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ELECTRONICS WORLD

THE ESSENTIAL ELECTRONIC ENGINEERING MAGAZINE

FUTURE R&D
CONTRACTOR'S VIEW

3D TV
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TECHNOLOGY NEWS
MOBILE PHONE – THE NEW SHOPPING PAL

ALSO IN THIS ISSUE: TOP 5 TIPS ON PREVENTING DATA LOSS AND INFORMATION LEAKS

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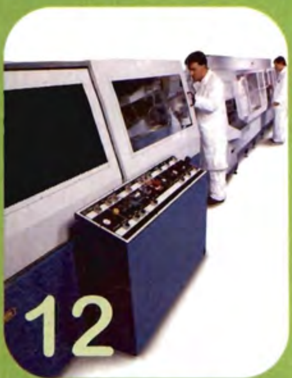

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Time's up

The world's changing – and fast. Many of those changes are being fuelled by advances in electronics: just think of the mobile phone, the printed electronic paper, the interactive systems (it could be your fridge!) and all the communications technologies.

But, the world might be changing a little bit too fast. Technology businesses are having problems predicting the performance of a product or a service in five years' time, and teaching (at universities or schools) cannot catch up with current advances at all.

So, who are going to be our new generation of engineers (and I sincerely hope this discipline remains for many years to come)? Interestingly, it'll be the children today that will teach themselves through the devices they are using. The way they have taken to new technologies is akin to a duck taking to water.

Whilst many of us remember our first PCs and the scramble to own one when the hard disc drive's storage volume reached half-a-gig – we were overwhelmed with its sheer capacity! And yet, no child today will settle for an iPod of less than 40Gbytes. For most of us, working with a PC means using a keyboard and a screen; but the children today will have a different interface tomorrow, where no keyboards will be used but sensor-laden touch-screens and computing devices that will manipulate audio, video, photos and data by a mere scroll of a hand across them.

We can get the glimpse of the future even today as it is children and teenagers that are the ones advising on the type of mobile phone handset or broadband operators to select for the home.

Another case in point is the way they communicate: mainly through texting (SMS) and mobile phones, whilst most of us above thirty years of age still prefer the landline. It seems anybody above a certain age struggles even to press less than two keys on a mobile phone or distinguish what's on the handsets' small screens.

And just think of how their way of thinking will shape the future: digital mirrors that will show a selection of outfits fitted on you to compare them all at once. Contact lenses that will not only improve eye sight, but offer augmented reality too. People and buildings that will emit digital 'auras', which will create virtual reality environments to walk into. Just think: you can have the (virtual) luxury of 'an empty beach' ... bliss!

There's something called PowerPaper that even exists today. It is a proprietary, printable power cell on a polymer film substrate, composed of environmentally-friendly ink-based cathode and anode. Today, these power-papers deliver wrinkle-fixing concoctions onto the skin, tomorrow they could allow active make-up, where facial make-up or skin adornments can be changed on the go with the help of a mobile phone.

And not to mention the advances we are going to see with the help of other technologies to converge with electronics: nano, bio, cogno and info.

The future will be a fun place and our children will take us there. Is our time up?

Svetlana Josifovska
Editor

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Fluke flies high with RF calibrator

Fluke, the test equipment supplier, is making a foray into the high frequency domain with its new 9640A RF Reference Source – an RF calibrator that combines level precision, dynamic range and frequency capability in one.

"Normally we are not seen as 'high frequency'," said Martin Finch, field product manager. "But the workloads are changing. Four years ago the workload was below 3GHz, now that's a lot higher and we decided to make a source designed for calibration purposes."

The 9640A provides frequency coverage from 10Hz to 4GHz, with a best level accuracy of ±0.05dB. The domain can be changed in steps of 10dB.

"We are not trying to compete with Agilent, Rohde&Schwarz in ATE [automatic test equipment] because we are only in calibration [with our instrument] and the others are general purpose equipment," added Finch. Instead, Fluke hopes to reach the calibration labs and a total market worth some $40m.

The 9640A can be used to calibrate various RF test equipment including spectrum analysers, modulation meters and analysers, RF power meters and sensors, measurement

The Fluke 9640A comes with a 50Ω levelling head and has an option to add a 75Ω head, which extends the instrument's capability to calibrate workloads with 50Ω and 75Ω inputs

receivers, frequency counters and attenuators. But to calibrate some other products, it will still need some additional pieces of equipment. According to Finch, "that's why we called it [the instrument] a 'source' and not a 'calibrator'."

The 9640A is the first in a family of products Fluke plans to introduce over the next few months.

Electrical components firm comes to energy rescue

The compact sized, split-core transducers of Wi-LEM can easily be installed inside limited spaces

Energy saving is high on the agenda of many companies and governments and LEM of Switzerland is coming to the rescue with a wireless sub-metering solution which promises to help users monitor and hence cut energy consumption, and the costs associated with it.

The new Wi-LEM family of products uses the ZigBee (IEEE 802.15.4) protocol to monitor and control energy consumption at multiple nodes. The family consists of energy meter nodes – an assembly of one to three current transducers with a signal processing module; mesh nodes – repeaters linking various nodes; and a mesh gate – a gateway managing the mesh network. The data is provided via a serial interface to a PC.

"The reason we selected ZigBee for our solution is that this standard has a proven robustness in industrial and commercial environments. It sends less data than other wireless protocols; it is good for energy management; and it's lower in cost than Wi-Fi. Also, we believe that the ZigBee market will be billion pieces per year market in the near future," said Tarek Boumegoura, sales manager for energy and automation at LEM.

LEM's energy meter nodes are claimed to provide more information than a simple sub-meter as they also measure active, reactive and apparent energy plus maximum current and minimum voltage. The nodes take measurements at 5 to 30 minute intervals and transmit the results over the wireless network.

The mesh nodes act as repeaters and can be added to the network without any need for additional configuration or programming. The mesh gate is a standalone wireless network management gateway that connects the transducer network with a PC using the serial interfaces RS-232 or RS-485 with a MODBUS RTU protocol. Each mesh gate allows monitoring of up to 240 energy meter nodes.

New trends will shape IT

The future of the IT infrastructure will be shaped by four key trends, says the industry. These are virtualisation, information security, service orientation and standards.

Virtualisation is the layer that sits between the hardware and the applications; the abstract layer between data and storage that can be scaled up or down with the help of software. "We are talking about virtualising not only the storage industry but the whole IT infrastructure. This is going to be key in the future," said Tom Burns, senior director at US-based storage firm EMC Corporation.

Virtualisation is going to help many enterprises that have made significant investments in multiple storage architectures to support a variety of different application requirements which, to date, have proven to be rather inefficient and underutilised, difficult to manage and costly to scale. There are many providers of virtualisation packages already that that can help to tier heterogeneous storage into a unified solution. One of these is US-based Network Appliance.

"The fundamental thing we believe the future will hold is virtualisation as a standard and unified storage," said John Rollason, product marketing manager for EMEA at Network Appliance.

Information security is also the next big thing in IT. "Two or three years ago nobody was talking about information security. But that's about to change. It's about creating a security profile at the point of creating the information and that profile stays with that information until the end."

"The next generation of IT infrastructure will be service-oriented too rather than platform-oriented. We'll break the shackles of operating systems to offer seamless information services," added Burns.

Steve Legg, chief architect at IBM, added that the fourth key trend will be collaboration through standards. "Although it's fun to invest in new things [on your own], it's better to standardise technologies," he said.

NXP plans to increase its semiconductor strength

The newly divested semiconductor arm of Royal Philips Electronics – named NXP, is planning to increase its dominance in several key markets and in the process invest in advanced processing technologies.

The firm has already inherited the association with STMicroelectronics and Freescale Semiconductor in the Crolles 2 alliance in France to collaborate in the research, development and commercialisation of CMOS process technologies – from 90nm down to 32nm nodes. However, now NXP is looking at bailing out of this venture.

"Indeed, the Crolles 2 alliance is under review," said Marc de Jong, general manager at NXP. "We still have some months to decide what to do with that – until 2008, so all of 2007."

Currently NXP uses foundry for around 20% of production, but would like to increase that figure. "Now is the next capital intensive stage in the [Crolles 2] alliance so it's a good time to evaluate our options," de Jon told *Electronics World*. "And there are alternatives; alternatives in terms of advanced processes and investments. Options like the IBM-Chartered alliance or even joining forces with foundries like TSMC are possibilities."

NXP plans to be a leading semiconductor player in mobile and personal communications, set-top boxes, automotive applications, and control electronics for solid state lighting, among others. In the process, "focused acquisitions" will be made to gain additional strength in those fields.

"We want to turn NXP into one of the leading semiconductor companies," said de Jong. "We are looking at R&D and potential acquisitions [to achieve that]. We are looking into focused acquisitions, those that can hep us gain extra in our leading positions and acquire specific IP."

The company is currently owned by a group of venture capitalists. Kohlberg Kravis Roberts & Co. (KKR), Bain Capital, Silver Lake Partners, Apax and AlpInvest Partners own 80.1% of the semiconductor operation with Philips retaining a 19.9% interest.

According to de Jong, the new investors are "true believers" in the semiconductor business. "It's good to have our investors believe in semiconductors. At Philips they did that in the 90s, but it kind of died down in 2000 to 2006."

Mobile phones will be your best flexible friend yet

Near Field Communication (NFC) will enable the mobile phone to become a portable payment, ticketing and access system within the next few years. The handset will be used to pay for goods and services in a wide range of retail shops.

Major drives by semiconductor, communications, software and financial organisation are behind the efforts to have NFC integrated in all mobile phones within the next five years, just as prevalently as cameras are in these devices today. Nokia is one of the first handset makers to offer NFC-enabled mobile phones already.

"There will be a point where NFC will be built into all types of devices," said Mark Gillott, European business development manager at Philips Semiconductors (now NXP) USA. "There has to be a point when NFC will be built into the mobile phone just like the camera is today. It'll be just as easy and cheap to add than to leave out," he said.

Trials and pilot schemes have already started throughout the world. In Japan and Taiwan, NFC will be used for mobile phone payments in supermarkets. In The Netherlands, an NFC trial focuses on mobile phones opening hotel room doors, as well as for ticketing applications, and in the UK it is used to collect information from posters.

Motorola, NXP, Deloitte and Bull have started a project that combines financial with retail services based on NFC in July 2006. "We are working with NXP on a new project covering the needs for the retail sector to combine payment with e-purse, e-ticketing, access control and others. The mobile phone will be the new device for shopping," said Andreas Schaller, marketing manager for short-range communications at Motorola.

However, before NFC takes a complete hold of our mobile phones, there are still issues that need to be urgently resolved, including that the receiving transaction has to be automatic and secure.

"Although the system trials have been very successful, the ecosystem [for NFC] has to develop further," said Gillott. "The idea of the pilots is to create niche applications and these will start to build the case up for NFC. There are a number of commercial roll-outs that are imminent [too] – and this is a big step forward."

"In the next three to five years, NFC will be a lot more prevalent out there," he added.

Mobile phones will soon be geared to help with the shopping

NFC enables mobile phones and fixed devices to exchange data. It's a short range technology – operating distance is up to 10cm at the frequency of 13.56MHz. The maximum data rate exchange is 1Mbit/s.

There are two proposed categories of applications for NFC:

(1) Connectivity, for example to trigger a Bluetooth or Wi-Fi connection. This solution is being looked at by all the key mobile phone suppliers in the world.

(2) Payment.

Major applications are in payment (using the mobile phone as a point of sale terminal) with credit, debit and e-purse; business card and access to public transport.

NFC was originally a cooperation between Philips and Sony that started in mid-2002.

Among the current NFC Forum members are NEC, LG, Microsoft, Sony, Philips, Texas Instruments, Infineon, Renesas, Visa, MasterCard and others.

Samsung Electronics claims it has developed the industry's first process to enable innovative production of a 16-chip multi-chip package (MCP) of memory. The 16-chip MCP technology, when applied to 8Gbit NAND flash chips, can enable up to a 16 gigabyte (GB) MCP solution.

For the new 16-chip process, Samsung introduced wafer thinning technology that eliminates 24 over 25 (24/25) of the thickness of each fabricated wafer to reduce the overall thickness to only 30µm. This is just 65% the thickness of the 10-chip MCP wafer (45µm) Samsung developed in 2005 and similar to the size a human cell, which measures 20-30µm.

* * *

Engineers from Denso have developed a windscreen display on which information from the car's navigation system or a night vision camera can be superimposed. What makes this system unique is that the entire windscreen can be used as a display. Symbols from the navigation system are visualised in such a way that they appear to be integrated into the traffic, which makes it much easier for the driver to take in the information. However, several problems with a driver's image perception still have to be solved before the system is ready for the market.

* * *

Scientists and engineers at BAE Systems have created technology to 'write' electrical circuits directly onto surfaces. Direct Write works by depositing electrical wires, resistors, capacitors and other electrical components in 3D onto conformable surfaces. As such, it is promised to increase the functionality and flexibility of existing structures and designs in both defence and commercial applications, including the printing of clothing with sensors and display systems with moving images and logos. The integrated sensors in clothing could be used for tracking children, to monitor a person's health and even dispensing drugs.

The first load cells using this technology have been evaluated on McLaren Mercedes's Formula 1 cars.

Infineon Technologies has unveiled a chip that aims to improve the energy efficiency of power supply units (PSUs). A good portion of all the electrical energy used today flows through PSUs into electrical equipment such as computers, TVs and consumer electronics devices. Infineon's OptiMOS 3 chip offers fewer components, a real estate saving of up to two thirds in the PSU and one third less resistance. According to the company, the power generated by an entire 360MW power plant could be saved if OptiMOS 3 was fitted to deliver the right efficiency to all the computer server power systems in use.

* * *

University of Kent was awarded nearly £323k from the Engineering and Physical Sciences Research Council (EPSRC) for study into the electro-magnetic architecture of buildings with the aim of better controlling indoor radio signal strengths.

The research will involve integrating frequency selective surfaces into building walls. These surfaces can either pass or block certain radio frequencies so that transmissions can be contained in, or passed out of sealed rooms. This has promising implications for 'reusing' radio signals in adjacent rooms and increasing the total number of wireless channels available, or conversely, blocking signals completely and stopping people from making unauthorised mobile phone calls.

* * *

The Glider Mouse from Hela (see below) is a new type of ergonomic mouse designed to prevent computer related injuries including RSI (Repetitive Strain Injury) and upper limb disorder.

The mouse features twelve programmable click buttons, including a scroll wheel. With its low-rise design and USB interface, the Glider Mouse is compatible with both PC and MAC, and works well in combination with a slim-line or mini keyboard, as well as with laptop computers.

