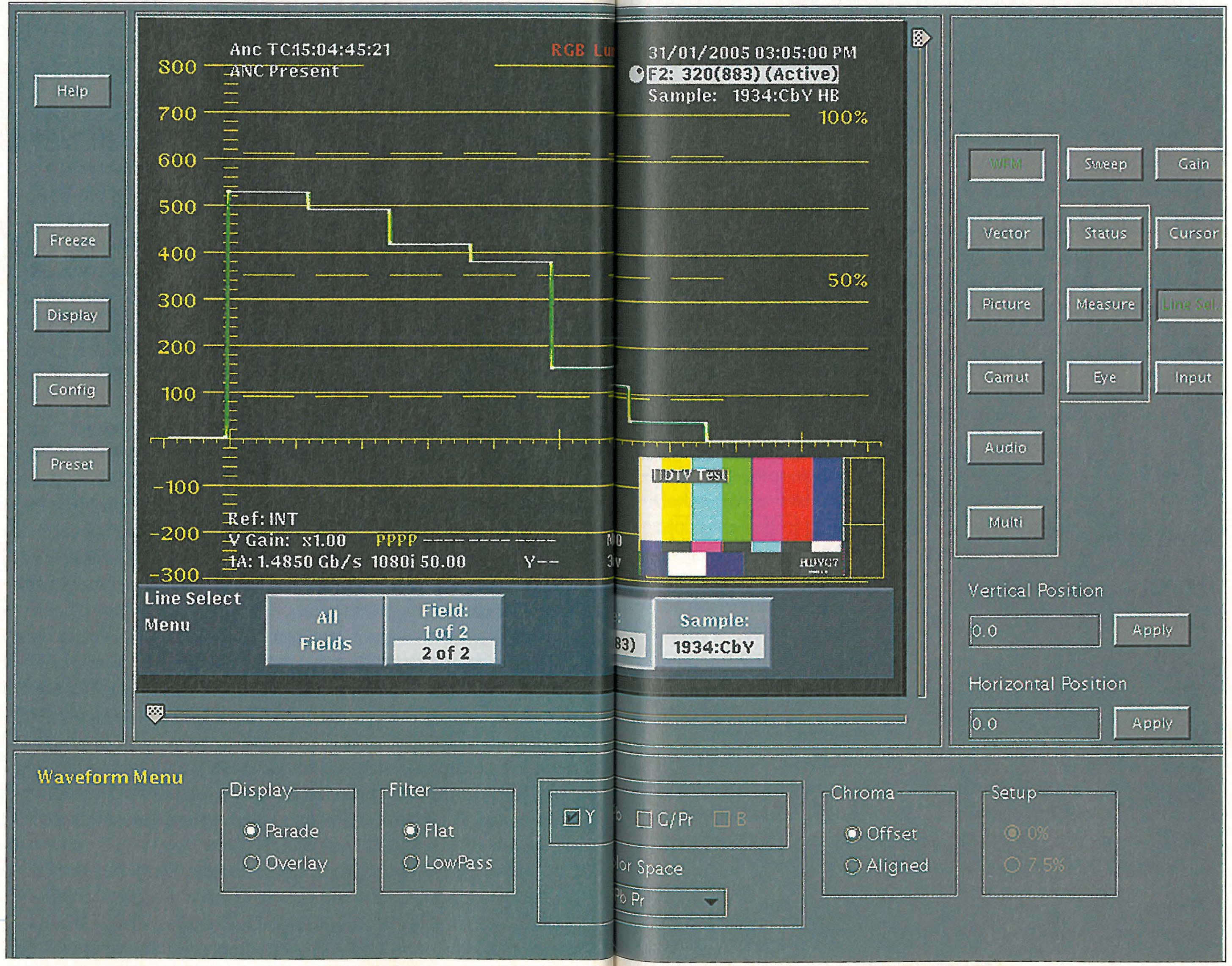


Figure 7: Web browser view of the remote interface. Operation, not surprisingly, incurs a delay of several seconds before execution of a remote command. Local operation of the instrument is also slowed down slightly.

PROS AND CONS

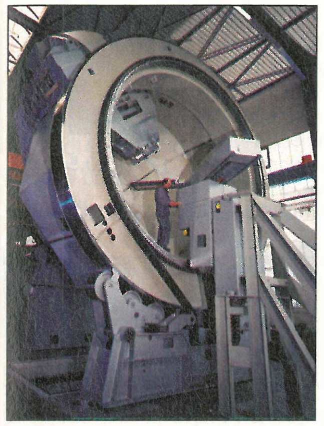
- ✔ Clear and bright TFT display
- ✔ Intuitive operation
- ✔ Picture-in-picture display for confidence monitoring
- ✔ Automatic logging of video and audio errors
- ✔ Remote Ethernet operation
- ✔ Different SD/HDTV formats displayed all, in one self-contained unit
- ✔ Good build quality
- ✘ Front support feet create an inconvenient viewing angle
- ✘ Confusing audio mapping menu
- ✘ Mains fuse mounted inside the unit
- ✘ Course line-select control – scrolling through individual TV lines requires a deft touch
- ✘ Expensive

MOST USEFUL FEATURE

- ☛ Textual readout of the incoming signals' line and frame rates – absolutely essential for monitoring or fault-finding within HDTV's multiformat environment

SUGGESTED IMPROVEMENTS

- ☛ Built-in AES digital-to-analogue converter for audio monitoring
- ☛ More ANC analysis tools, particularly for nasty timecode problems
- ☛ Shallower cabinet version for portable use



Virtues and failings of C

I was very surprised to see that it is apparently legal to produce computerised machines for medical applications, which are controlled by programs written in C.

Although C has many virtues it also has many failings. Important in this kind of application are that explicit use of pointers can make code obscure e.g. pointers to pointers or de-referenced pointers to structs, or lead to writing or reading beyond the bounds of an array, and that improper and potentially dangerous type casts will probably be passed by the compiler.

Those managing the project, enforcing safer coding standards, can ameliorate these problems and/or by the use of programs like Lint, which can pick up many (possibly all) of the problems. Perhaps it would be better if 'safer' languages were used to program safety critical devices in the first place.

The on-board computer of the recently successful Titan lander was programmed in the language Ada83. Presumably, the team that specified this felt they had a good reason to reject C.

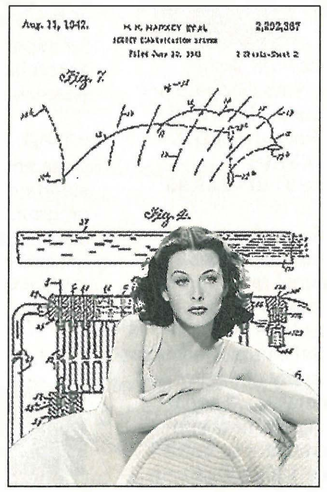
The very least that we can expect is that medical devices will be specified with at least as much care as expensive one-off devices like spacecraft.

The usual reason for not using a 'safer' language like Ada or Modula 2 is that there are not enough programmers familiar with these languages. But this eventually becomes a self-fulfilling prophecy, because programmers will only develop expertise in these languages if there is a demand for them to be used.

This is one area in which governments can legitimately seek to influence market-driven decisions, by insisting that the programs for all safety-critical programmable devices are written in languages that meet the highest possible standards for safe usage.

C and C++ do not.

Dr Les May
Rochdale
UK



Going lower in frequencies

Recent articles in Electronics World (March, pages 8 and 43) suggest that research workers investigating allegations of adverse health effects due to mobile phone technology are still focusing too much on high carrier frequencies (100kHz to 3GHz) and not enough on low frequencies (μHz to 100Hz), which are operant in modern telecommunications systems as well as cognitive and biological processes.