TOP 5 TIPS: DATA LOSS AND INFORMATION LEAKS

1. **Deploy content monitoring and filtering (CMF)** : A CMF solution monitors all outbound network traffic and generates alerts regarding activity (or sometimes blocks it), based on inspecting the data in network sessions. CMF tools monitor common channels, including e-mail, IM, FTP, HTTP and Web mail (interpreting the HTTP for specific Web mail services) and look for policy violations based on a variety of techniques.

2. **Encrypt back-up tapes and (possibly) mass storage** : It is in doubt whether many of the reported lost back-up tapes containing records have resulted in fraud. However, because there is no way to know for sure, companies have to assume exposure anyway. Encryption can ensure that the data will still be safe.

3. **Secure workstations, restrict home computers and lock portable storage** : Workstations and laptops can be a major source of loss, especially when a poorly configured or out-of-date enterprise or home computer is compromised by a virus or worm and, by losing portable storage media, such as a Universal Serial Bus (USB) drive or CD-ROM.
   Keeping an enterprise system up-to-date with the latest patches, a personal firewall, antivirus and anti-spyware software are the primary precautions that will prevent the vast majority of commonly encountered Internet attacks.

4. **Encrypt laptops** : If organisations give employees portable computers, employees will store sensitive data on it. Policies do not seem to matter, as users will always use the tools they acquire and sensitive data will always end up in unexpected places.
   A whole-drive encryption from a third-party vendor is the preferred option.

5. **Deploy database activity monitoring** : Most organisations struggle to secure existing databases that are rarely designed with effective security controls. While companies eventually need to encrypt some of the data in their databases, database activity monitoring is a powerful security control that's easier to implement and more viable than encryption for many types of data.
   Database activity monitoring tools observe all activity within a database, record this activity in a secure repository and generate instant alerts for unusual activity. Through detection of unusual behaviour, database activity monitoring can limit insider misuse of database systems, enforce separation of duties for database administrators and limit certain external attacks, all without affecting database performance.

These top five tips were compiled by Gartner analysts and were printed by Global-electronics.net. For event details on security issue log on to www.europe.gartner.com/security

If you want to send us your top five or ten tips on any engineering and design subject, please write to the Editor at EWeditor@nexusmedia.com.

Future Trends in R&D

A Sub-Contractor's Perspective

Trends in engineering R&D are becoming more demanding and, yet, fewer students are entering engineering degree courses, especially in the Western world. **Kees Ten Nijenhuis**, Head of Europe at Wipro says the answer may be in looking to use a diversity of people from all over the world to keep innovation alive

The R&D model of the industrial era had sustained growth throughout the 20th century by churning out product innovations but, with new market forces exposing their systemic inefficiencies and inadequacies, the trends in R&D are changing rapidly. In future, R&D will be more market focused, collaborative and adaptive. A study of the world's 1000 biggest corporate R&D spenders found little relationship between R&D spending levels and business success.

The higher-risk stakes in R&D will make it more collaborative and an outsourced activity rather then a captive activity. Over the past five years, US corporations spent an astounding $1 trillion in R&D assets – it takes Intel $2bn to build a new chip. But such big-ticket R&D projects' payoff is increasingly elusive; a major Intel OEM client can switch to rival Advanced Micro Devices (AMD), forcing Intel to write off its expensive R&D assets. It makes sense for Intel to outsource its R&D activity to low-cost service providers and become more market focused.

The globalisation has led to nearly three billion consumers wanting goods and services developed regionally to suit local needs, not offerings designed for Western buyers only. The global corporations that traditionally operated R&D centres close to the US or Europe realise that these Western labs – and their scientists – are unsuited to serve the 80% of the world's middle-class consumers who are expected to live in the non-industrialised world within the next decade.

The shrinking local talent pool in the West will shift R&D labs to low-cost, high-skill countries like India and China. Since the mid-1990s, engineering and physics PhDs in the US have declined by 15% and 22%, respectively, making it harder for US corporations to hire scientists and engineers. At this rate, the US industrial sector won't find local talent to fill the 5.3 million highly skilled jobs, including R&D openings that it will generate in 2010, or the 14 million expected to be generated in 2020.

In future, R&D management will require competence to integrate external and internal knowledge assets so that innovation efficiency can go up while idea-to-market time goes down and product pipelines get richer. A new R&D organisation will emerge to match global demand for innovation with worldwide supply. It will let firms fluidly weave internally and externally available invention and R&D services to optimise the profitability of their products, services and business models. This will deconstruct vertically integrated invention-to-innovation cycles in software, finance and CPG industries and re-invent the formula for success in regional, national and global markets.

There are many electronics technologies, either just getting ready to take off, not widely available yet, or just around the corner that are going to become adopted quickly in the future. Some of the future trends in R&D in electronics include single molecules and one-dimensional structures such as nanotubes or nanowires, for example.

New technologies and standards are increasing the use of electronics in cars. Networking technologies for electronic modules and systems including local interconnect networks, Media Oriented Systems Transport, safe-by-wire, FlexRay, CAN and J1850 are having an impact on semiconductor and system design.

R&D in semiconductors will focus on DNA logic, quantum computing, molecular transistors, polymer memory, optical silicon, GaN devices, plastic transistors, carbon nanotube circuits, network-on-chip and others. Other future technologies will include silicon RF power amplifiers, hardware reconfigurable devices, micro fuel cells, MRAM, Organic Light-Emitting Devices, embedded FPGA cores, ferroelectric RAM, strained silicon and others.

In the communication industry, future R&D will focus on fourth generation wireless technologies for more efficient use of spectrum, wider band-width and QoS requirements for converged services. Almost all equipment vendors are focusing on integrated service delivery platforms and IP multimedia sub-systems.

The complexity of modern technology, especially its system character, has led to an increase in the number and variety of standards that affect a single industry or market. Standards affect the R&D, production and market penetration stages of economic activity and, therefore, have a significant collective effect on innovation, productivity and market structure. The future R&D policy will, therefore, include standardisation in analyses of technology-based growth issues.

“The shrinking local talent pool in the West will shift R&D labs to low-cost, high-skill countries like India and China”

Miniaturisation has always been on top of the list in the electronics industry. In the near future, the goal is the development of reliable manufacturing for giga-scale miniaturisation technology and this will also include vacuum micro tubes with controlled emitters for telecommunication, quantum electronics; quantum wells lasers, efficient solar cells and quality control and characterisation techniques (SEM-DVC, LEBEAMs, DLTS and ESEM).

To win in today's globally networked and volatile economy, firms must transform their R&D culture to drive not just technical innovations, but also business model innovations that cannot be replicated by competitors. It takes careful planning, sophisticated communications solutions and clever ways to increase productivity without stifling innovation for firms to be successful. For all the challenges, companies that get it right can expect substantial rewards, including lower R&D costs, improved access to the world's fastest growing markets and, above all, a steady stream of innovative products. The greater the diversity of people in R&D, the more ideas you will get.

Still going STRONG...

Spellman High Voltage Electronics Corporation celebrates its 60th anniversary this year. By Juan Pablo Conti

An element of unfairness invariably surrounds the field of power supply technology. There isn't really a single high-tech industry that won't deny finding the issue of power sources boring and, yet, none of them would truly exist if it weren't for them. What's more, while those unfamiliar with the intricacies of power supply might hold the view that nothing exciting or new ever really happens there, they would be surprised to learn that this is actually a very different

Aqueous wave solder equipment used in the manufacturing of PCBs

industry than it used to be only a few years ago. Just as in the general electronics industry, new designs are getting smaller, lighter, more powerful, intelligent, reliable and efficient all the time. This means these devices, too, are finding their way into a growing number of applications. This is especially true for high-voltage power supplies. The latest designs, which are operating at high frequencies between 20kHz and 100kHz, have practically replaced all products operating at line frequency, even at high power levels.

Getting ready to celebrate its 60th anniversary this year, Hauppauge, New York-based Spellman High Voltage Electronics has been a consistent innovator in the high-voltage technology arena. The privately owned company, which currently boasts the industry's largest design team, holds a series of pioneering HV power conversion and control system patents. It has built up expertise in switching topologies that include resonant, quasi-resonant, soft switching, pulse width modulated and linear converter designs.

High-voltage power supplies are typically specified by the next-level system designer. In other words, by the engineer responsible for the development of the equipment that will be using the power supply. Whenever these engineers approach Spellman, they'd better know exactly what they're looking for or risk feeling overwhelmed by the selection task in front of them. The vendor's product line spans a wide range of specifications that goes from miniature 200mW SMT modules to powerful 120kW multi-chassis units used for industrial magnetrons.

At the lower end of high-voltage generation, Spellman has hardware running at 250V used for example to bias a detector. At the other end, 360kV power supplies are built for ion beam implantation tools, and products of up to 500kV can be ordered.

Spellman High Voltage Electronics Corporation

........60 years on

The company has developed a proprietary solid encapsulation technique

Medical Breakthrough

During its 60 years of life, the company has frequently turned to its R&D infrastructure to solve a number of technical challenges facing particularly the medical community. Chief among these was the development in the early 1980s of the world's first X-ray generator, small enough to be mounted onto a computed tomography (CT) gantry. The invention heralded the mass production of helical CT scanners used today for multi-slice imaging.

"Before Spellman's innovation in this area, generators were located in a separate equipment cabinet and connected to the rotating gantry via long cables," explains Robert Frankland, Spellman's director of sales for the Americas. "Obviously, this limited the number of rotations of the gantry. Making the generators gantry-mountable allowed for continuous rotation, thus multi-slice machines with much higher resolution and imaging capabilities could be developed. In order to create a power supply that could physically rotate at very high speeds, we needed to address not only the electrical but also the mechanical issues. It was a tremendous R&D effort on Spellman's part, but it resulted in a viable product that is now used on most CT machines."

One of the main challenges facing the engineering team was how to get a smaller and lighter power supply that could maintain or improve its power density. Then again, this is a task the company is increasingly having to learn to live with, as Frankland acknowledges: "One of the critical challenges that we are increasingly confronting is finding ways to improve or enhance the performance parameters of our power supplies while reducing both the size of the packaging and the cost."

In order to do that, the vendor is again turning to its R&D department in search for innovative insulation techniques. Because the output section of HV power supplies operates at very high voltages, its appropriate packaging is vital to the ultimate reliability of the end product.

Using proprietary solid encapsulation (or 'potting') techniques, Spellman has been able to miniaturise the packaging and boost the power density of a variety of products compared with the use of air as the primary insulating media.

Over the years, the company has built up expertise in practically all forms of insulation, including silicone rubbers, epoxies, air, gas and dielectric oil. The latter provides another way to reduce weight and size. Spellman has used this high-voltage packaging technology successfully in a number of its Monoblock X-ray sources for bone densitometry equipment, which feature an integrated X-ray tube assembly and power supply. This results in a much more compact bone densitometer that can be located in a doctor's surgery where space is at a premium.

"Spellman's specialised encapsulants, which are designed jointly with formulators and the whole encapsulation process are key to the compact yet extremely reliable designs," adds Godrej Mehta, vice president of operations.

The company has also been recognised for pioneering the use of voltage multiplier circuits at extreme voltage and power levels. It claims its engineers have repeatedly broken limits normally associated with this type of circuit – which essentially consists of an arrangement of capacitors and rectifier diodes used to obtain DC voltages higher than a given AC input.

The company uses surface mount PCB fabrication as one of its advanced manufacturing techniques

SPELLMAN IN BRIEF

Founded:	1947 by Bill Spellman (purchased in 1968 by Merrill Skeist)
President and owner:	Loren Skeist
Headquarters:	Hauppauge, New York
Manufacturing facilities:	US (3), Mexico and UK
Revenues:	Undisclosed
Employees:	over 1000 worldwide
Engineering team:	approximately 120

Electronic Control

Apart from improving performance while reducing cost and size, Frankland says customers are increasingly demanding very sophisticated forms of control. "We've been putting a lot of our internal emphasis and energies on developing microprocessor based control of power supplies, designing methods of control that provide greater intelligence. I see that as an ongoing challenge – more sophisticated programming and processing. In fact, probably the fastest growing segment of our engineering organisation at the moment is really software development."

An example of the type of products emerging from Spellman's factories as a result of this trend is a new standard digital interface control card that the firm launched last August. The SMT board can be installed inside many of Spellman's high-voltage devices, whose output can then be controlled with a computer via three possible communication interfaces: RS-232, Ethernet or USB. It features a 40MIPS DSP, a network processor and a USB controller. Via a diagnostics web server, power supplies equipped with the interface card can even be remotely configured and monitored from a standard web browser.

From New York To Tokyo

Spellman was born and continues to be a private company. In 1947, when Bill Spellman founded the firm, only seven employees worked in it. Today, the staff count has risen to over 1000.

In 1968 the company was acquired by Merrill Skeist, a mechanical engineer who had previously been working in New York with Maxson Corp. Credited as the person who brought the customer focus and technical vision that took Spellman to its current position, he remained actively involved in the company until his death in 2005.

Meanwhile, his son Loren, president and owner, is in charge of a firm that now operates in three continents. In October 2004 he presided over Spellman's acquisition of Del High Voltage, maker of the Del, Bertan and Dynarad product lines. The move ensured Del's 35,000 square foot manufacturing and engineering facility in Valhala, New York, was added to Spellman's own NY plants in Hauppauge (100,000 sq ft) and Bohemia (65,000 sq ft).

Two other manufacturing complexes – one in Matamoros, Mexico (88,000 sq ft) and the other in Pulborough, West Sussex, UK (20,000 sq ft) – complete the company's manufacturing infrastructure, which is ISO 9001-2000 and ISO 14001-2004-certified. Functioning as its European headquarters, the British site is also a centre of excellence for the design of precision high voltage systems.

A sales and service office was opened in Tokyo (Japan) ten years ago and – more recently – outside Shanghai in China. This geographic expansion has been reflected on the financial side of the business, with the company growing in excess of 10% on average over the past five years.

But which industries are particularly driving the highest demand for Spellman's high-voltage power supplies? "The medical imaging segment – and particularly CT imaging – has and continues to be a major driver of Spellman growth," details Frankland. "Beyond medical, all other X-ray modalities (such as security, analytical and non-destructive testing applications) represent a large share of our total business."

Powerful Sources For Powerful Chips

Memory storage device and semiconductor fabrication also relies heavily on highly controlled, efficient HV power sources. "High-voltage is present in a large number of the techniques and processes that are part of semiconductor manufacturing," explains Frankland. "Examples include capital equipment companies using high voltage to power ion implanters, electrostatic wafer handling systems and many of their metrology and inspection processes."