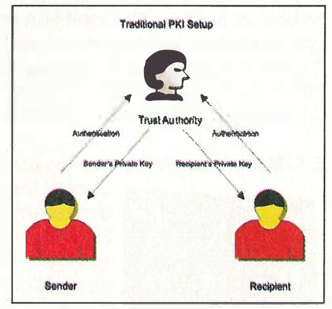
Frequency-hopping, after the fashion originally envisaged by Hedy Lamarr in her patent, granted in 1942, appears to have settled in the range 56ms (Ian Poole on Tetra, EW December 2004) to 660ms, which equate to 18Hz and 1.6Hz respectively, both of which occur in the brain-wave frequency range. Kitai and Plenz showed that 0.8Hz and 0.4Hz are of primary importance in normal basal pace-making (ganglia) formed by phase-locking between the subthalamic nucleus and the external globus pallidus (Nature, 12th August 1999, 677-682, 621-2), which would resonate or phase-lock, with an external signal of 1.6Hz; possibly that a natural resonance of 0.8Hz between the earth and the moon, which may be a factor in language development in children (Laura Anne Pettito); may be over-ridden.

A good example of importance of these low frequencies is Cysarz's work (Scientific American, October 2004, page 13), illustrating how reciting the Odyssey can improve one's health substantially, by synchronising cardiovascular rates (Mayer waves of 0.12Hz) with breathing rates.

Previous correspondence in EW suggested that this was a load of "incoherent nonsense" – but not now (v. 'Chronicles', pp158-9, Simon & Schuster, 2004).

Researchers investigating mobile phone technology in relation to health will find Dannah Zohar and Dr Ian Marshall's book 'SQ' invaluable (published by Bloomsburg, UK 2000), especially the section on 40Hz.

Tony Callegari
Much Hadham
UK



Concel don't encrypt

Mark Chimley's IBE system (EW March 2005, p22) is an interesting idea that may find useful applications, but I am sure that he is wrong to think that it will be used for email. People who require moderate security typically use PGP or GPG, which have a slight difficulty with the distribution of public keys. However, that difficulty has never been much of an impediment.

The IBE system involves a third party having potential access to encrypted messages, which would be completely unacceptable to most users, as it defeats the object of encrypting a message in the first place. This is a matter that the author mentions only in passing. He is, therefore, proposing a cure worse than the disease.

The IBE system might be useful not as a replacement for such things as PGP, but as an additional method of distributing and verifying its public keys, which are intended as public information, in any case.

The outstanding problems in secure communications are not really in such things as encryption and key distribution, but rather in methods of concealing the fact that a message has been transmitted and received, as much can be learned from traffic analysis.

Robert Baines
Newcastle upon Tyne
UK

Fight security breaches

Recent security breaches, such as the intruder in Channel 4's Big Brother enclosure and numerous attempts to scale the walls surrounding Buckingham Palace, not only encouraged more businesses to consider the potential threats these security breaches pose, but have also highlighted the debate surrounding intrusion detection techniques, questioning how important building this level of security actually is.

Although these high profile cases of intrusion are not commonplace in an every day business environment, the threat of someone tapping into communication lines coming in and going out of the building is a serious and very realistic issue.

Whereas, an intruder trying to break into an establishment like the Big Brother House may be picked up on CCTV or by a security guard, someone tapping a phone line may be more difficult to detect and may go unnoticed.

Just because a cable is laid underground does not mean it is impervious to risk. For example, many businesses fail to recognise manhole covers as being a serious threat to building security and information integrity. Businesses have measures in place to make e-mails and information secure once they have entered the building, but surely these measures should be taken into account as information comes into and goes out of the building too?

Fibre intrusion technology is the next logical step in securing the flow of information and the business from physical attack.

As soon as a cable of this type is touched it will raise an alarm and pinpoint exactly where the interference has occurred, meaning it can be dealt with immediately. This is valuable for not just underground cables but can be put at the top of razor or barb-wire fences to detect a disturbance and highlight an intrusion before someone manages to get over the fence and into the building.

Phillip Coombes
Managing Director
Fibre Technologies

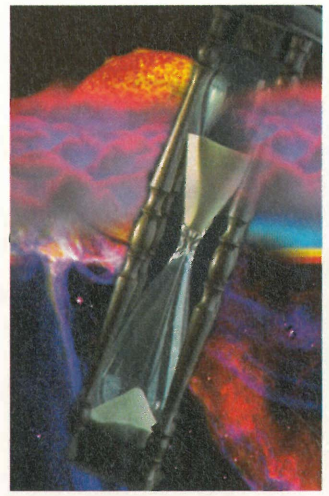
Renewed interest in amps

Reading Mr. Stan Curtis's letter in the February 2005 issue [p48], in which he stated that he designed amplifiers that emphasised bass, rekindled my interest in building my own. I'm interested in building three amplifiers for each 3-way speaker and connect each driver directly to its amplifier. An active 12dB per octave low-pass, high-pass and bandpass would provide the required signals for each amp.

I need a design of 30W to 40W rms for the woofer, maybe 25W for the midrange driver and 10-15W for the tweeter.

Better yet, what power ratings would you suggest for this arrangement? Should the tweeter be driven from a class A amp?

Robert Bliek
Calgary
Canada



Dilated time, expanded space

As wacky ideas go, dark matter seems to be the wackiest, and we don't even now if there has really been a 'big bang', because the theory is based on the 'red shift' of distant galactic light. Then, there is the problem of galaxies accelerating without an accelerating force, and now, 'dark matter gravity'? Cosmologists are desperate to find dark matter, because they cannot explain how stars can orbit faster and further out than is normal under Newton's laws. The alternative answer is that they are looking at either expanded space or dilated time. This of course counters the theory that the universe is expanding, since the expanded space is far back in time where the big bang is. Expanded space would neatly explain the problem and the red shift of light that we assume is due to the big bang is light coming from expanded space, which might well be travelling faster or slower, hence the observed distances may be wrong and, maybe, the energy mc^2 too.

Without the solution of hidden dark matter our current calculations are way, way out. If time is dilated too, observed stars are travelling at the wrong orbital speeds, and light coming from such a system might not have the 'correct' speed either and may be red-shifted, hence our observation that the universe is expanding with distance, if time is changing across the universe since the 'big bang'.

Chris Doherty
UK

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High-linearity 12-bit DAC with only two micro pins

Referring to the Circuit Idea '*6 1/4 bit DAC requires only four output pins*' by Ian Benton in *EW*, November 2004 (p46), I salute him for his elegant solution. I too have been working on this problem and would like to pass on an effective two-pin solution, which is even more efficient if wide bandwidth isn't a requirement.

Precision frequency oscillator control can be achieved using pulse-width modulated DAC feedback, which gives very good linearity. The usual circuit (**Figure 1**) involves one micro pin (PD5) and a simple RC filter (R1/C1), which integrates the pulse-width modulated output and removes the "clock" frequency component. With one pin output, the PWM hardware available in several micros can be put to good effect. The upper frequency response is limited by the requirements of the RC filter, but is still appropriate for applications such as frequency control.

High resolution and good linearity are features of the PWM DAC, but a further problem is that the higher the required resolution, the slower the system response, since the PWM period is related to the power of the number of bits. For example, using a 10kHz PWM rate, 8-bit resolution results in a "clock" of 10,000/256 = 39Hz. This low PWM period is the major limitation of this technique.

My improvement allows higher resolution, modestly faster response, or both. Two (or more) separately (but preferably synchronously) PWM'd outputs can be combined to provide a single voltage on a single integrating capacitor. For example (see **Figure 2**), if R1 is 10k and R2 is 160k (ratio 1:16), the lower four bits of an 8-bit value can be PWM'd on R2 and the upper four bits on R1. The output has a resolution of eight bits but, most significantly, the PWM period is much faster. To use the previous example, 10,000/16 = 625Hz. This makes the PWM noise easier to remove and improves the frequency response of the DAC. If the micro has two high-speed PWM registers, the response could be even faster.