The company has designed solutions of up to 500kV to operate in the severe arcing conditions typical of a number of vacuum processes such as ion beam etching, e-beam vapour deposition and ion implantation. Special care is taken to design the precision circuitry, a critical element when it comes to applications requiring low ripple and high-stability outputs.

For special cases, where an application might require particularly small values of either high-frequency or line frequency ripple, Spellman is prepared to adapt its original designs to provide lower ripple at one of these frequencies.

Frankland says this level of customisation and the ability to respond to specific OEM needs is what has traditionally distinguished his company: "The areas where we've historically innovated are in developing our power supplies in a way that uniquely comports to customers' applications. It's the example of the CT scanner manufacturer, or other types of systems where basically an OEM comes to us with a problem: 'I need to power my system with high voltage and I've a unique set of physical, electrical, geometric, packaging or even economic constraints'.

"We're really an OEM-driven type of company. Most of our R&D is generally oriented towards the development of a practical product, aimed towards a specific application for a particular customer. We are not really an 'off-the-shelf-product' type of company. I mean, we do have a catalogue and off-the-shelf products, but this is only a fraction of what our business really is."



From top:

Valhalla, NY manufacturing and engineering facility

Manufacturing and engineering centre at Bohemia, NY

The newly expanded manufacturing plant in Mexico

Headquarters are located in Hauppauge, NY

Spellman UK is a centre of excellence for the design of precision HV products

Spellman's Japan location

A sales and service office was recently opened in China

TYPICAL APPLICATIONS TARGETED BY SPELLMAN'S HV SUPPLIES

- Analytical X-ray
- Automated test equipment
- Capacitor charging
- PCB inspection, NDT, thickness gauging and tube testing
- Chromatography equipment
- CO2 lasers
- CRT (display, flight simulation and test)
- Detectors (gamma, MCP, PMT)
- Dielectric breakdown testing
- Electron beam lithography
- Gel and capillary electrophoresis
- Electrostatics (coating, flocking, precipitators, spraying)
- Image intensifiers
- Industrial colour printing
- Industrial X-ray (luggage inspection/ EDS, food inspection/irradiation)
- Ion beam (FIB for mask repair)
- Ion implantation
- Lithotripsy
- Mass spectrometers
- Medical imaging (PET, MRI)
- Medical X-ray (computed tomography, bone densitometry, mammography)
- Medical oncology
- Microwave (magnetrons, klystrons)
- Neutron generators
- Nuclear instrumentation
- Nuclear medicine (gamma camera)
- Land-based and shipboard power feed equipment
- Scanning electron microscopes
- Medical blood analysers
- Spectrophotometers
- Sputtering
- Stress testing
- Surface analysis
- Water purification

NOT ALL RADIOS are equal

by Myk Dormer

"ISM band: is that garage door openers and door bells?"

"You need a licence to do that?"

"10mW? That won't reach the next room!"

"BlueFiBee will fulfill all possible wireless connectivity requirements."

There are an awful lot of misconceptions to be found when looking into the subject of low power or ISM radio. Partly it stems from this being a very broad categorisation indeed and, partly, from the (all too human) attempts by suppliers to push their solution in this area. In this article I will attempt to untangle a few of the confusions.

The terms 'low power radio', 'ISM' (industrial, scientific and medical) and 'SRD' (short range device) have come to refer to a wide class of data communication radios with transmitter output powers of less than 1W (although many are below 10mW), operating at ranges of less than 500m (but some can reach over 10km) and a wide variety of data rates (from below 100bit/s to over 1Mbit/s). They are used in general data communication, remote control, monitoring and alarm applications. The term 'telemetry' radio is also applied to these devices but incorrectly, as 'telemetry' means 'remote measuring' which covers only some of these applications.

Most radios in this class operate in the unlicensed part of the spectrum, where regulatory authorities allow suitably approved and tested radios to be used without the need for individual user licenses. Some parts of this spectrum are assigned to general usage, while other bands may be limited too, for instance alarms or remote meter reading. Unfortunately, despite attempts to harmonise usage within the EU and beyond, the permissible bands and approval standards can vary from country to country. Most of Europe, Africa and Australia have fairly similar regulations (look for the "EN300-220-3" standard approval), but America and Canada are totally different (FCC chapter 15, part 247). Great care is needed in selecting radios for a globally marketed product.

So what is available? Assigning any absolute categories is fraught with difficulty so, instead, we will consider them in terms of usable range. In all these cases the 'range' quoted is in a typical in-building or urban environment. Much longer ranges are seen across valleys, over sea, or air to ground. In fact, any range quoted by a manufacturer must be taken with a large pinch of salt.

- **Up to 10m**. Two very different types of radio provide very short range coverage. Simple remote control tasks (toys and gadgets, controls for domestic goods) are typically handled by primitive 27 and 40MHz designs, while high data throughput links (digital wireless audio, computer peripherals, point of sale terminals) use complex integrated circuit solutions, frequently using protocol standards such as Bluetooth in the 2.4GHz band (although in-car control and monitoring applications use simpler, low data rate conventional wireless).
- **Up to 50m**. Wireless LAN and other high throughput systems use Wi-Fi or similar in the 2.4GHz or 5.8GHz bands. Complex mesh-network systems (data gathering, home automation networks) use ZigBee, or one of its imitators. Simpler one-to-one, or polled network, data systems and higher end remote control tasks use lower cost, lower power conventional wideband radios in the 433 or 868MHz (915MHz in the US) allocations – either simple modules, or single chip radios.
- **Up to 200m**. Alarm systems, vehicle data download systems. As range increases, the 2.4GHz

"Most radios in this class operate in the unlicensed part of the spectrum, where regulatory authorities allow suitably approved and tested radios to be used without the need for individual user licenses"

high-speed units reach their limit. Conventional wideband modules begin to show superior RF performance to single chip solutions and simpler narrow band radios are used for critical industrial and alarm tasks. High data rate links using 2.4GHz require more sophisticated, fixed aerials. In the US and Canada this market segment is addressed by high power 915MHz spread spectrum radios.

- **Up to 500m**. Industrial control and monitoring, large site alarm systems. More complex narrow band radios dominate, frequently multi-channel to improve adaptability and allow multiple co-sited systems. Data rates rarely exceed 10kbit/s. Low power VHF equipment is used (lower path loss, giving more range for given power).
- **Over 1km**. Long range telemetry and command, remote operated vehicles, high value asset tagging. Only VHF band and higher powered (500mW) UHF radios offer sufficient link reliability. National regulations become more of an issue, as not all countries have suitable bands. GPRS infrastructure modems begin to compete where good network coverage is available.
- **Over 5km**. Marine data telemetry, agricultural control. Of all the unlicensed ISM band radios, only VHF units can offer this range and, even then, good aerials will be needed. At these ranges licensed operation (UHF, with much higher allowable transmitter power) starts to become economic, as does GPRS and admittedly high cost satellite-based systems, such as ARGOS for instance.

Any more range than that and we're in a very different area indeed.

Myk Dormer is Senior RF Design Engineer at Radiometrix Ltd
www.radiometrix.com

HOT AUDIO POWER Revisited

Electronics World originally published Jeff Macaulay's elegantly simple hybrid solid state/valve 30W audio amplifier in October 1995.

Using only a handful of passive components, the following modifications will overcome some limitations in the original circuit and improve the dynamic range and power supply noise rejection. When adjusted correctly, the modified amplifier's residual hum and noise across a test load measures unweighted at -68dBu rms, which is minuscule for a valve amp with a simple bridge/capacitor HT power supply.

The main points improved by the modified circuit are:

1. Balance of grid drive to the output EL34 valves.
2. Input sensitivity too high.
3. Hum/power supply ripple cancellation.
4. Waste of HT through the use of cathode bias.

Drive Balance

Although the original circuit (**Figure 1**) looked symmetrical, the grid signal drives to the pair of output valves are unequal, increasing distortion and reducing output power. Assuming similar EL34 characteristics, the drive to V2 is about 6% lower then that to V1. **Appendix 1** shows that the current gains of transimpedance driver stages (op-amp A1+Tr1 and A2+Tr2) are mismatched by 6.3%, due to different impedances in the main driver stages.

The modified circuit in **Figure 2** uses a more straightforward approach for the phase splitting function and achieves perfect drive balance. Op-amp A2 becomes a unity gain inverting stage by changing R11 to 10kΩ and taking its feed from Tr1 emitter instead of the inverting input of A1. At the same time, this clears up the over-sensitive input by reducing the gain of the driver stages by over 20dB. C4 can also be reduced to 22uF, still keeping the C4/R11 time constant at about the same value of 0.2s.

As valve amp enthusiasts will probably agree, finding a perfectly matched pair of valves is almost impossible, so some means of adjustment of the bias and drive balance is highly desirable. VR3 adjusts the current gain of A2+Tr2 to compensate for differences in the EL34 characteristics, and is set by feeding the amp from a test tone oscillator and minimising the level of (even) harmonic distortion at the output.

Don't expect silicon amp performance figures at high output levels. Valves can generate copious amounts of low order harmonic distortion when driven hard.

Input Sensitivity

Overall voltage gain in the original design is directly influenced by R11, which sets the two NFB loops around the input of TL072. The EL34 drives

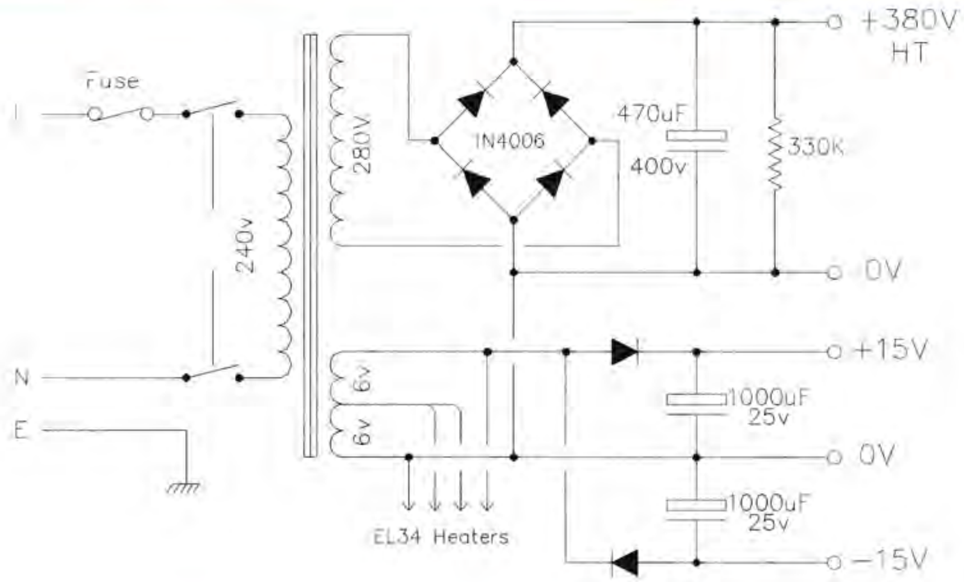


Figure 1: *Hot audio amp power supply*

are better matched if R11 has a low value compared to R2 and R5, but this pushes up the signal gain. The optimum value for matched feeds to the output valves would be zero, but at the expense of trying to achieve infinite gain.

With a value of 680Ω for R11, the input is debatably over-sensitive, requiring only a 100mV input to achieve full output, but still not avoiding a mis-matched valve drive. Although this low input level might well suit a totally passive tone control arrangement, having a basic loss of 25dB or so, it is uncomfortably low for most active pre-amps.

The modified circuit in Figure 2 has been reconfigured to provide a non-floating balanced input if required and has an input sensitivity of about 1V for full output. Each input leg has a signal impedance of 6.6kΩ to ground and the inverting input should be bridged to ground if an unbalanced pre-amp is used.

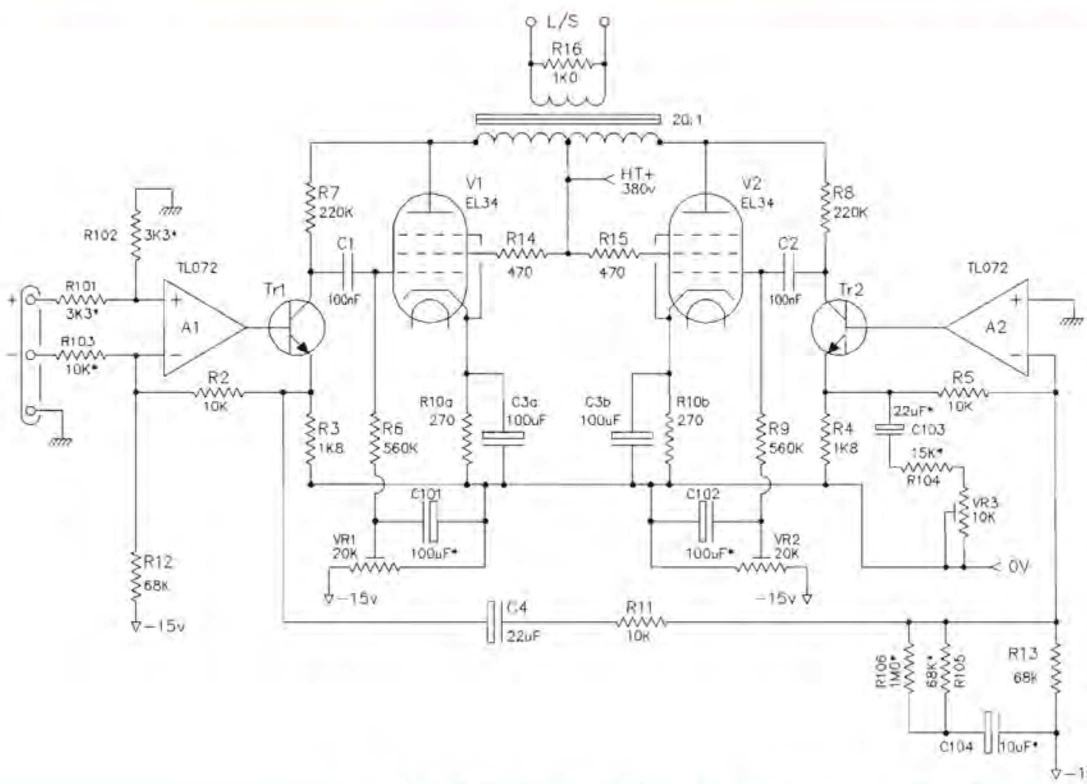


Figure 2: *32W power amp. Jeff Macaulay EW1995 modified circuit. By Peter Sullivan 2005*

This will slightly affect the optimum setting of VR3 as it alters the emitter dynamic load impedance of Tr1.

Hum/Power Supply Ripple Cancellation

One sure way to kill any 100Hz or 50Hz ripple noise from the LT & HT supply lines would be to use stabilised supplies; quite a trivial task for the 15V driver stage supplies, but rather daunting for a 300mA 380V HT feed.

The alternative is to maintain good power supply noise rejection within the circuit. It was decided that it was far easier and cheaper to achieve this goal than affront the horrors of designing a heavy duty HT stabilised supply.

On the prototype, 120mVpp ripple was measured on the 15V negative rail and about 3Vpp on the simple HT supply. DC biasing resistors R12, R13 both inject a 50Hz ripple from the simple 15V negative supply rail into the inverting inputs of the input op-amps. The original circuit had good rejection as A1 and A2 amplified the noise by the same factor (10k-68k), and the two in-phase noise components nicely cancelled out in the output transformer.

By reconfiguring the phase splitter in the modified circuit for good drive balance, the hum cancellation of the original circuit no longer applies. Despite the fact that R12 and R13 still inject similar 50Hz ripple noise into the op-amp inverting inputs, the phase inverted noise component from A1 exactly cancels out that from R13 when mixed in A2. The result is a complete loss of ripple cancellation in the output transformer and an annoying hum from the loudspeaker.

To bring silence back to the sitting room, double the amount of hum and noise must be deliberately introduced into A2 to maintain an equal in-phase component in each valve driver. This is the function of the additional 68k resistor R105. The series 10uF capacitor prevents the additional resistor upsetting the DC conditions around Tr2.

To achieve optimum cancellation, further adjustments are required than just equalising the noise voltage outputs of driver op-amp stages A1 and A2. As op-amp A1 operates in virtual earth mode for any signal injected via R12, Tr1 has a slightly lower emitter AC load and correspondingly higher current gain then A2+Tr2. For complete PSU ripple rejection, identical in-phase ripple currents at Tr1 and Tr2 collectors are required.

Additional resistor R106 injects the extra ripple noise required to balance exactly the noise currents in Tr1 and Tr2. Theoretically, its value should be 1.035MΩ, but 1.0M is practically close enough with 1% tolerance components to fit the bill. See **Appendix 2** for the details.

Output Valve Partial Cathode Bias

A single 470Ω 3W cathode bias resistor was specified in the original circuit (R10), shared between both EL34 cathodes. Using this method the 3W rating of R10 is easily exceeded if each output valve draws more then 40mA average, 40V of the effective HT supply is lost and power is wasted as heat in R10. The annoying loss of HT was particularly of concern for the modified prototype as it is located in a rural area of France were the mains supply voltage is often less then 220Vac. The original 1995 mains toroid transformer had a 240V primary, a 230V version not being available at the time, so is frequently used with a mains supply that is 10% low.

As well described by Morgan Jones in his book *"Valve Amplifiers"*, another problem with cathode bias is the tendency to cut off the bias at high output levels by the potential rise across the cathode resistor as more current is drawn. This pushes the operating point of the output pair towards and beyond pure Class B and the likelihood of severe distortion. Recovery from this overload condition is governed by the cathode resistor/capacitor time constant. With values of 470Ω and 100uF this is relatively short (0.047s) but causes gross distortion at very low frequencies as the cathode bias point is unintentionally modulated by the signal itself.

Several tube amplifier designs solve this problem by using a special adjustable negative grid bias supply for the output valves and reducing the cathode series resistor(s) to a very low value, but just sufficient to monitor the cathode currents with a switched voltmeter. Failure of the negative grid supply would rapidly risk destroying the output valves.

A split combination of grid and cathode bias will greatly reduce the problems of HT loss, heat dissipation and bias drift, but retain some auto-bias control and protection to the EL34s if something untoward happens. How can this be implemented simply?

A power output pentode like the EL34 needs its control grid kept around 25V negative with respect to its cathode for Class AB operational bias. In the modified circuit half of this is taken from the driver stage 15V negative supply and the remainder from the voltage drops across the cathode resistors (R10a and R10b). Adding pre-set pots VR1, VR2 provides a convenient means to set the output valve grid biases and trim the quiescent currents. Each EL34 is fitted with a reduced value cathode resistor of 270Ω dissipating only 0.675W at an anode current of 50mA for each valve and the bias currents are easily set by adjusting for 13.5V across each cathode resistor.

It is a good idea to leave one of each pair of grid bias pots accessible with a screwdriver when the amplifier is complete and assembled. The setting is crucial to balancing the anode standing bias currents and to cancel any 100Hz power supply ripple from appearing at the output.

The Modified Circuit Performance

Measurements made with a technical projects MJS401D analyser reveal some improvements over the original design. In all cases, measurements are taken using the unbalanced input and an 8Ω resistive test load across the output.

- Hum and noise: -68dBu rms with 20Hz-20kHz flat filter, -78dBu rms with "A" weighting filter.
- THD, at 1kHz: at 1W out 0.08%, at 10W out 0.42% (mainly second and third harmonic).
- Frequency response: relative to 10W out, -1dB down at 12Hz and 45kHz.

The original design article quoted 0.07% THD distortion at 1kHz, 20W output. It is curious to know how such a figure was obtained with the unmodified circuit. The only comparison that could be made was by taking a measurement with the 8Ω test load removed, leaving just the internal 1kΩ resistor. Under these conditions, THD figures very close to 0.07% were measured at similar output voltage levels to that when driving 20W into 8Ω (+24.3dBU).

For a given grid bias, the anode current of a pentode is mainly determined by the screen grid potential. One of the main possible sources of hum in this design is the unwanted modulation of the anode currents by the unfiltered HT ripple voltage on the screen grids, so it is expected that adding some additional pre-G2 R/C filtering would improve this point. It is also expected that using alternatively an output transformer with the screen grids connected to 43% ultralinear taps would improve the overall distortion figures, however, the author has not tested this to date.

The completed modified stereo amplifier has now been in use for well over a year and has given very satisfactory stable performance and many enjoyable hours of listening to favourite CDs. Visitors to the house often enquire to the nature of this rather bizarre piece of equipment. They all leave suitably impressed after a demonstration from an excellent piano CD recording that has fortunately preserved the stunning dynamic range of this musical instrument.

It is intended to soon finish the development of a suitable valve pre-amplifier with low (by valve standards) output impedance for use with this hybrid power amplifier.

Soon, it is also intended to document the design of an accompanying valve line pre-amplifier with low output impedance for use with this hybrid power amplifier. Initial measurements are giving 0.05% THD at +20dBm and the capability to drive over 24dBm into a 4k7 load.

Appendix 1

1.1 EL34 drive balance error of original circuit (Figure-1).

Driver stage A_1+Tr_1:

Signal voltage gain at Tr_1 emitter $= \dfrac{R_2 + R_{11} // R_{12}}{R_{11} // R_{12}} = \dfrac{10k + 680 // 68k}{680 // 68k} = 15.85$

Tr_1 emitter ac load $= R_3 // \{R_2 + R_{11}//R_{12}\} = 1k8 // \{10k + 680//68k\} = 1.540k\Omega$

Signal current gain (gm) at Tr_1 collector $= \dfrac{stagevoltagegain}{emitterload} = \dfrac{15.85}{1.540} = 10.29$ mA/V$_{in}$

Driver stage A_2+Tr_2:

Signal voltage gain at Tr_2 emitter $= \dfrac{R_5}{R_{11}} = 14.71$

Tr_2 emitter ac load impedance $= R_4//R_5 = 1k8//10K = 1.525k\Omega$

Signal current gain at Tr2 collector $= \dfrac{14.71}{1.525} = (-)\ 9.641$ mA/V$_{in}$

Drive imbalance = 9.641 ÷ 10.29. Hence 6.3% low at Tr_2

D. C. Haigh (EW letters, January 1996) came to exactly the same conclusion by a lengthier route, but the suggested new driver circuit in the letter still has very high gain. To achieve the same lower gain, the two resistors making the virtual earth point (labelled R17 & R5) between Tr1 & Tr2 emitters would need a value of 6.5kΩ rather then 100Ω.

1.2 Modified circuit EL34 drive balance (Figure-2).

Unbalanced input used, inverting input bridged to ground.

$$\text{Voltage gain at Tr}_1\text{ emitter} = \frac{R_{102}}{R_{101}+R_{102}} \times \frac{R_2+R_{103}}{R_{103}//R_{12}} = 0.5 \times \frac{10k+10k//68k}{10k//68k} = +1.074$$

Tr_1 emitter ac load impedance = $R_3 // R_{11}//\{R_2 + R_{103}//R_{12}\} = 1.410k\Omega$

$$\text{Signal current gain at Tr}_1\text{ collector} = \frac{1.074}{1.410} = 0.7611\ \text{mA/V}_{in}$$

$$\text{Voltage gain at Tr}_2\text{ emitter} = -1.074 \times \frac{R_5}{R_{11}} = -1.074 \times \frac{10k}{10k} = -1.074$$

With VR3 set to its default mid-point:
Tr_2 emitter ac load impedance = $R_4//R_5//(R_{104}+VR_3)$ = 1k8//10K//20k = 1.417kΩ

$$\text{Signal current gain at Tr2 collector} = \frac{1.074}{1.417} = (-)\ 0.7574\ \text{mA/V}_{in}$$

Drive imbalance = 0.7574 ÷ 0.7611. Hence 0.48% low at Tr_2

For zero error, VR3 should be set to 3.718kΩ so Tr_2 emitter load impedance is equal to that of Tr_1.

Appendix 2

Hum cancellation in modified circuit (Figure-2).
V^h = -15v rail ripple noise.
R_{add} = Additional hum injection resistor required for A2.

Op-amp A1 in virtual earth mode, Tr_1 emitter ac load = $R_3 // R_2 // R_{11}$ = 1.324kΩ

$$\text{Noise current at Tr}_1\text{ emitter} = -V^h \times \frac{10k}{68k \times 1.324k} = -0.1111V^h\ \text{mA}$$

For optimum noise rejection, noise current at emitter Tr_2 should equal that at Tr_1.
When VR3 is set for best drive balance, Tr_2 emitter load impedance = 1.410kΩ

$$\text{Final noise current at Tr}_2\text{ emitter} = -V^h \times \frac{10k}{R_{add} \times 1.410k} = -0.1111V^h\ \text{mA}$$

$$R_{add} = \frac{10k}{0.1111 \times 1.410k} = 63.81k\Omega$$

68kΩ in parallel with 1MΩ comes near enough (63.67k) for 1% tolerance components in a practical circuit.

Appendix 3

Extra components required for the modifications.
Resistors 1% metal film 0.6W, unless otherwise stated.

R10a, R10b changed to 270R 2W or 3W
R11 changed to 10k

R101	3k3
R102	3k3
R103	10k
R104	15k
R105	68k
R106	1M

VR1	20k cermet pre-set
VR2	20k cermet pre-set
VR3	10k cermet pre-set

Capacitors

C3a, C3b 100uF 100V
C4 changed to 22uF 25V

C101	100uF 33V
C102	100uF 33V
C103	22uF 25V
C104	10uF 33V

IMAGES IN SPACE from BAIRD to the INTERNET

In this article, Dr Barry G. Blundell outlines some of the general principles that underpin stereoscopic and volumetric systems that have led to the modern 3D displays

In the first half of the 19th century, Charles Wheatstone and David Brewster both independently developed the stereoscope (see **Figure 1**) by means of which images depicted on a surface appear to reside in three physical dimensions and, thereby, exhibit a dramatic sense of *relief*.

By the mid 1850s, these two giants of the Natural Sciences were locked in battle, with Brewster making every effort to ensure that Wheatstone would be denied all credit for the invention. In letters published in the *Times* newspaper strong words were exchanged and there can be little doubt that if they had had a greater comprehension of the importance and longevity of their discovery (which today, some 150 years later, underpins the operation of various 3D computer display systems), their discourse would have been even more acrimonious.

The Stereoscopic Approach

When we view our surroundings, the physical separation of the two eyes results in each eye being presented with a slightly different view of a scene. Differences (disparities) in these views are identified by the visual system and interpreted as providing a strong sense and appreciation of depth. This powerful cue to the relative and absolute location of objects within a three-dimensional (3D) space is known as binocular parallax.

In contrast, when we view a scene rendered on a two-dimensional (2D) tableau, such as an artist's canvas, photograph, or conventional computer screen, the eyes are presented with identical views and so binocular parallax is absent. Our sense of the 3D content of such images is, therefore, solely reliant on the presence of the various 'pictorial depth cues' discovered, derived and disseminated during the Italian Renaissance many centuries ago.

For example, in this respect artists make use of a range of cues, such as shading, occlusion and height in the visual field and place these within a perspective framework. Both Wheatstone and Brewster realised that it is possible to artificially mimic our observation of the physical world by capturing a scene from two slightly different locations, i.e. by creating a pair of 2D images – called a stereopair – and presenting them to the visual system so that each eye can only see a single view. In this way, disparities in the two views are accessible and this is used to provide a strong perception of *relief*.

Figure 1: Hand-held stereoscope – this facilitates the viewing of stereopairs

Early stereopairs were created by hand, but with the discovery and development of photographic techniques, stereophotography gained rapid popularity. The stereoscope provided a way of greatly enhancing the realism of images and gained tremendous popularity in the Victorian era as a means of augmenting the experience of the 'armchair traveller'. The military use stereophotography advantageously, not as a means of

Figure 2: *Viewing is facilitated through the use of a stereoscope – but this in not a requirement. With a little practice, the two images can be superimposed and will then demonstrate a remarkable sense of relief. In* ***(a)*** *a small tree stands in front of another. Since their textures are similar, they are not readily distinguished when depicted on a single photograph. However, when the stereopair are fused, the two trees are clearly visible. This provides a simple example of the enhanced information content associated with stereo images. In* ***(b)*** *a stereoscopic image taken using two digital cameras is reproduced. [Image (b) Mona Vale, Christchurch, New Zealand. Reproduced by permission of Robin Ramsey]*

Figure 3: *When volumetric images are photographed in a conventional way, the binocular parallax and motion parallax cues are lost, so too are the cues of accommodation and convergence. As a result, it is very difficult to produce meaningful and representative photographs of volumetric images. Here, an early image displayed on the Cathode Ray Sphere is shown as a stereo pair. As with the images shown in Figure 2, if this pair is fused, the binocular parallax cue is preserved and the simple stick figure takes on a three-dimensional form. When this photograph was taken, the animated stick figure was able to naturally run around the image space. Various current volumetric images are available from LightSpace Technologies (**www.lightspacetech.com**) and Actuality Systems (**www.actuality-systems.com**)*

enhancing realism but rather as an aid to the capture and extract of information. In this context, components within an image scene that lie one behind the other and that have similar textures can be readily distinguished (see **Figure 2a**). Furthermore both, object size and relative distances, can be more accurately gauged. **Figure 2b** provides an example of a stereopair captured using two digital cameras.