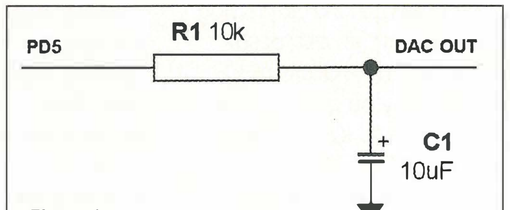


Figure 1

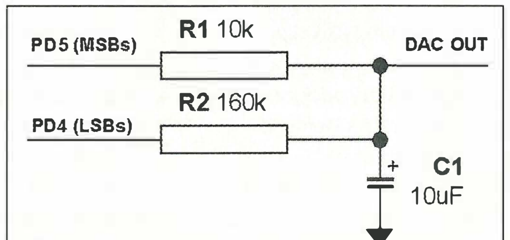


Figure 2

Table 1

```
        push    DAC_LO
        ldi     MASK, 0x3F          ;6-bit mask
        inc     PWMCNTR
        and     PWMCNTR, MASK       ;force counter 6-bit
        lsl     DAC_LO
        rol     DAC_HI
        lsl     DAC_LO
        rol     DAC_HI              ;6 MSBs now in DAC_HI
        cp      PWMCNTR, DAC_HI
        brcs    MSB_LO
        sbi     PORTD, 5            ;set hi PWM
        rjmp    LSB
MSB_LO:
        cbi     PORTD, 5            ;clear hi PWM

LSB:
        pop     DAC_LO
        and     DAC_LO, MASK        ;looking for six lower bits
        cp      PWMCNTR, DAC_LO
        brcs    LSB_LO
        sbi     PORTD, 4            ;set lo PWM
        rjmp    LSBDONE
LSB_LO:
        cbi     PORTD, 4            ;clear lo PWM

LSBDONE:
        reti
```

This very simple design is easily expanded to 12 or more bits, by increasing the number of bits per output, or the number of outputs. The 12-bit is best achieved with two 6-bit PWMs rather than three 4-bit PWMs. In a system requiring only 10Hz frequency response, I routinely use a two output 12-bit DAC, with R1 = 5k0 and R2 = 320k (ratio 1:64), and achieve extremely good 12-bit monotonic output with a PWM "clock" of 10,000/64 = 156Hz. The resistors need to be 1% to ensure an accurate transition at the centre of the range. I use two parallel 10k resistors for R1 and 100k + 220k in series for R2. The availability of accurate resistors ultimately limits the useful resolution of this technique and some trimming may be necessary to get the ratio exact.

Software PWM control algorithm is best used in a high-speed interrupt loop and dual PWM can be achieved using a single counter that has half as many bits as the output. A 12-bit example for the AVR is in **Table 1**.

As a final comment, this technique, which can easily provide 12-bit D-A output with only two micro pins and three passive components, also permits the outputs to be set in high impedance mode when no voltage change is anticipated (for example in phase-locked loop applications). This can further reduce the PWM ripple.

Murray Greenman
Papakura
New Zealand

Voltage-controlled optoisolated resistor

This is an idea of a voltage-controlled resistor that incidentally is not just very cheap and simple but also very flexible and optoisolated.

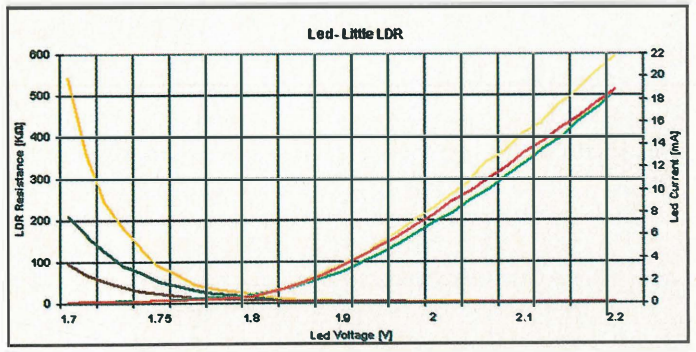
To make it work right, you should use a photoresistance driven by an LED. Both components should have to be in the dark and placed closely one in front of the other. Varying gently the voltage in the LED (from 1.7V to 2.2V) I have made the plot of voltage versus current and resistance (see plots). It refers to two of these classic LDRs (for which I incidentally learned too late that have its peak light sensibility around 550nm), one little and the other bigger than the first. I've done my tests in a controlled lab and varied LED voltage by steps of 0.01V and 0.02V for three different colours of LEDs, as it can be seen in the plot. Both LDRs react with a lower initial resistance with the red LED, but for "low" resistance (around 3k), the trend inverts and it's the green that makes its way for a lower value.

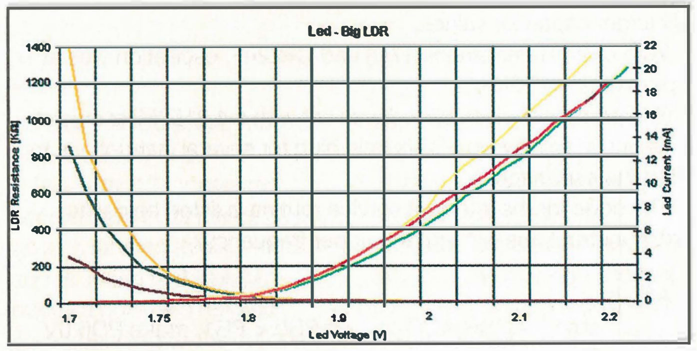
Obviously, different uses should have different combinations, and it would be interesting to see how they react to blue, white or orange LEDs. In any case, this combination is easily used to control AC connected devices like SCRs or triacs directly from a microprocessor's output, for example. Control methods could be PWM'd by microcontroller, several digital outputs with a R-2R resistor network, directly from a voltage source, or you can lower LED's current needs for the controller by adding a BJT or a little power MOS (which I work with). Two of these arrangements working in opposite can form a full potentiometer.

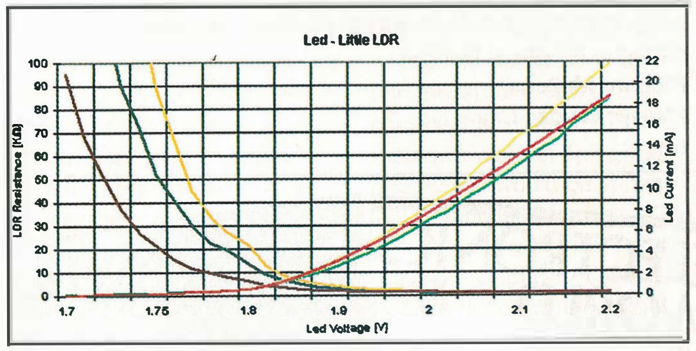
As it can be seen, this circuit is easy to do, extremely cheap and very flexible. However, it should kept in mind that "precision" control would be hard to achieve with this arrangement (but not impossible), because of the differences in LEDs and the same reasons are valid for the LDR. These types of LDRs are not too fast (several ms to vary the value) but, either way, this combination is worth a try.

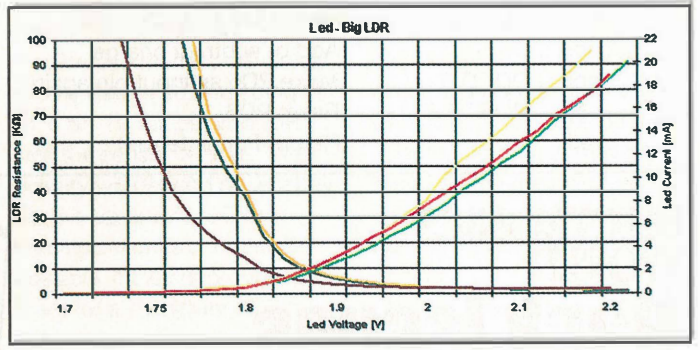
Manuel Alberto Valero Uribe
Catania
Italy

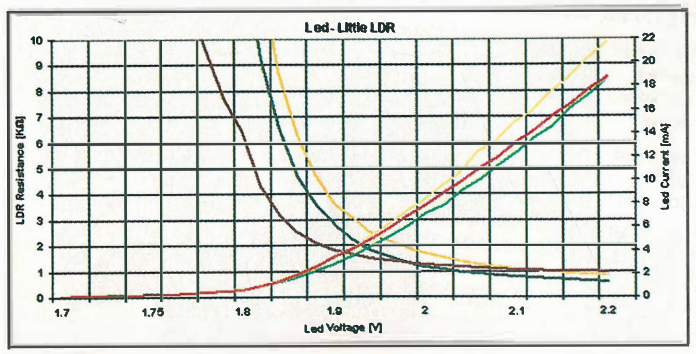
Green resistance
Yellow resistance
Red resistance
Green current
Yellow current
Red current