It appears that Joseph Bayer may well have been the first to consider the replacement of the photographic stereopair with two electromechanical image projection systems. This patent, number US1,876,272, filed in 1930, purports to describe a 'fog penetrating radar system' for use in aircraft.

Bayer writes: "This invention relates to new and useful improvements in a fog penetrating televisor for seeing through fog, clouds, rain and smoke...invisible infra-red rays are translated into visible light."

"This invention is designed to eliminate these hazards by allowing the pilot to see through them...Clearer images and more details are possible... when viewed by the operator through a stereoscope."

From a mechanical point of view it demonstrates great ingenuity but exhibits a number of basic flaws. The use of electronic systems for the computation of perspective views received great attention in the early 1940s in connection

Figure 4: *Baird's volumetric system. In* ***(a)*** *the side view is shown and in* ***(b)*** *the front view*

with the visualisation of radar data. This work provided the foundations of modern computer graphics. Electromechanical displays were rapidly superseded by the use of two separate cathode ray tube (CRT) displays (one for each eye). (For further details see Barry G Blundell and Adam J Schwarz's, *"Volumetric Three-Dimensional Display Systems"* and *"Creative 3D Display and Interaction Interfaces: A Trans-Disciplinary Approach"*).

Although the traditional stereoscope supports binocular parallax, it provides only a single view on a scene – the observer cannot move from side to side and see the image from a different viewpoint. In their seminal paper, Parker and Wallis describe work undertaken by the Royal Signals and Radar Establishment (RSRE, Malvern) during WWII, and refer to the use of head-tracking hardware, whereby the computational engine can determine changes in an observer's orientation and, thereby, update the image scene accordingly.

Unfortunately, it has not proved possible to get further information about the extent to which this and other display techniques mentioned in the paper were actually implemented at the RSRE.

Immersive Techniques

In the 1960s Ivan Sutherland further developed the head-tracking technique. Here, a small stereoscopic display employing two miniature CRTs, with the image depicted on each screen being visible to a single eye, formed a wearable headset and a mechanical head-tracking system enabled the host computer to monitor and respond to changes in viewing location. A user could, therefore, experience computer-processed images that contained not only the traditional depth cues that we associate with painting and conventional computer graphics, but also the powerful cue of binocular parallax.

In addition, the view would change in accordance to changes in the observer's position, called motion parallax. This approach has gradually been refined and led to the immersive virtual reality systems that received so much, but often greatly exaggerated, publicity in the 1980s and 90s. It also led to the desktop-based systems now commercially available and which commonly use ultrasonic position sensing systems.

The head-tracking approach has several weaknesses. In particular, when used for the depiction of more complex image scenes, there can be significant latency between observer motion and screen update. This can cause discomfort and detract from the usefulness of the technology. Additionally, such displays are often suitable for use by only a single observer.

The projection of stereopairs using two separate displays represents only one approach to the implementation of a stereoscopic system. A wide range of ingenious techniques have been investigated and three general classes of display are briefly summarised below.

* **Chromatically Coding:** Here, the two stereo images are displayed in a different colour or narrow band of colours. Filter glasses are worn and ensure that each eye can only see one of the two images.
* **Temporal Coding:** Alternate frames depicted on a display are directed into each of the two eyes. For example, the left eye is presented with frames 1, 3, 5, etc, and the right eye frames 2, 4, 6, etc. Various forms of glasses may be used to ensure that each eye sees only the intended frames. Since each eye receives only one half of the frames displayed on the screen, image flicker can be problematic and, so, it is necessary to use graphics hardware and a display system able to support a high refresh frequency (typically ~100Hz).
* **Spatial Coding:** The left and right views of a stereopair are simultaneously depicted on a flat screen display. The views are interleaved and an optical arrangement is used to direct each view to the appropriate eye. In more advanced systems, a number of stereopairs are simultaneously depicted, each corresponding to a particular view onto the image scene. Only one pair is visible from any particular location and this enables

support for motion parallax without the need to employ head-tracking.

However, since all views are simultaneously depicted on the screen, the total number of pixels that can comprise an individual stereopair is given by the pixel capacity of the display divided by the number of views.

Display systems based on the principle of the stereoscope are able to satisfy a range of pictorial depth cues, together with binocular and motion parallax. However, when we view a stereoscopic image, the eyes focus on the surface on which the stereopair is depicted and converge on the feature of interest.

This is contrary to our experience when viewing physical objects that are in fairly close proximity. In this case, the eyes focus on the feature of interest and their optical axes meet at this distance. In the case of a stereoscopic image, these two actions of the visual system are forced to become decoupled (referred to as accommodation/convergence breakdown) and this can cause a degree of eye strain.

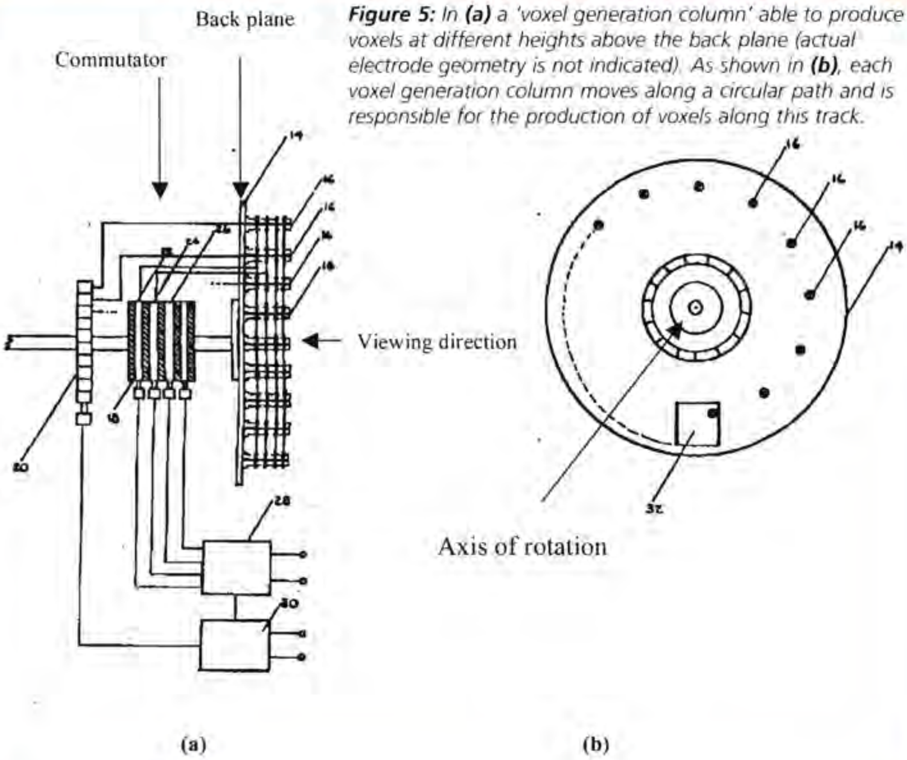


***Figure 5:** In **(a)** a 'voxel generation column' able to produce voxels at different heights above the back plane (actual electrode geometry is not indicated). As shown in **(b)**, each voxel generation column moves along a circular path and is responsible for the production of voxels along this track.*

Volumetric Displays

The basic stereoscope underpins the operation of a range of creative 3D display systems. There are also a number of other techniques that may be employed and here we turn our attention to volumetric systems. These displays enable images to be formed within a physical transparent volume and, since they may occupy three spatial dimensions, various depth cues are automatically and naturally associated with the image scene. As a result, there is little chance for depth cue conflict and this reduces the possibility of causing strain to the visual system, see **Figure 3**.

As with systems based on the stereoscopic technique, volumetric displays also have a rich and colourful history. In 1926, John Logie Baird gave the first demonstration of practical television. Within five years, he had filed a patent, number GB373,196, that described not only three volumetric displays, but also an imaging system able to capture data on the 3D shape of objects.

It is apparent that Baird was quick to appreciate that benefits could be derived from breaking away from the 2D screen, thus enabling 3D images to occupy three spatial dimensions and, thereby, automatically supporting binocular and motion parallax. One of these displays offers a simple, highly practical and cost-effective display solution.

Baird's Display

A diagram showing the general structure of Baird's display is shown in **Figure 4**. Here, a cylindrical display vessel rotates about a central axis and contains a low pressure gas (the actual vessel is not shown in the illustration). This vessel forms the image space within which 3D images may be depicted. Its front face and curved surface are transparent, so enabling the viewer to see into the volume.

All volumetric images are constructed from voxels, which is the 3D equivalent of a pixel, and Baird employed a gas discharge technique for voxel generation. Through the application of a suitable voltage between two wires that are in close proximity, a gas at an appropriate pressure may be induced to emit visible light. Baird constructed columns of light emitting elements based on this principle.

As indicated in **Figure 5a**, a central wire (k) stands out from the rear surface of the rotating cylinder (back plane), and by applying a voltage between this central electrode and one of the adjacent electrodes (L), a voxel may be formed at various heights above the back plane. Baird located such voxel generation columns at different radii from the axis of rotation and, as may be seen from **Figure 5b**, during a single rotation of the cylinder each is able to generate voxels throughout the circular track on which it moves. Had Baird not employed rotational motion, then a very large number of columns would have been needed.

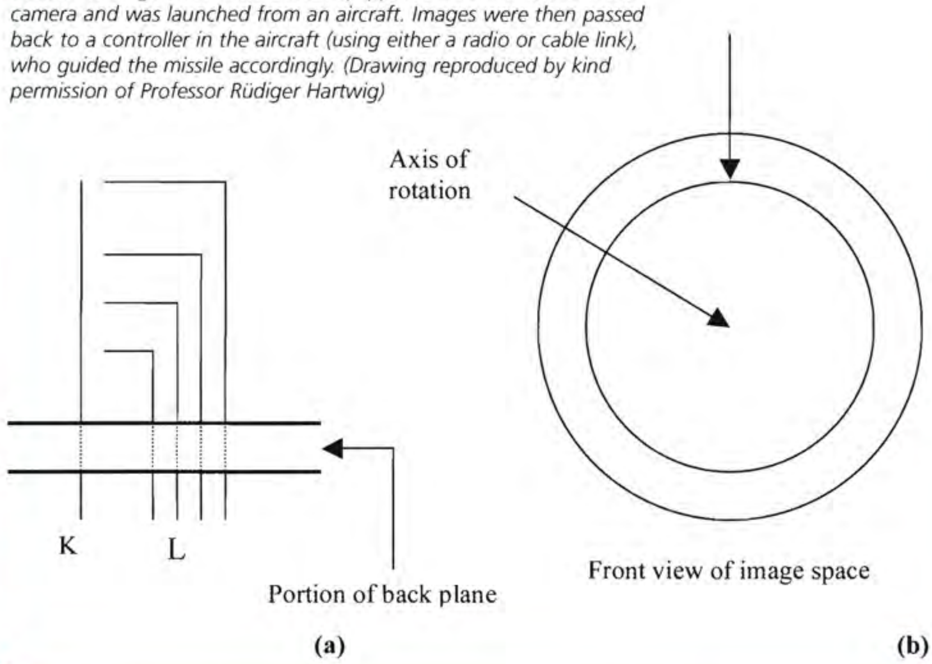
Display Performance

Any volumetric display comprises three sub-systems: voxel generation, voxel activation and image space creation. An insight into volumetric displays in general and the characteristics of Baird's simple but well thought out technology can be gained by briefly considering these three aspects of its operation:

1. Voxel Generation

Voxels are the fundamental 'particles' from which volumetric images are constructed and the voxel generation sub-system represents the underlying physical technique used to produce these visible voxels. Baird chose a simple

Figure 6: *The HS239D rocket propelled guided missile that was under development in Germany during the latter part of WWII. This provides an example of applications in which it is necessary to interact with electronic images. The missile was equipped with an on-board video camera and was launched from an aircraft. Images were then passed back to a controller in the aircraft (using either a radio or cable link), who guided the missile accordingly. (Drawing reproduced by kind permission of Professor Rüdiger Hartwig)*



but effective method – gas discharge.

The technique used for voxel generation must ensure that voxels possess a satisfactory maximum brightness, are well-defined in their extent and can be turned on and off with sufficient rapidity. The time it takes to turn a voxel on and off is particularly critical in the case of swept-volume displays in which the voxel generation mechanism is subjected to continuous cyclic motion, because if, for example, the turn-off time is unduly long, visible trails may be seen in the wake of an activated voxel.

It appears likely that the gas discharge method would be satisfactory in all these respects, although it is important to ensure that the wiring to the electrodes is constructed in a manner that avoids extraneous discharge and, hence, unwanted light emission.

2. Voxel Activation

This represents the process used to stimulate the voxel generation sub-system. In the case of Baird's display this involves the use of electrical signals. Had Baird not chosen to use rotational motion of the voxel generation elements, then a far greater number of elements would have been required and this would have increased the complexity of the display and necessitated the use of automated production technique. Furthermore, the presence of so many elements would have impacted on the transparency of the image space.

3. Image Space Creation

Baird employed the rapid rotational motion of a cylindrical volume for image space creation. To ensure flicker-free images, this volume would need to rotate at no less than 30Hz. Careful attention must be given to the transparency of the image space and to its refractive index relative to the surroundings.

As light emitted from the image traverses the image space, non-transparent elements may block its passage and so obstruct image visibility. Furthermore, should the refractive index of the image space be highly non-uniform, or should its refractive index be considerably different from that of the surrounding air, then image distortion is likely to ensue. In this case, image quality will vary with viewing direction. Boundary refraction is problematic in a number of volumetric architectures, however, in the case of Baird's display the refractive index of the image space is approximately equal to that of the surrounding air. The only refraction would, therefore, be caused by the relatively thin containing vessel. Additionally, very fine wires and electrodes can be employed and these would have little impact on image visibility.

In Baird's patent he describes the use of a multi-ring commutator for the passage of signals from the external hardware to the rotating electrodes. Today, this could be replaced with a simple parallel optical data transfer link, coupled with a conventional commutator for the passage of the necessary DC voltages.

Interestingly, Baird limited the viewing window to a rectangular region. However, this was as a result of the characteristics of the data capture hardware and the absence of processing hardware. If used with a modern graphics engine, no such restriction would be necessary.

Certainly, there are more elegant approaches to the implementation of volumetric displays, using for example digital micro-mirror technologies (see Actuality Systems's website), but without doubt Baird's approach is simple, effective and provides an extremely low-cost solution. The number of depth planes is determined by the number of electrodes incorporated into the voxel generation columns. The viewing freedom offered by this display is restricted in as much as it does not offer a 360-degree view, but, then, there are situations in which some restriction in viewing angle can actually be advantageous. A display of the type described by Baird can be mounted vertically on a wall or horizontally on a table.