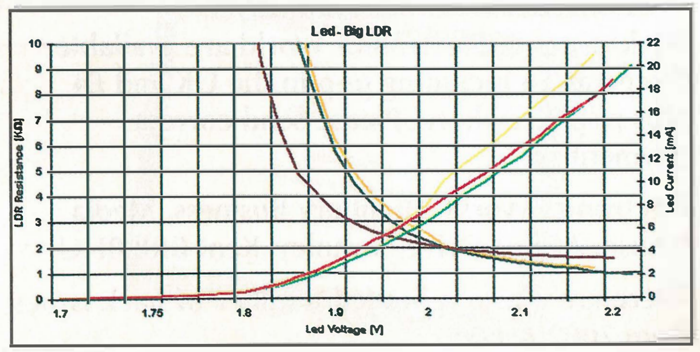












Microcontroller drives LC oscillator

In the **Figure 1** circuit, if there is an imbalance in the capacitor voltages, charge will flow from one capacitor to the other and a sine wave with frequency:

$$\frac{1}{\pi\sqrt{2LC}}$$

will appear across the inductor.

In the circuit of **Figure 2** the comparator senses the waveform and energy is supplied each time the comparator switches. The implementation uses an Atmel AT90S2313 microcontroller, though many other chips will be suitable. The on-chip comparator (pins PB0 and PB1) is configured to interrupt when it toggles, when the interrupt service routine switches PD6 from a high impedance state to either 0 or Vcc for a short period to keep the oscillation going.

This scheme allows an oscillator to be integrated with the microprocessor used to monitor the frequency, as in a metal detector, for example.

Circuit operation is non critical, though changes may be needed for larger capacitor values.

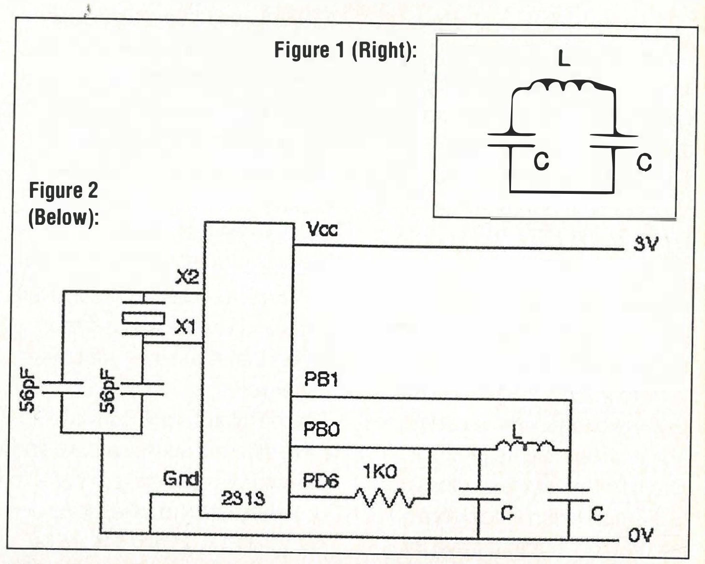
With L=2mH (resistance 17Ω) and C=22nF, oscillation was at approximately 33kHz.

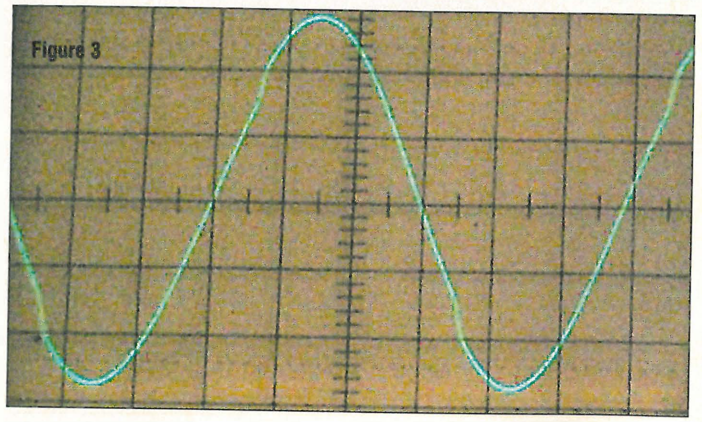
The processor clock speed was set with a 4.9152MHz crystal.

During initialisation, PD6 is held high for several instructions to start the oscillation.

The code for the interrupt service routine is listed below (too many instructions will limit the upper frequency):

```
AC_Int:
        sbic   ACSR,ACO     ;If PB0 < PB1, make PD6 0V
        sbi    PORTD,6      ;Otherwise make PD6 Vcc
        sbi    DDRD,6       ;Make PD6 an output pin
        nop                 ;Add or subtract charge
        cbi    DDRD,6       ;Make PD6 an input pin again
        cbi    PORTD,6      ;Reset PD6
        reti                ;Return from interrupt
```

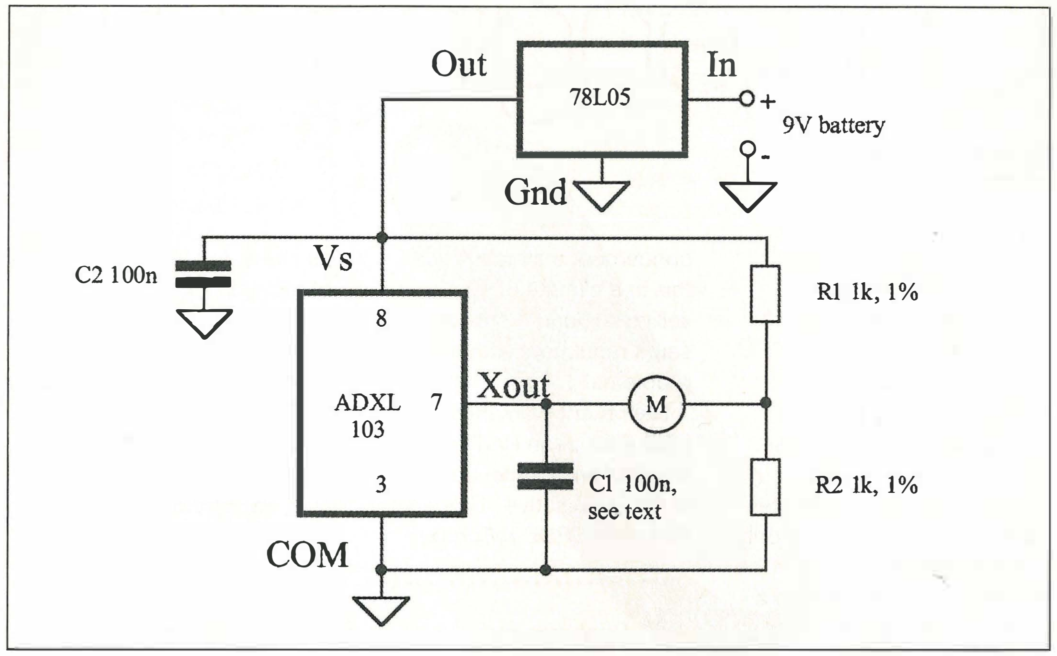




The trace in **Figure 3** shows the waveform on pin PB0; the timebase is 5μs per division.

Richard Mullens
Welwyn Garden City
UK

Ultra-simple accelerometer



It is possible to make inexpensive but accurate accelerometers using the new MEMS-based accelerometer chips, now on the market. Here is a simple application of the ADXL103 accelerometer chip from Analog Devices. The ADXL103 is a MEMS (Micro-Electro Mechanical System) device that is capable of measuring accelerations of ±1.7g (1g being 9.8m/s^2). It has an analogue output, which is $V_{supply}/2$ for an acceleration of zero and swings to either side of that value, depending on the acceleration. The sensitivity of the device is specified to be 1V/g (typical) at V_{supply} = 5V, which is high enough for the output to be read directly by a digital multimeter or panel meter. The only requirement is that the input impedance of the meter is high enough so as not to load the output of the ADXL103.