Interactive Systems

Previously, we identified two situations in which stereoscopic displays, and creative 3D displays in general, are advantageous: in enhancing realism and, also, information content. Much of the work devoted to the development of 3D displays has focused on these two areas and relatively little attention has been paid to an equally important – or perhaps even more important – aspect: their ability to offer new and more intuitive interaction opportunities.

It was not until the early 1940s that we had a real need to interact with electronically processed images (see **Figure 6**). Since that time there has been an ever-increasing need to support interaction and, today, interaction forms a pivotal part of our communication with the digital world. A number of creative 3D displays have failed to reach their proper potential, simply because they have been used in conjunction with traditional interaction techniques.

A great amount of research is yet to be undertaken in terms of developing interaction tools that make better use of human capabilities. By way of example, in both medicine and computer-aided design, haptic feedback has great potential. However, to use haptic feedback effectively, it is often important to be able to bring the interaction tool, such as a pointer-based tool for example, into direct 'contact' with the displayed image.

The majority of volumetric displays proposed and developed to date have not accommodated this scenario and, so, physical interaction tools are precluded from physical image space – the image and interaction spaces are not coincident. However, a few researchers have considered optical techniques that allow the volumetric image to be projected into 'free space', so opening up many exciting opportunities for intuitive and synergistic interaction.

As mentioned earlier, the stereoscope provided enhanced realism to the armchair traveller and, thereby, gained enormous popularity. Today's Internet provides only minimal support for creative 3D display systems and the modern armchair traveller who is surfing the web must view images that include neither binocular or motion parallax. This may well have been as a result of historical considerations, when many Internet users had highly restricted bit-rate connections (e.g. the 56k modem). However, over time, connection speeds have increased dramatically and today they are well able to handle the additional bandwidth demanded by 3D displays. In fact, whilst the conventional stereoscopic approach necessitates the download of image pairs, this does not necessarily double the bandwidth requirements, since information contained in one image of a pair can be used to infer information relating to some of the content of the other.

The proliferation of creative 3D displays as computer peripherals could mark a major step forward, not only for applications such as medicine and computer-aided design, but also with regard to the advancement of the Internet. However, this necessitates the development of interface standards and data formats, together with a concerted effort to advance the human-computer interaction experience.

Research and experimentation into creative 3D displays provides exciting opportunities for the student, researcher and hobbyist. As Baird has demonstrated, the technologies needed to develop an effective 3D display need not be complex and there is great scope for experimentation.

Baird patented a further volumetric display system in 1942, patent number GB557,837. Today's researchers should not focus solely on the display itself, but should place equal emphasis on how a display is better able to support natural synergistic forms of interaction.

Just A Vision Or A Reality?

In reviewing the history of this field, I continue to be amazed by the extent of the research effort that has been carried out. Published works are often intriguing. Did Baird ever build the display that we have discussed or did it simply represent a vision? Why was Baird excluded from the war-time efforts to develop stereoscopic and volumetric displays? And in this context, to what extent were the displays described by Parker and Wallis working at the RSRE during WWII actually prototyped? Perhaps readers may be able to shed light upon some of these historical milestones.

Whilst this brief article has focused on outlining some of the general principles that underpin stereoscopic and volumetric systems, it is appropriate to mention another type of creative 3D display that is based on the principle of the varifocal mirror.

These displays employ a flexible surface that is used to create a mirror with ever-changing focal length. Image slices projected onto such a mirror appear to reside either behind the mirror or in front of it, and only a small change in mirror curvature is needed to form a satisfactory display volume.

Although considerable research was carried out in this area during the 1960s and 70s, some recent publications tend to dismiss this technology on the basis of the acoustic noise produced by the moving surface. However, this is a problem that can be readily resolved and the varifocal technique offers great scope for experimentation. It also has considerable potential as a low-cost display suitable for Internet-based applications.

THIS INVENTION RELATES TO NEW AND USEFUL IMPROVEMENTS IN A FOG PENETRATING TELEVISOR FOR SEEING THROUGH FOG, CLOUDS, RAIN AND SMOKE – INVISIBLE INFRA-RED RAYS ARE TRANSLATED INTO VISIBLE LIGHT

Whether Baird described a vision or a reality in his patents is unclear. Either way, it is appropriate that 75 years later, and in the light of modern technologies and requirements, his display should be given the chance to be put through its paces.

The author would like to hear from anybody interested in collaborating on such a project and, of course, from readers who can shed light upon the milestones of the past and so help to illuminate the future.

Powering Europe's THRUST INTO SPACE

The short development time frame for the SMART-1 project – and now the Prisma PCDU project – was one of the main challenges for the small Omnisys team, who developed the full PCDU hardware and electronics from the ground up. The efficiency and speed of the design process is greatly assisted by Altium Designer which provides a single, unified application that incorporates all the capabilities needed for complete electronic system development

AS EUROPE'S PROLIFIC SATELLITE PROGRAM MOVES TO MORE COST-EFFECTIVE SPACE MISSIONS, THE CHALLENGE OF EFFICIENTLY GENERATING, STORING AND UTILISING POWER HAS LED TO INNOVATIVE NEW DESIGN TECHNIQUES AND A REASSESSMENT OF THE COMPONENTS AND TOOLS INVOLVED. BY ROB EVANS, TECHNICAL SPECIALIST, ALTIUM LIMITED

Since the inception of unmanned space missions in the late 1950s, satellite design has evolved through the heady days of almost unlimited budgets, near decade development times and large satellites through to the cost-efficient, rapidly developed designs of today's small satellite systems. In line with modern commercial design, trends in the multi-billion dollar satellite industry are directed towards reducing cost and maximising profit, which is reflected in the designs themselves and the processes used to create them.

The name of the game is efficiency, in both system design and the development process. This has promoted smaller, more innovative designs built within short deadlines, the use of lower cost components and modules, and a new efficiency in the design processes used – an approach encapsulated by Europe's ground-breaking SMART-1 mission and new Prisma satellite program.

Launched in 2003, Europe's innovative SMART-1 space probe has successfully travelled to the Moon using an efficient solar-powered ion engine as its primary propulsion system, while acting as a test platform for new space technologies. SMART-1 is the first Small Missions for Advanced Research Technology project by the European Space Agency (ESA) to use efficient solar electric propulsion as an alternative to traditional chemical rocket systems.

The probe's ion engine has used just 60 litres of inert Xenon to gently power the craft through a series of expanding Earth obits, and ultimately to a stabilised Moon orbit in 2004. During this time SMART-1's solar-electric engine, which uses an electrostatic field to project Xenon ions at high velocity, has been activated 843 times since launch and was run for almost 5000 hours. In all, the performance and reliability of SMART-1 has been exceptional, which has led to a one year extension in mission length. After a series of final maneuvers, the probe has been left in a natural orbit determined by Moon's gravity where it will perform an extended series of surface observations and science operations. According to ESA, SMART-1 meets a natural end by crashing into the lunar surface in August 2006.

The SMART-1 project has been a very successful and valuable operation for both ESA's mission of developing Europe's space capability and for the main project contractor, the Swedish Space Corporation (SSC). SSC's project team managed and carried out the development of the sophisticated lunar probe from the ground-up in only 39 months, thanks in part to specialised contractors such as Sweden's Omnisys Instruments, which developed the system's critical Power Conditioning and Distribution Unit (PCDU). As SMART-1's solar-electric propulsion relied exclusively on power supplied by this sub-system, the performance and reliability of the PCDU was a fundamental ingredient in the mission's success.

Smart Power

SMART-1's solar electric propulsion places substantial demands on the both probe's power generation system and the sub-system used to regulate and distribute that power within the satellite. Power is provided by a large solar array with almost 2kW of initial power using highly efficient, triple-junction, solar cells and five large Li-ion batteries.

The critical task of controlling and distributing this power is handled by the PCDU system designed and produced by Omnisys. Weighing in at 12.3kg, the complex 2700W PCDU has several functions, but most importantly, it conditions and distributes power from the batteries and solar panels. This in turn means regulating the 50V bus voltage under both sunlight and eclipse modes, controlling the discharge and charge functions of batteries, switching power to platform loads and protecting all of probe's electronic subsystems from damage due to overloads and surge transients.

Within the PCDU, a power control section is responsible for the health check of the space craft controller and, in the case of malfunction, will shut down the on-board processor board in a controlled manner then reboot the redundant backup controller. During such a phase, essential information is stored within the PCDU, which also acts as a data acquisition system for critical external signals, such as antenna switch and transponder status.

The large power capability of SMART-1's solar array, combined with the weight and size restrictions on PCDU proved challenging for the Omnisys engineers, who ultimately took the unusual approach of building the system in modules assembled on a backplane. Each module consists of two compartments with each containing two circuit boards – some of which conserved space by using custom ceramic packages that have several transistors and resistors inside LCC-18 packages. The compact construction also posed heat transfer challenges, which in the airless space environment can only occur through structure contact between the high power components and the radiation surface of the satellite platform.

To achieve the required compact yet high power construction for the PCDU, Omnisys elected to base of the power conditioning circuitry on a Sequential Shifting Shunt Regulator (S3R) topology developed by ESA in the 1970s. This proven technology for space power systems essen-

The Omnisys engineers relied on Altium Designer to achieve the design efficiencies needed for the complexity and density of the advanced PRISMA PCDU system

With no chance of repairing a fault later on, space hardware has to be flawless from the beginning and underlies stringent quality control

Omnisys developed the critical Power Conditioning and Distribution Unit (PCDU) for SMART-1, the first Small Missions for Advanced Research Technology project by the European Space Agency (ESA), to use efficient solar-electric propulsion as an alternative to traditional chemical rocket systems

tially controls power from the solar arrays and batteries via multiple switched shunts, under the control of a sophisticated domain controller (DOC). The controller in turn is fed by loop error amplifiers which monitor the power system status.

Considering a fixed load on the bus by way of example, if more current is delivered by the solar panels the DOC will sequentially shunt each solar array until the system reaches equilibrium. The last shunt will regulate the power as a bang-bang regulator, which will be manifested as a saw-toothed ripple on the bus.

For the SMART-1 PCDU, Omnisys further developed this system by the inclusion of resistive shunts and a more sophisticated digital control system. Along with the relatively high currents involved, the solar array shunts also deal with the large capacitance of the arrays plus the inductance of the wiring harness, which all leads to transient pluses and ringing on the probe's main 50V supply bus. In SMART-1 the additional resistive shunts become a fault tolerant resistive dump that acts as the main regulation device in sunlight mode, which then reduces switching of the normal solar array shunts and only occurs when the load or input power changes.

One radical change in the power demands on the DOC occurs after the satellite's transition into sunlight. Prior to this event – in 'eclipse mode' – the probe operates from a ripple-free supply derived from the batteries via DC/DC converters, but when the solar arrays begin to produce power this will be directed at recharging the batteries. During charging mode, the battery load effectively regulates the supply bus until the power from the solar arrays exceeds what is needed by the probe electronics and that required by the batteries – which will reduce as they charge. At this point, the system reverts to full sunlight mode with the array shunts being progressively switched in by the DOC and fine regulation provided by the resistive shunts.

Distribution of the satellite's power is handled by the PCDU's collection of Solid State Power Controllers (SSPC), which are intelligent power switches featuring over-current protection, timed switch-off and current measurement. The PCDU hosts low power versions with current limits ranging from 1-3A and a high power version which are able to distribute 30A with a variable current limit. This high power SSPC distributes 1500W of the unit's total 2700W, which Omnisys suggests is comparable to the power used in much larger satellites.

The Next Generation

Capitalising on the success of the SMART-1 project, Omnisys has now embarked on developing the PCDU for SSC's new Prisma satellite mission. Financed in the main by the Swedish National Space Board (SNSB), together with the counterpart space boards of France and Germany, Prisma is intended to demonstrate formation flying and advanced rendezvous technologies. This satellite system consists of two spacecraft, an advanced and highly maneuverable 140kg 'main' satellite and a simplified 40kg 'target' spacecraft without maneuverability.

The two spacecraft will be launched as one in a docked position, but will ultimately separate for a series of complex rendezvous exercises. Over the mission period, the largely autonomous main craft will use its array of sensors and guidance systems to perform a series of maneuvers around the target craft, at both long and short ranges. Due to launch into a sun-synchronous orbit in 2008, Prisma will form a flying laboratory for testing advanced techno-logies and sensors for the next generation of rendezvous satellites.

From the Omnisys perspective, the Prisma PCDU differs from that of SMART-1 in two main respects – the components used and the size and capacity of the unit. Significantly, this project is being developed by SSC and, therefore, not directly governed by the ESA's rigorous rules regarding space-certified components. This means that Omnisys can use components based on experiences from other space projects where some commercial components and processes have been used.

The Prisma PCDU power and size requirements will reflect that of the craft itself, which is much smaller than SMART-1, does not require high power capabilities for solar-electric propulsion and will operate in a fixed sun-synchronous orbit that minimise the eclipse time for the craft's solar arrays. As such, there will be two PCDUs – one per craft – that offer a total capacity of around 30% of that in the SMART-1 unit. They will, however, employ the same modified S3R design as used in SMART-1, allowing Omnisys to exploit the knowledge and tools used in the past project.

As before, Omnisys is using electronics design solutions from Altium Limited for board-level and system design of the advanced PCDU system. The complexity and density of the Prisma PCDU will again place high demands on the Omnisys engineers, and they will rely on the high level of design integration provided by Altium Designer, the industry's only unified electronic product development system, to achieve the design efficiencies needed. With its advanced multi-channel features, Altium Designer allows the engineers to precisely and automatically repeat design sections with specified variations, such as the large number of SSPCs required, which differ only in component-determined current limit and trip-off time. In past projects this needed to be done in a time-consuming manual fashion that pushed tight deadlines.

The short development time frame for the SMART-1 project – and now the Prisma PCDU project – is one of the main challenges for the small Omnisys team, who develop the full PCDU hardware and electronics from the ground up. Altium Designer's version control features and advanced component library management allow Omnisys to keep the project on track, while focusing on the design and development process. The efficiency and speed of the design process is greatly assisted by the fully-integrated nature of Altium Designer, which provides a single, unified application that incorporates all the technologies and capabilities needed for complete electronic system development.

These features also allow the Omnisys engineers to develop embedded FPGA systems within the same integrated design package and seamlessly link these with the physical design process. The PCDUs main power controller uses three Actel APA-750 FPGAs in a redundant configuration to control the system and communicate with the satellite platform via a master CAN bus. The FPGAs in turn are hosting a number of Altium's TSK51 soft processor cores, which are supplied pre-verified and royalty-free with the Altium Designer system.