The supply voltage for the ADXL103 can range from 3-6V. Here, a 78L05 regulator is used to maintain a 5V supply voltage. This is necessary because the sensitivity (V/g) of the device is proportional to the supply voltage. Resistors R1 and R2 form a voltage divider so that the voltage at their junction is $V_{supply}/2$. Voltmeter M is connected between the outputs of the ADXL103 and the divider, so that zero acceleration will give zero volts output. M can be a DMM or any of those 2V f.s. panel meters with 1MW or higher impedance.

Capacitor C1 serves to limit the bandwidth of the ADXL103. The value depends on the application. A value of 2.2nF would give a bandwidth of 2200Hz (suitable for vibration measurement with an oscilloscope instead of the meter). A value of 1μF gives 5Hz, which would be suitable for measuring the acceleration of a vehicle, while filtering out vibration. Capacitor C2 is used to decouple the chip from any noise present on the power supply line.

The ADXL103 measures acceleration in its plane, along an axis running through pins 4 and 8. Tilting that axis produces a non-zero reading corresponding to the component of the earth's gravity present along that axis. This may be used to test the circuit or to measure tilt. A reading of +1 V or -1V will be produced with the sensor vertical. The polarity will depend on whether pin 8 is up or down. Direct readings in units of cm/s^2 are possible, if the supply voltage is set for a sensitivity of 980mV/g instead of 1000mV/g (1g is ~980cm/s^2).

There are other chips in this series. For example, the ADXL203 is identical to the x103 except it can measure acceleration in two directions (X and Y). The acceleration output may be time-integrated to give velocity or double-integrated to give displacement, but this simple circuit is enough in order to start using these interesting devices.

More information may be found on the manufacturers website: www.analog.com

Aarohi Vijh
Toledo
USA

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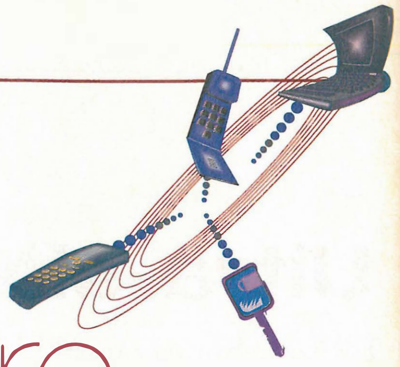


Challenging future

By Mike Brookes

Fifteen years ago, pioneering short-range devices (SRDs) were considered just about capable of opening garage doors, but little else. Alternative high-quality, usually narrowband, devices were expensive and sold only in small quantities.

So, SRDs' confinement to a rigidly defined spectrum as secondary occupants seemed reasonable at the time.

Today, highly sophisticated transceivers are available in chip form, featuring frequency agility and programmability, with features such as 'listen before transmit' built in.

All of this is available at unit prices of below $10.

This technological explosion/price-implosion has led to rapid expansion of SRD applications. This, in turn, required better access to the existing spectrum but, also, a growing demand to access different frequencies. As far as licence-free devices are concerned, a situation like this in a climate of spectrum selling at huge numbers presents regulators with real problems.

The recent workshop at ERO (European Radio communications Office) devoted to an EC initiative, *'Strategic future for SRDs in Europe'* recognises this challenge, drawing comparisons with action to confront similar problems in the US and Asia, with the basic question being "restrict SRDs – or give them access to more spectrum free of charge".

> "Such freedom, however, brings many other questions for regulators, including Declarations of Conformity within the meaning of the R&TTE Directive"

Also, a new nightmare will soon present itself to regulators in the shape of Software Defined Radio (SDR). In this respect, previous limitations to radio module flexibility, through the need to use fixed hardware components such as filters, are lifted. The speed of today's microprocessors, relative to the frequency bands in which most SRDs reside, leads to the real practicability of internal processing being much faster than the data transmission and, so, to real-time digital signal processing. In effect, this means that a future SRD module will have an inherent ability to operate dynamically on almost any part of the spectrum up to 1GHz, without physical component limitation. They will also have an inbuilt 'intelligence' to detect interference and adjust output power. All this is likely with unit prices still within the $10 band, which will further stimulate demand.

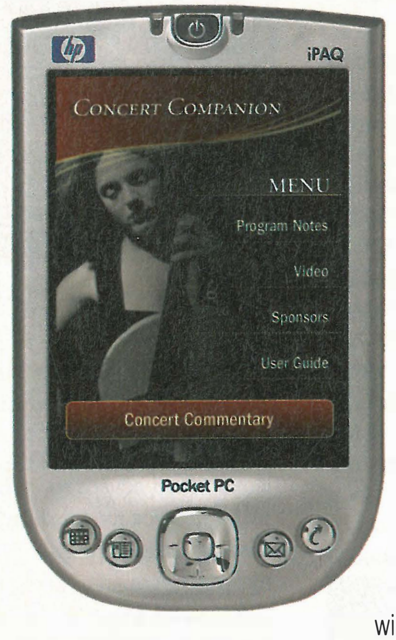
Such freedom, however, brings many other questions for regulators, including Declarations of Conformity within the meaning of the R&TTE Directive. Until now, test houses and manufacturers have been able to define the performance and intent of a radio module, giving regulators a baseline from which to work. Given today's addiction to software downloads from the Internet, it will be difficult for a manufacturer to provide meaningful declarations that cannot be overwritten by replacement software.

This brings about a challenging future for manufacturers and administrations in controlling the use and spread of these devices.

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.

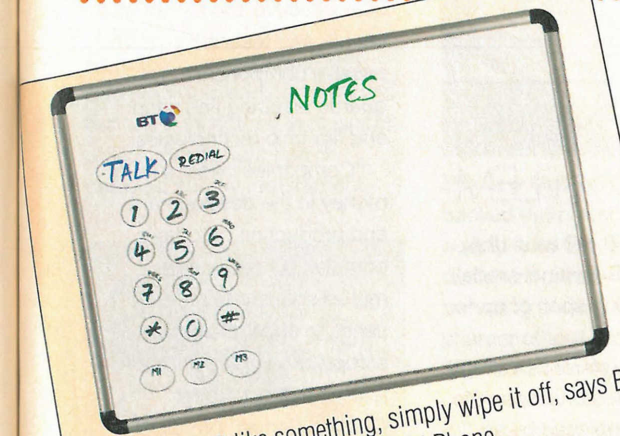


This little number made its UK debut at the Association of British Orchestras (ABO) annual conference in February this year. It is a handheld gadget for concert-goers, dubbed CoCo (Concert Companion). At its heart this is a PDA that offers real-time commentary and video, promising to transform the concert experience. It picks up a wireless link that enables each concert-goer to focus their personal screen on any aspect of the concert to get the best view. "CoCo can be compared to audio guides in museums or supertitles at the opera," said Roland Valliere, CoCo's creator. CoCo has been developed in co-operation with the Kansas City Symphony and tested with the New York Philharmonic, the Philadelphia Orchestra and the Pittsburgh Symphony.