The Omnisys PCDU designs have placed high demands on the engineers and tools used during development of this complex space hardware, which offers unique challenges due to the hostile, isolated space environment. There is no prospect of popping open the lid to repair a fault, retrieving the unit for service, or even perform testing in a truly realistic environment – the systems have to be flawless from the beginning.

Design For Space

When compared to familiar commercial design, developing space electronics demands processes and disciplines that not only cause extraordinary hikes in project cost and complexity, but also cause vast increases in development time. Reliability in a potential environment of intense radiation and extreme temperature swings is the core challenge to the design of both hardware and software systems – however, blind over-engineering is not the solution.

When designing the SMART-1 and Prisma PCDUs, Omnisys engineers needed to consider every aspect of their systems from the basic wiring through to embedded software. Most critical systems, for example, use redundant circuitry where both analogue and digital stages perform voting on essential signals. This is typically a majority rule, two out of three voting system to ensure the PCDU systems will continue to operate correctly in the event of a sub-circuit failure. Redundant wiring is also used for all essential signals and even FPGA I/O signals are duplicated on non-adjacent device pins.

While intelligently-arranged redundancy greatly reduces the possibility of circuit failure, in the event of a fault there must also exist arrangements to prevent that event propagating through the system or surrounding circuitry. This demands systems such as separate power supply lines, independent wiring to sub-circuits and single, rather than multiple, device packaging. The isolation process must also be incorporated at the board level where in general, a track or via failure cannot disable downstream or nearby circuitry.

THERE IS NO PROSPECT OF POPPING OPEN THE LID TO REPAIR A FAULT, RETRIEVING THE UNIT FOR SERVICE, OR EVEN PERFORMING TESTING IN A TRULY REALISTIC ENVIRONMENT – THE SYSTEMS HAVE TO BE FLAWLESS FROM THE BEGINNING

From a component standpoint, the Omnisys engineers face the challenge of implementing the PCDU design while ensuring absolute reliability. Regardless of the choice of commercial grade or space-certified components, the space environment demands that engineers consider a range of factors:

- **Derating:** Voltage rating and other key component performance specifications can be derated by as much as 50%.
- **Radiation:** Space radiation can be a relatively continuous exposure on components or arrive in a strong burst. Latch-up in logic circuits is the prominent danger induced by radiation, as this will cripple the device and cause excessive power consumption. Systems in the PCDU use watchdog timers and current monitoring circuitry to sense this overload and reboot systems as required.
- **Thermal transfer:** Components in an airless space environment must transfer heat via physical contact with the satellite's structure.
- **Outgassing:** Many component materials are subject to outgassing (particularly when hot), which is undesirable in the closely-controlled satellite internals.
- **Magnetic materials:** In many cases even the slightest magnetic field can interfere with that from the Earth, which in turn has the potential to compromise critical navigation and sensor systems.

From a PCB design perspective, the space environment requires conservative approach to board design, with substantial (in commercial design terms) via and track clearances. In this instance, the boards are glass/ polyimide for high power sections and Thermount 85NT for low power areas and do not use a solder mask – this allows for detailed board inspection and to prevent outgassing. Further, surface tracks are few and reflowed with tin-lead to prevent oxidation and vias are not permitted under components for inspection reasons. After assembly, a conformal coating is applied to all boards.

Generally, testing and verification procedures for space systems are extensive. During the manufacture the engineers test boards individually in custom test set-ups to verify the basic operation and protection features that can't be tested after full assembly. After assembly a full performance test occurs to verify all parameters and redundancy of the systems.

The environmental tests on the PCDU systems are vibration, shock thermal cycling in vacuum and radiation exposure and each of these tests is followed by a repeat of the performance tests. Many of the measurements are run by automated test scripts, which significantly reduced the time involved. For example, the characteristics of the 40 SSPCs could be tested in about twenty minutes, as opposed to the four hours taken by manual testing.

This level of testing will invariably highlight and trigger fault conditions and component failures. During the SMART-1 PCDU development the Omnisys engineers uncovered significant failures in the SSPC units when undergoing vibration testing. These faults took some time to track down, but were eventually traced to transistors housed in custom-built ceramic packages, as supplied by an ESA-qualified part manufacturer.

It transpired that these hand-built components designed for high-reliability space use did not have the required glasivation to insulate the silicon die and particles from the assembly process had shorted the transistor's base-collector connections. All boards needed to be removed from the PCDU, then disassembled and all 147 transistor devices replaced. The irony of this situation was not missed by the Omnisys engineers who point out that this type of failure would not have occurred in an equivalent low-cost commercial device.

With the current Prisma project, Omnisys is more than happy to use standard components in all places where performance allows it. The use of off-the-shelf components combined with the high levels of integration across design disciplines provided by the Altium Designer electronic product development solution has enabled the Omnisys engineers to meet the tight deadlines dictated by the Prisma project. Going forward, Omnisys sees this approach fuelling greater efficiencies as they push the boundaries of space exploration.

ALTIUM DESIGNER

ALTIUM DESIGNER IS THE INDUSTRY'S ONLY ELECTRONICS PRODUCT DEVELOPMENT SYSTEM THAT REMOVES THE BARRIERS IMPOSED BY DISPARATE DESIGN FLOWS AND UNIFIES THE DIFFERENT DESIGN DISCIPLINES INVOLVED IN ELECTRONICS PRODUCT DEVELOPMENT – THE DESIGN OF THE HARDWARE, THE PROGRAMMABLE HARDWARE AND THE EMBEDDED SOFTWARE.

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Revolution in ELECTRONICS

By Chris Williams, UKDL

Have you heard? There is a revolution coming in electronics and we can all take part. It will affect every part of our daily lives: at home, at work and at play.

The revolution will be the digital printing of electronic materials as inks and pastes to form electrical circuits, which will allow each of us to create many of our own simple and complex circuits if we wanted to. Not only that, but we can invent many new circuits.

To complete the revolution the materials will be printed on to plastic film or coated papers, allowing us to have even more freedom in shaping the future of the products that we create. The emerging revolution has many shapes and forms, and will use many different materials that will be based on both organic and inorganic materials, semiconductors, dielectrics and insulators. For ease of reference, we can broadly refer to this as the Plastic Electronics revolution.

By having the freedom to print functional electronic materials, we will each be able to do the following:

- Print organic semiconductor photovoltaic cells
- Print battery cells
- Print electrical circuitry including organic semiconductors, resistors, capacitors, inductors, conductive electrical tracks and transparent electrical conductors
- Print chemical, gas and medical sensor elements
- Print electro/optic materials to form lamps, indicators and displays
- Of course, we can also still print coloured inks to form conventional text and graphics.

Think about what this will mean to us. By being able to print photovoltaic cells and batteries as part of a system design, we can create self-powered units that require no external power source – a truly "energy neutral" device. Apply that idea to the millions of electrical devices that we use in everyday life, and we can take our own steps to reduce our personal consumption of the overall power budget and reduce the need for extra power stations in the first place.

We can create new categories of simple devices to make our lives easy – how about if we print restaurant menus with printed touch switch overlays and printed text and picture areas, so we can "choose" the language we want to read the menu in, or have immediate recommendations for the wine we should drink?

Or how about if we print a chemical sensor and display element as part of a food packaging material so that the container itself "smells" when the food or drink it contains has gone off and should be disposed of? This could significantly extend the shelf life of various foodstuffs that are thrown away today, even though our personal experience may show that they are still perfectly good. We replace a rigid statistical expectation of probable "fitness for consumption" with an actual real-time measured one.

Why is this revolution happening anyway, and what is the key driver?

Every aspect of conventional electronics is wasteful and polluting: at the point of manufacture, during its use and at its eventual disposal. Almost every production process in conventional electronics, whether it be the manufacture of a printed circuit, a flat panel display, or even a silicon chip, is based on the same principle – coat a complete surface with a material, overcoat it with a photoresist material, pattern it, etch away the bits you don't want and then clean away the rest of the photoresist you don't want before you proceed to the next step.

This "coat-pattern-etch" process requires noxious chemicals and frequently involves high temperatures. Disposal of the noxious waste from these manufacturing processes has been the source of many of the contamination and pollution stories that emerge from every continent that has an indigenous electronics industry. Any process that can move industry away from the need to use the coat-pattern-etch process is beneficial and will be welcomed.

Plastic Electronics achieves this. By digitally printing the key materials, we put material only where it is needed, so waste and pollution reduces. By seeking to use plastic or paper substrates, we must use lower temperature processes that reduce overall power consumption and lower carbon emissions. By designing the substrates and functional materials correctly, we even have the opportunity to make fully bio-degradable electronic devices, or at least devices that are much easier to disassemble and recycle at end of product life.


Plastic paper newspaper concept

Here, I have often referred to 'our' involvement in making this revolution happen. This is perhaps the most enlightening aspect of the whole topic.

If you want to establish your own factory to make flat panel displays suitable for making high volumes of HDTVs, it will cost in the range of £1bn-£5bn, depending on the volume and size of panels. Spending between £0.5m and £50m will allow to make a range of the new simple printed devices in modest production volumes. But above all, if you are adventurous and want to enter into the world of printed electronics with the same pioneering spirit as the early experimenters in electronics, then you can start work on very simple devices by modifying a £60 ink-jet printer from your local computer supplier.

In the next few articles, we will explore the revolution of Plastic Electronics in more detail.

Chris Williams is Network Director at UK Displays & Lighting KTN (Knowledge Transfer Network)

SPACE WARS:

With a renewed global commitment to space exploration comes a new demand for high-performance, space-ready electronics. The battle then ensues – which technology fits the bill – ASICs or radiation-tolerant FPGAs, asks Ravi Pragasam, Senior Marketing Manager of MilAero product marketing at Actel

Traditionally, designers of high-reliability space applications, particularly those designing digital sub-systems for satellite payloads, have turned to application-specific integrated circuits (ASICs) due to their ability to integrate unique design features and deliver low-power benefits – all the while meeting stringent radiation requirements. ASICs have often been selected because they are very efficient at integrating large quantities of logic and system-critical functionality into a single chip that offers a small footprint and low power consumption.

ASIC solutions offered an extensive set of library elements that grew over time to include support for new and emerging standards and guidelines. ASICs were also chosen due to their radiation performance and immunity against Single-Event Upsets (SEUs). The satellite industry benchmark is that a linear energy transfer threshold (LET_{th}), or the rate at which a device becomes susceptible to SEUs, should exceed 37MeV-cm^2/mg, a requirement radiation-tolerant ASICs can easily meet.

Despite their capabilities, ASICs used in space applications have a very high cost of ownership. Typically, ASICs are associated with large volumes, where the high up-front costs can be absorbed over a large number of units. As process geometries continue to shrink, the mask set costs for sub-micron technologies are going to rise rapidly. Unlike high volume commercial applications, NRE costs for ASICs are amortised over a minimal number of devices because satellite programs usually consume small quantities of ICs, thereby threatening program budget overruns.

ASICs can also create significant technical and schedule risks, due to the lengthy lead times required in the fabrication and verification processes; the likelihood of multiple silicon re-spins before the final flight design is signed off and approved; required design changes after board layout; and inventory issues if requirements change. Other hidden costs of ASIC methodology include: expensive design tools, CAD support infrastructure, potential program delays or missed launch windows, and the lack of flexibility to run new functions and applications to adapt to changing operation and mission requirements.

With the emergence of high-reliability Field-Programmable Gate Arrays (FPGAs), designers began to consider the option of a more flexible solution. However, the wide use of FPGAs in space applications has historically been hindered by two factors. First, ASIC-comparable densities, I/O count and other embedded features were just not available with older FPGA families. Specifically, with space designs increasingly becoming complex system-on-chips (SoCs), system implementation with tremendous amounts of logic resources and memory available is critical and FPGAs were falling short.

Secondly, very few FPGA suppliers offered products that met the reliability standards expected of space solutions. Even for the broad spectrum of FPGA products "optimised" for space applications, SRAM-based FPGAs required modification and fortification, such as customer-initiated Triple Module Redundancy (TMR), to protect against chance of failure, which reduced effective gate counts by up to two thirds. Even still, because satellites for space missions have to endure harsh environmental conditions over the mission's lifetime, an inability to withstand constant bombardment by radiation and still perform as expected without interruption or failure is a show stopper.

Unfortunately, SRAM-based FPGAs were repeatedly proven to be susceptible to neutron-induced errors. The schemes to detect and correct these firm errors added extra complexity to the system design and significantly increased board space and bill-of-materials cost, thereby limiting the widespread deployment of SRAM-based FPGAs in mission-critical space applications.

Because no one technology is perfect for all applications, the designers of satellites faced the same issues that challenge designers in the commercial and other segments, trading off one attribute for another to find the best fit for a particular application. So, designers continued to search for a

Radiation-Tolerant FPGAs Challenge ASICs

solution that offered the features and benefits of an ASIC, and that tolerated exposure to harsh radiation and extreme environmental conditions without malfunction or system failure. In recent years, however, the evolution of FPGAs has lead to high-density, radiation-tolerant, non-volatile FPGAs with advanced features and capabilities. FPGAs also began to quickly approach ASIC performance levels and could offer designers a solution that is capable of addressing their system needs without compromising development time. And so, the space war between radiation-tolerant FPGAs and ASICs began.

Radiation-Tolerant FPGAs – A Closer Look

Radiation-tolerant FPGAs are becoming increasingly popular for many space applications for several reasons. These solutions provide the flexibility to make design changes after board layout is completed; shorter component lead times; low cost of ownership with fewer vendors to qualify; zero NRE; lower risk since the design does not have to be completed six months in advance of device delivery; design security and firm-error immunity in a single chip. Further, these non-volatile space FPGAs offer the following additional benefits: reduced weight and board space due to a decrease in the devices required; ease of implementation with no configuration components (unlike volatile SRAM-based solutions); high reliability; and availability of low- to high-density solutions.

Compared with radiation-hardened (RH) ASIC solutions, these high-density, radiation-tolerant non-volatile FPGAs will deliver cost and time-to-market advantages. RH-ASICs can deliver high gate-counts, but they require a large up-front tooling charge that, in combination with the minimal volume requirements for many of these applications, often translates into a higher total unit cost. In addition, the lead times for RH-ASICs can be long, often making them a last resort. As discussed earlier, changes to the ASIC design, whether due to a design error or a change in the specification, will require the customer to pay a portion of their engineering expenses again and may cause a schedule delay. With a programmable fabric, customers can take advantage of the flexibility to make design changes without impacting schedule and overall system cost.