Price and availability to be advised

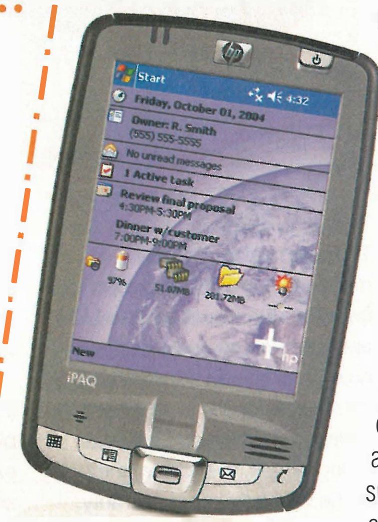
Logitech is working with Microsoft to build the next-generation Harmony universal remote to control a PC running Microsoft Windows XP Media Center Edition 2005 – and any entertainment devices that may be connected to it. The device is powered by Logitech's patented Smart State Technology and uses a USB connection to interface with the PC for programming the remote to control any electronic component with an infrared receiver. Being Internet-connected, it can access a shared, online database containing information about tens of thousands of home stereo components and remote-controlled devices. Customers of the Harmony remote for Media Center PCs will have their own online home page that details their exact setup and can be viewed and managed through the Windows XP Media Center Edition 2005 interface. The retail version of the Harmony remote will be available in the summer. **Price TBA**

www.logitech.com



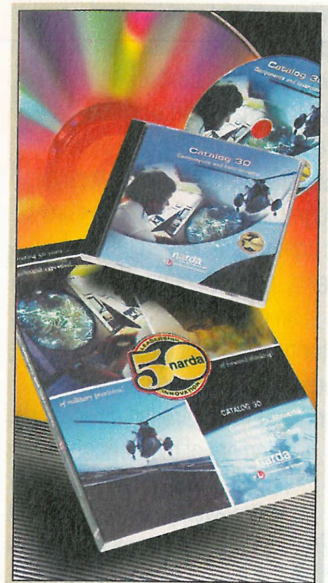
If you don't like something, simply wipe it off, says BT who has created the Wipeboard Phone. This is a limited edition, wall-mounted speakerphone that doubles up as a memo-board, complete with a pen and wipe-down surface. The BT Wipeboard phone has a three number memory with last number redial. **It costs £19.99**

www.shop.bt.com
0800 102800



HP's iPAQ hx2700 series pocket PC line contains a FingerChip sensor from Atmel. It is aimed at providing a secure and convenient way to protect their users' information without the need to manually enter a password. It can also be used in conjunction with a password, if required. The FingerChip sensor uses a patented method for imaging the entire finger. A sweeping motion across the sensor captures successive images (slices), applying software to reconstruct the fingerprint. This method allows the space-efficient FingerChip sensor to return a large, high-quality 500 dots per inch image of the fingerprint. This image is then processed through authentication software, which creates a template to be used for later comparisons.

www.hp.com and www.atmel.com



Catalogue offers Narda

A new catalogue from Link Microtek features over 60 new products from US manufacturer Narda to mark its 50th anniversary.

The catalogue consists of 600 pages and it comprises of Narda's entire product range. The catalogue is divided into coloured sections for ease of navigation, covering fibre optics, active components, passive components, electromechanical RF switches, power meters and monitors, satcom products, RF radiation safety products and low-cost of wireless components.

Equally, the catalogue carries specifications, outline drawings, performance charts, applications notes and articles.

Also available is a CD version of this catalogue, with information presented in PDF format, featuring a part-number search facility.

www.linkmicrotek.com

Clare expands its Horizon

Clare Instruments has a new set of specialist cable and wiring harness testers for electrical safety. Dubbed Horizon 1500, the series tests variety of applications from simple data cables to complex wiring assemblies used in electrical and electronics systems in the automotive, aerospace, computing, medical, military and telecom industries.

The unit is in a rugged benchtop format and includes automatic product-learning, fault location and test report generation, making it suitable for in progress functional and final testing of electrical wiring harness configurations.

The Horizon 1500 series is equipped with 128 high-voltage test points as standard and it can be expanded to 1024 points with high current (up to 1A) and hi pot testing up to 1500VDC and/or 1067VAC.

The system has a touch-screen and a hard disc drive for high capacity data storage.

www.clareinstruments.com

Miniature PCB-mounting transducers now on offer from LEM

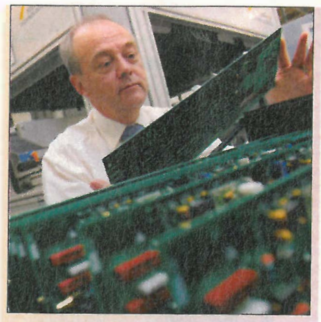
The new miniature PCB-mounting current transducers for unipolar +5V operation from LEM are based on an open-loop technology combined with an ASIC. They have access to an internal voltage reference and come in many ranges. In addition, they come with a five-year warranty.

The HXS series is designed to operate from a single +5V power supply. The units measure 18.5x16.5x10mm and integrate a multi-range primary conductor. The pinout on this conductor allows the HXS 20-NP to be configured as a five, 10 or 20 ARMS nominal model and the HXS 50-NP as a 12.5, 25 or 50 ARMS nominal model, with a measuring span of up to $\pm 3 \times I_{pn}$.

The internal reference voltage (2.5V) is provided on a separate pin or can be replaced by an external reference (between 2V and 2.8V).

The ASIC used with these transducers is combined with open-loop Hall effect technology, which in turn guarantees better offsets, gain drifts and linearity. It also offers operating temperature that ranges between -400°C and 850°C.

www.lem.com



Advanced PCB testing from Remploy

Remploy Electronics has launched an advanced PCB testing service for small and medium sized contract manufacturers.

Its facility, which is equipped with some of the latest equipment, including the double-sided flying probe Scorpion FLS 450 in-circuit tester from Scorpion Technologies, enables automatic and simultaneous testing of PCB assemblies. The company says testing is cost-effective and simple to set up, and tests active and passive components and boards featuring fine pitch and flip-chip technologies.

"Companies invest a lot of money in the development and production of today's complex boards and it makes sound commercial sense to apply the same scrupulous approach to the testing process," said Graham Denyer, project engineer for Remploy Electronics. For lese technically demanding boards, Remploy an offer a range of testing options including automatic optical inspection (AOI) as well as Wayne Kerr and Schlumberger automatic test equipment.

www.remployelectronics.co.uk

Versatile range of slip rings

The Endura-Trac range of modular industrial slip rings from I.D.M. Electronics contains 92 different combinations, offering flexiliby and cost-effectivness of design, and, yet, great reliability and durability. They are crucial in applications where transfer of electrical, digital and video signals or electrical power from stationary to rotating components is required. Endura-Trac can accomodate all colour or black and white video signals, high-speed digital data up to 80Mbit/s and high frequency signals up to 125MHz, with higher frequency options also available, increasing bandwidth to 250MHz and speeds of up to 125Mbit/s.

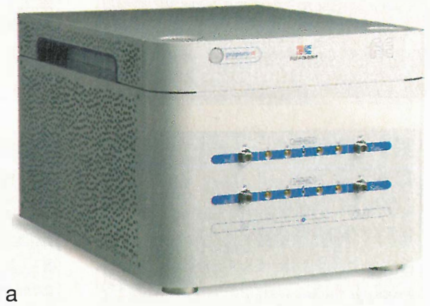
Units are available for shaft or flange mounting and offer up to 100 signal circuits of 250V/5A and 24 power circuits with capacity of 600V/30A. They offer full 3600 continuous rotation in either direction. There are options for sealed units, high-speed rotation and high voltage. All of them are supplied with 600mm flying leads as standard but any connectors, lead lenght or lead exit pattern can be selected for any requirement.

www.idmelectronics.co.uk

Multipath fading emulator

Elektrobit Testing Ltd introduced a new Multipath Fading Emulator for the testing of 2/2.5/3/3.5G (GSM, GPRS, EDGE, CDMA, CDMA2000, WCDMA, WLAN) wireless networks, terminals and chipsets.

The new Air Interface Emulator, PROPSim FE, is a turnkey solution that includes all the required test system components, latest multipath fading emulation technology, integrated interference generation and advanced test connection configurability, in a single box.



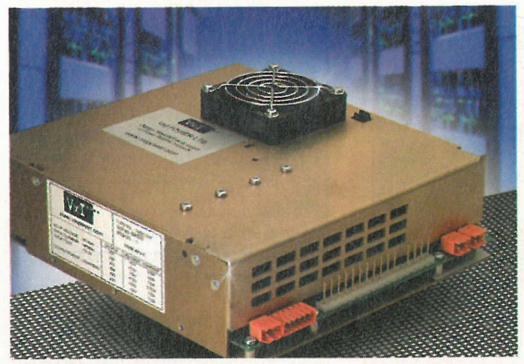
This is the latest product in the Elektrobit PROPSim family. It is especially suited to customers who are looking for a cost-effective solution for standard requirement testing without compromising quality.

The PROPSim FE with interfaces RF, analogue and digital baseband, provides a fading test solution for all stages of chipsets, mobile phones, BTS and wireless network development.

The PROPSim FE introduces an integrated solution for creating test case connections of TS34.121, TS25.141, TS51.010, TS51.021 TIA/EIA and IS-95/97/98/2000, including AWGN (additive white Gaussian noise) generation and faded modulated interfering signals inside a single tool.

www.propsim.com

200W battery-backed PSU with multiple outputs



The new Oracle III 200-9 battery-backed switch-mode power supply from Vxl Power offers designers greater flexibility by providing one main output, one charger output and up to seven 35W auxiliary outputs.

Operating from an 85-264V AC autoranging input, the PSU is available in both 12V and 24V versions and features fan cooling as standard, enabling it to deliver 200W continuously at the maximum permissible ambient temperature of 700°C, with a peak output capability of 300W. In the event of a mains failure, the backup battery supplies power to the load via an internal diode, thereby ensuring that the output is maintained without interruption.

The unit is capable of charging 'Cyclon' cells over the full temperature range and can also be configured for either 2- or 3-stage charging to reduce battery recharge times in cyclic applications.

The 200-9 features the standard Oracle III RS232/RS485 serial communications interface, with a choice of Modbus, Canbus, DeviceNet or IrDa protocols. As well as enabling data to be downloaded to a PC, this facility makes it possible for users to input parameters such as battery type and battery test interval. In addition, the serial interface allows the PSU to be integrated into a SCADA system, if required.

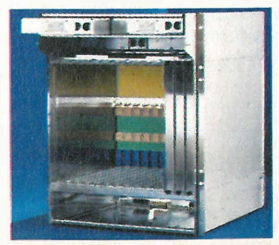
www.vxipower.com

Alternative ATCA units cooling

UK-based enclosure manufacturer Rittal has introduced high-capacity RiCool II fans for heat dissipation of up to 3.2kW and above for an entire Advanced TCA (ATCA) shelf. To achieve a reliable system, Rittal has used liquid cooling technology that was developed for cooling multiple high power servers in image processing applications in conjunction with the Max Planck Institute. The package allows the locating of heat exchangers, away from the rack, office or equipment room, saving on noise and heat build-up.

Rittal expects even higher heat losses to be incurred in the future, as integration levels rise and clock frequencies extend beyond the 10GHz.

www.rittal.co.uk



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NEWNES GUIDE TO RADIO AND COMMUNICATIONS TECHNOLOGY

Ian Poole

This is a guide to the technology and applications of modern radio and communications equipment. The author's approach provides a useful foundation for college students and technicians seeking an update on the latest technology.

Jul 2003 ▲ 352 pages ▲ Index ▲ PB
Published in UK

Code 0-7506-5612-3 £16.99

DICTIONARY OF VIDEO AND TELEVISION TECHNOLOGY

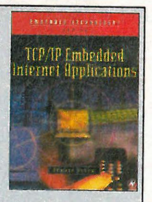
Jack Tsatsoulin

This work provides comprehensive and contemporary information on the essential concepts and terms in video and television, including coverage of test and measurement procedures. The CD accompanying the text includes an electronic version of the book.

Sept 2002 ▲ 365 pages & CD-Rom
Published in UK

Code 1-878707-99-X £29.99

TCP/IP EMBEDDED INTERNET APPLICATIONS



Edward Insam

This text highlights an engineer's approach to Internet protocols and applications, reducing R&D time for engineers. The book aims to be the main design guide for the cutting edge of Internet-enabled electronic products and systems.

Aug 2003 ▲ 384 pages ▲ Index ▲ Appendix
PB ▲ Published in UK

Code0-7506-5735-9 £32.50

ELECTRONIC CLASSICS: COLLECTING, RESTORATION AND REPAIR

Andrew Emmerson

This text encompasses all aspects of buying, collecting, restoring, repairing, sourcing parts, professional services, clubs and societies. The first part covers technical aspects of restoration and details where components can be found. The second part presents useful information for collectors.

Aug 1998 ▲ 256 pages ▲ Index
10 halftones ▲ 50 line illustrations ▲ PB
Published in UK

Code 0-7506-3788-9 £21.99

INTRODUCTION TO DIGITAL SYSTEMS

John Crisp

This self-study text introduces digital electronics from first principles, before going on to cover all the main areas of knowledge and expertise. It covers the practicalities of designing and building circuits, including fault-finding and the use of test equipment.

Feb 2000 ▲ 302 pages ▲ Glossary ▲ Index
PB ▲ Published in UK

Code 0-7506-4583-0 £18.99

NEWNES DICTIONARY OF ELECTRONICS

S W Amos; R S Amos

Aimed at engineers, technicians and students working in the field of electronics, this dictionary provides clear and concise definitions, including TV, radio and computing terms, with illustrations and circuit diagrams.

4th edition ▲ Mar 2002 ▲ 394 pages
100 illustrations ▲ PB ▲ Published in UK

Code 0-7506-5642-5 £12.99

NEWNES GUIDE TO TELEVISION & VIDEO TECHNOLOGY

Eugene Trundle

An exploration of television and video technology. It covers the fundamentals of digital television (satellite, cable and terrestrial) and digital video, as well as providing a grounding in analogue systems.

3rd edition ▲ Feb 2001 ▲ 432 pages ▲ Index
PB ▲ Published in UK

Code 0-7506-4810-4 £17.99

NEWNES GUIDE TO DIGITAL TV

Richard Brice

Covering all aspects of digital television, this text encompasses the electronics of the equipment, data compression, television production, servicing and the different transition methods - terrestrial, satellite and cable. The text has been updated with developments since the 2000 edition.

2nd edition ▲ Oct 2002 ▲ 304 pages ▲ Index
45 illustrations ▲ 15 photographs ▲ HB
Published in UK

Code0-7506-5721-9 £24.99

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING

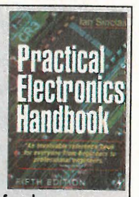
Robin Pain (Design Engineer, Cotag International Ltd)

A text using simple circuit examples to illustrate principles and concepts fundamental to the process of analog and digital fault finding. It aims to help the reader tackle any job, from fixing a TV to improving the sound of a hi-fi. A digital multimeter and oscilloscope are needed for these jobs.

Apr 1996 ▲ 284 pages ▲ Index
50 line illustrations ▲ PB ▲ Published in UK

Code 0-7506-2461-2 £21.99

PRACTICAL ELECTRONICS HANDBOOK



Ian Sinclair

A collection of all the key data, facts, practical guidance and circuit design basics needed by a spectrum of students, electronics enthusiasts, technicians and circuit designers. It provides explanations and practical guidance, and includes new sections on SHF techniques and intruder alarms.

5th edition ▲ Feb 2000 ▲ 571 pages
Illustrations ▲ PB ▲ Published in UK

Code 0-7506-4585-7 £16.99

RSGB RADIO & ELECTRONICS COOKBOOK

Radio Society of Great Britain

Only a basic knowledge of electronics is assumed for this collection of electronics projects, and it is ideal for all electronics and DIY enthusiasts and experimenters. Designed by the RSGB, the UK radio amateurs federation, the projects are clearly explained step by step.

Nov 2000 ▲ 336 pages ▲ PB ▲ Illustrations
Published in UK

Code 0-7506-5214-4 £17.99

REFERENCE DATA FOR ENGINEERS: RADIO, ELECTRONICS, COMPUTERS AND COMMUNICATIONS

Mac E Van Valkenburg; Edited by Wendy Middleton

Written by professionals for professionals, this is a complete reference for engineers, covering a broad range of topics. As well as addressing radio technology data, it covers digital electronics, computers and communications.

9th edition ▲ Aug 2001
1568 pages & CD-Rom ▲ 1385 line illustrations
HB ▲ Published in UK

Code 0-7506-7291-9 £90.00

FUZZY LOGIC FOR EMBEDDED SYSTEMS APPLICATIONS

Dr Ahmad Ibrahim

Written by a recognised expert in the field, this covers all the basic theory relevant to electronics design, with particular emphasis on embedded systems. It shows how the techniques can be applied to shorten design cycles and handle logic problems that are tough to solve using conventional linear techniques. All the latest advances in the field are discussed, and practical circuit design examples presented.

Oct 2003 ▲ 312 pages ▲ PB

Code 0-7506-7605-1 £35.00

ANALOG INTERFACING TO EMBEDDED MICROPROCESSORS

Stuart Ball

Provides hard-to-find information on interfacing analog devices and technologies to the purely digital world of embedded microprocessors. Gives the reader the insight and perspective of a real embedded systems design engineer, including tips that only a hands-on professional would know. Covers important considerations for both hardware and software systems when linking analog and digital devices.

March 2001 ▲ 288 pages ▲ PB
100 line illustrations

Code 0-7506-7339-7 £19.99

HANDBOOK OF RF AND WIRELESS TECHNOLOGIES

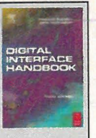
Farid Dowla (Lawrence Livermore National Laboratory, University of California-Davis, USA)

Subjects covered include third-generation wireless, wireless sensor networks, RF power amplifiers, spread spectrum modulation, signal propagation and antennae. This is far more than just a tutorial or reference guide—it is a "guided tour" through the world of cutting-edge RF and wireless design, combining theory, applications and philosophies behind the RF/wireless design process.

November 2003 ▲ 720 pages ▲ HB

Code 0-7506-7695-7 £59.99

DIGITAL INTERFACE HANDBOOK



John Watkinson, Francis Rumsey

A detailed manual for those who need to get to grips with digital audio and video systems. It sheds light on the differences between audio interfaces and shows how to make devices "talk to each other" in the digital domain. Also includes detailed coverage of all the regularly used digital video interfaces. New information included in this third edition: dedicated audio interfaces, audio over computer network interfaces and revised material on practical audio interfacing and synchronisation.

3rd edition ▲ September 2003 ▲ 392 pages
231 line illustrations ▲ PB

Code 0-2405-1909-4 £29.99

TV FAULT-FINDING GUIDE

Edited by Peter Marlow

A distillation of the most-used fault reports from 11 years of *Television* magazine. Arranged by make and model, it features over 200 reports on over 300 models of television, including diagnosis and repair advice.

Mar 2000 ▲ 387 pages ▲ Illustrations
PB ▲ Published in UK

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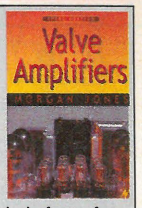
VALVE AMPLIFIERS



Morgan Jones

The author's straightforward approach, using as little maths as possible, should be of use to those with only a limited knowledge of the field as well as being the standard reference for experts in valve audio. Design principles and construction techniques are also provided.

3rd edition ▲ Aug 2003 ▲ 624 pages ▲ Index
PB ▲ Published in UK

Code 0-7506-5694-8 £29.99

VCR FAULT-FINDING GUIDE

Edited by Peter Marlow

A distillation of the most-used fault reports from 11 years of *Television* magazine. Arranged by make and model, it features over 2000 reports on over 200 models of VCR, including diagnosis and repair advice.

Mar 2000 ▲ 447 pages ▲ Illustrations ▲ PB
Published in UK

Code 0-7506-4634-9 £20.99

DESIGNING AUTONOMOUS MOBILE ROBOTS

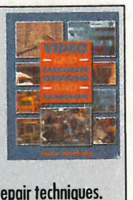
John Holland

Covering topics such as advanced sensor fusion, control systems for a wide array of application sensors and instrumentation, and fuzzy logic applications, this volume is essential reading for engineers undertaking robotics projects as well as for undergraduate and graduate students studying robotic engineering, artificial intelligence and cognitive science. Its state-of-the-art treatment of core concepts in mobile robotics helps and challenges readers in exploring new avenues in an exciting field.

January 2004 ▲ PB & CD-Rom ▲ 352 pages

Code 0-7506-7683-3 £35.00

VIDEO AND CAMCORDER SERVICING AND TECHNOLOGY



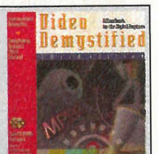
Steve Beeching

A comprehensive guide to domestic VCR technology and repair techniques. This edition brings the information fully-up-to-date, with expanded coverage of camcorders, sections on DVD equipment and the latest VCR technology.

5th edition ▲ Apr 2001 ▲ 323 pages
Illustrations ▲ PB ▲ Published in UK

Code 0-7506-5039-7 £20.99

VIDEO DEMYSTIFIED



Keith Jack

This edition has been updated to include information on digital television, datacasting, interactive video, digital camcorders and VCRs, and video interfacing. Coverage is international, including European, Asian and North/South American video standards, methods and techniques.

3rd edition ▲ Jul 2001 ▲ 784 pages & CD-Rom
References ▲ Glossary ▲ Index ▲ PB
Published in UK

Code 1-878707-56-6 £50.00

ANALOG ELECTRONICS: CIRCUITS, SYSTEMS AND SIGNAL PROCESSING

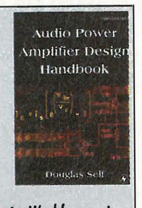
D Crecraft (formerly Open University); S Gergely (formerly University of Coventry)

Designed to complement the digital systems modules and develop the essential skills needed for RF circuit design, this book demystifies the art of analogue circuit design and analysis. The content meets the requirements of first and second year electronics engineering courses.

May 2002 ▲ 435 pages ▲ 150 line illustrations
PB ▲ Published in UK

Code 0-7506-5095-8 £19.99

AUDIO POWER AMPLIFIER DESIGN HANDBOOK



Douglas Self

This text on the design of audio amplifiers is based on Douglas Self's work in *Electronics World* magazine and a career at the cutting edge of audio design. This handbook aims to provide a practical guide to the state of the art, and includes detailed design and construction information.

3rd edition ▲ May 2002 ▲ 448 pages
62 line illustrations ▲ Index ▲ PB
Published in UK

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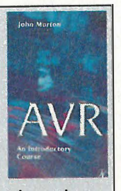
AVR: AN INTRODUCTORY COURSE



John Morton (University of Cambridge)

AVRs have certain strengths compared to other microcontrollers but are less well-known or understood. The author wrote this guide to introduce AVRs to those who have little or no microcontroller background and to encourage them to start using these useful devices with easy projects to try.

Sep 2002 ▲ 256 pages ▲ 150 illustrations
Glossary ▲ Further reading ▲ Index ▲PB
Published in UK

Code0-7506-5635-2 £16.99

BEBOP TO THE BOOLEAN BOOGIE: AN UNCONVENTIONAL GUIDE TO ELECTRONICS

Clive Maxfield

The second edition of this comprehensive introduction to contemporary electronics now has added material. It is written for the engineer, hobbyist or student who needs a thorough electronics reference, as well as for non-technical people, and is accompanied by a CD-ROM.

2nd edition ▲ Jan 2003
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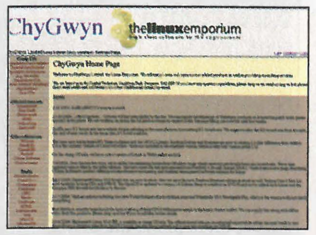

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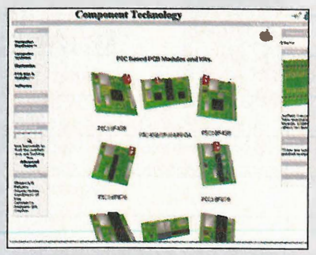

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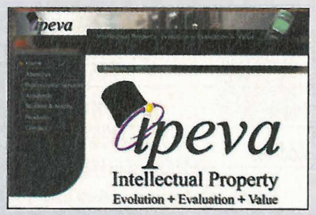

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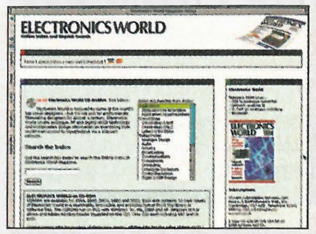

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