Today, FPGAs are no longer relegated to mere prototyping solutions nor are they only used to implement glue logic in the non-critical design sections of the aerospace application. With the move toward SoC platforms, the FPGA industry has identified and exceeded the requirements for the library elements, such as intellectual property (IP) cores, required to design high-performance space systems, nullifying the advantage ASICs had historically. FPGA-optimised SpaceWire, 1553 (BRT and EBR) communication bus, external memory interfaces and soft processor cores like 8051, Leon-2 and Leon-3 are now readily available to implement critical functions within the system. Further, with high-speed standards, such as PCI Express and RapidIO, gaining rapid adoption in the space community, it is expected that the number of library elements supporting FPGAs will continue to grow to meet this demand.

For those applications that require high gate-counts, high-density FPGAs are now available, enabling designers to consider non-volatile FPGAs for both bus and payload applications. As an example, the RTAX-S family from Actel offers up to four million equivalent system gates and optimised feature sets to address the system-level needs of this market, such as embedded SRAM with built-in FIFO control logic, segmentable clocks, chip-wide highway routing and a wide variety of I/O standard support and carry logic.

The architecture of the non-volatile, antifuse-based RTAX-S FPGA family is designed for high performance and total logic module utilisation. The architecture is fully fractural, meaning that if one or more of the logic modules in a SuperCluster are used by a particular signal path, the other logic modules are still available for use by other paths. Unlike traditional FPGAs, the entire floor of the RTAX4000S device, for example, is covered with a grid of logic modules, with virtually no chip area lost to interconnect elements or routing. A

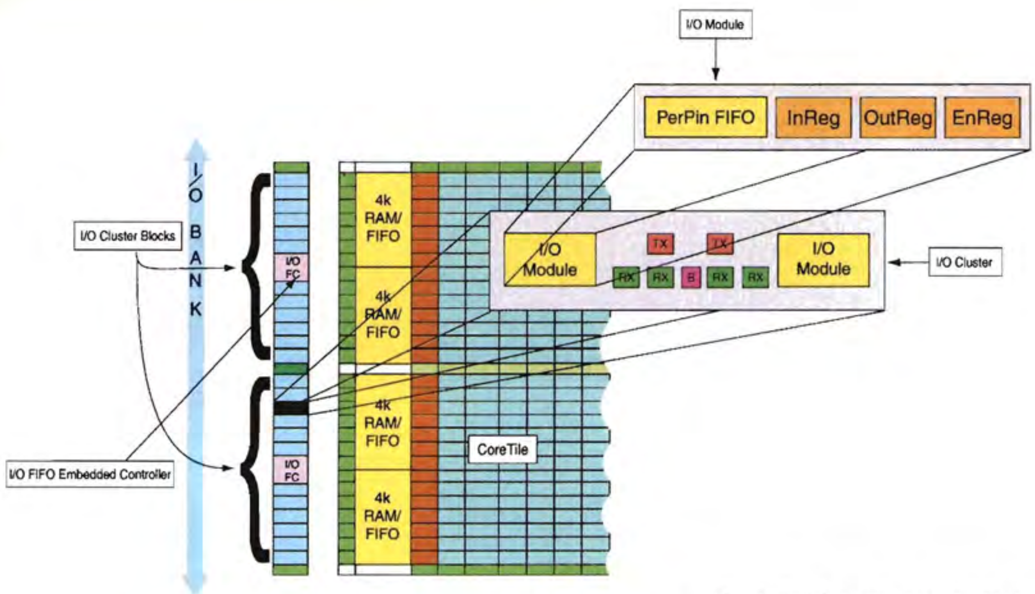


Figure 2: *I/O cluster arrangement*

patented metal-to-metal antifuse programmable interconnect element that resides between the upper two layers of metal eliminates the need to have channels of routing and interconnect resources between logic modules and enables the efficient sea-of-modules architecture.

With up to 540kbits of embedded SRAM for customer use, these devices allow designers to configure SRAM blocks in any one of the following memory configurations: 128 x 36, 256 x 18, 512 x 9, 1k x 4, 2k x 2 or 4k x 1 bits. The individual blocks have separate read and write ports that can be configured with different bit widths on each port. In addition, every SRAM block has an embedded FIFO control unit. The control unit allows the SRAM block to be configured as a synchronous FIFO without using core logic modules. The FIFO width and depth are programmable. The embedded SRAM/FIFO blocks

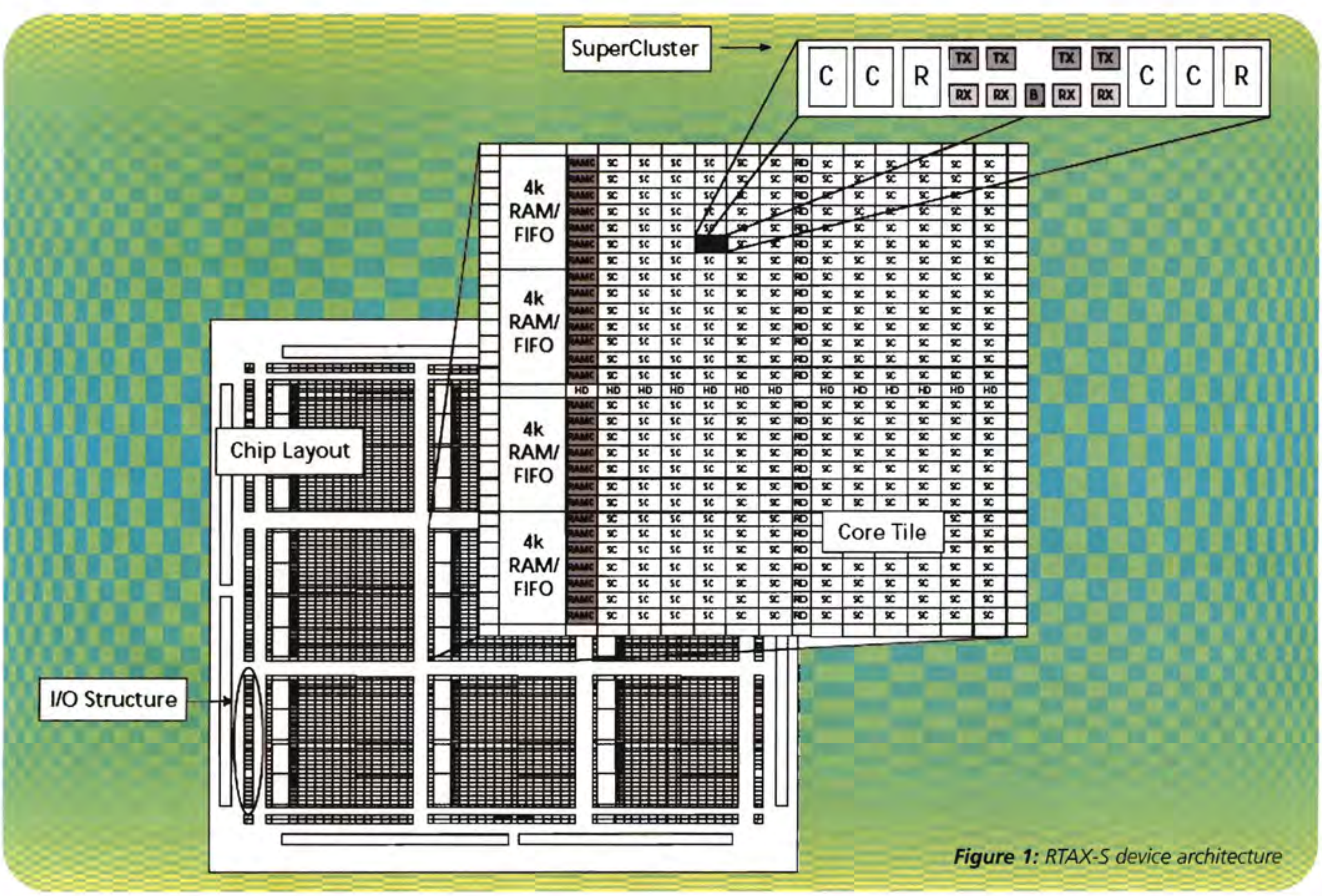


Figure 1: *RTAX-S device architecture*

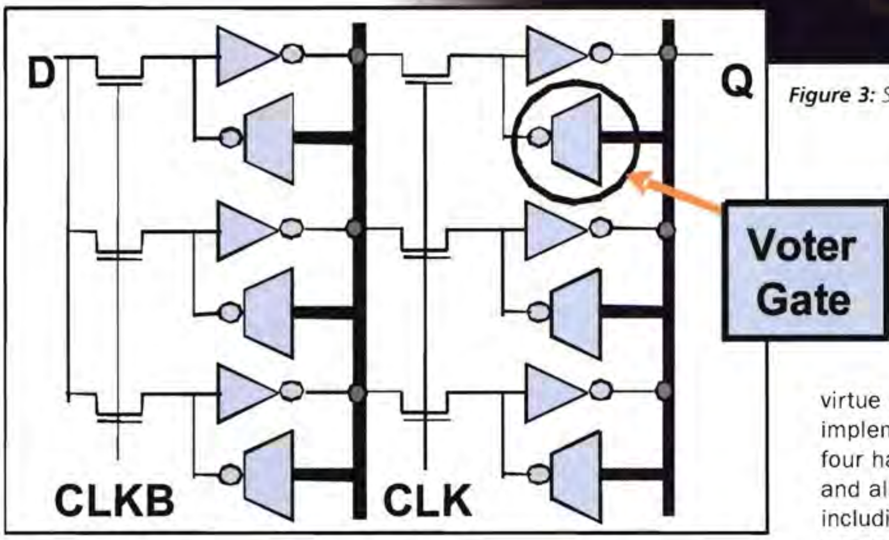


Figure 3: SEU enhanced flip-flops

can be cascaded to create larger configurations. The use of Error Detection And Correction (EDAC) IP, combined with the embedded memory scrubber circuitry, gives the RTAX-S an SEU radiation performance level of better than 10-10 errors/bit-day.

Hierarchical routing structures tie the logic modules, the embedded memory blocks and the I/O modules together. There are three local routing structures: FastConnect, DirectConnect and CarryConnect routing. DirectConnects provide the highest performance routing inside the SuperClusters by connecting a C-cell to the adjacent R-cell. FastConnects provide high performance, horizontal routing inside the SuperCluster and vertical routing to the SuperCluster immediately below it. CarryConnects are used for routing carry-logic between adjacent SuperClusters. They connect the carry-logic FCO output of one C-cell pair to the carry-logic FCI input of the C-cell pair of the SuperCluster (see **Figure 2**).

A flexible I/O structure is also available to support a range of mixed voltages with its bank-selectable I/Os: 1.5V, 1.8V, 2.5V and 3.3V. The I/Os are then organised into banks – eight banks per device (two per side). Each I/O module has an input register, an output register and an enable register. An I/O cluster includes two I/O modules, four RX modules, two TX modules and a buffer module.

Years of testing has shown that radiation-tolerant non-volatile FPGAs are immune to SEUs and their characteristics do not degrade over time due to Total Ionising Dose (TID). Unlike the soft TMR approach of SRAM-based FPGA solutions, recent generations of radiation-tolerant FPGAs have addressed this through architectural improvements, with each flip-flop implemented as a group of three with a voting circuit, resulting in no logic penalty. Hardened features also make the devices inherently immune to TID and Single-Event Effects (SEE) by virtue of their design and silicon implementation. By silicon design, all four hardwired clock (HCLK) resources and all four routed clock (CLK) resources, including clock buffers and clock lines, are resistant to SEEs. The charge pump was also enhanced for SEUs and is functional at high TID levels.

By design, all user flip-flops are immune to SEUs to a LETth greater than 60MeV-cm^2/mg, meeting industry requirements easily. These improvements have allowed space customers to achieve TID > 300Krads (Si), which compares favourably to the total dose requirement of most Mid-Earth Orbit (MEO), High-Earth Orbit (HEO) and geosynchronous (GEO) satellite programs of 100-300 Krad (Si). All told, these devices offer Single-Event Latchup (SEL) immunity to a LET_{th} >117MeV-cm^2/mg at 125°C and levels of radiation survivability far in excess of typical CMOS devices.

Rapidly Moving To Space

As with the commercial electronics design community, the space industry is moving rapidly toward faster, cheaper, smarter and more flexible satellite missions. The combination of these elements is contributing to the displacement of ASICs by high-reliability FPGAs in both the terrestrial-based and space environments. Today, FPGAs are no longer relegated to mere prototyping solutions nor are they only used to implement glue logic in the non-critical design sections of the aerospace application. Instead, non-volatile, single-chip FPGAs are beginning to rank higher on a design engineer's bill-of-material list for use in satellites and other space applications because of their reconfigurability and space-saving attributes.

Specifically, new, higher gate-count, FPGAs are finding their way into an increasing number of space satellites and more complex systems requiring high gate density and reliability, positioning them well to win the "space war".

ASAS – a project for africa

Stojce Dimov Ilcev from IS Marine Radio discusses the preliminary project for development of African Satellite Augmentation System (ASAS)

The Global Navigation Satellite Systems (GNSS) are represented by old fundamental solutions for Position, Velocity and Time (PVT) of military determination systems, such as GPS and GLONASS for the US or former-USSR requirements, respectively. The GPS or GLONASS are old GNSS infrastructures giving positions of accuracy to about 30-150 metres (horizontal and vertical) and they, therefore, suffer from certain weaknesses, which make them impossible to use as the sole means of navigation for ships, particularly for land (road and railway vehicles) and aviation applications. Augmented GNSS solutions of Global Satellite Augmentation System (GSAS) were recently developed to improve the mentioned deficiencies of current military systems and to meet the present transportation civilian requirements for high-operating Integrity, Accuracy and Availability (IAA). In fact, these new Satellite Communications, Navigation and Surveillance (CNS) systems are the European Geostationary Navigation Overlay System (EGNOS), Japanese MTSAT Satellite-based Augmentation System (MSAS) and the US Wide Area Augmentation System (WAAS).

ASAS Overview

The basic GPS and GLONASS service fails to meet the high-operating IAA requirements that are needed by many mobile users. In order to meet the requirements for better IAA of GPS or GLONASS, it is necessary to design the ASAS system over the entire African continent including the Middle East region.

In such a way, the ASAS service will improve the IAA requirements of the basic GPS signals and allows GPS to be used as a primary means of navigation for en-route travel, Precision Approach (PA) and Non-Precision Approach (NPA) for Air Traffic Control (ATC) and Air Traffic Management (ATM) in air corridors over the African continent, control of airports approachings and managing all aircraft and vehicle movements on airports surface. In the same manner, it will also serve

Figure 1: *Network configuration*

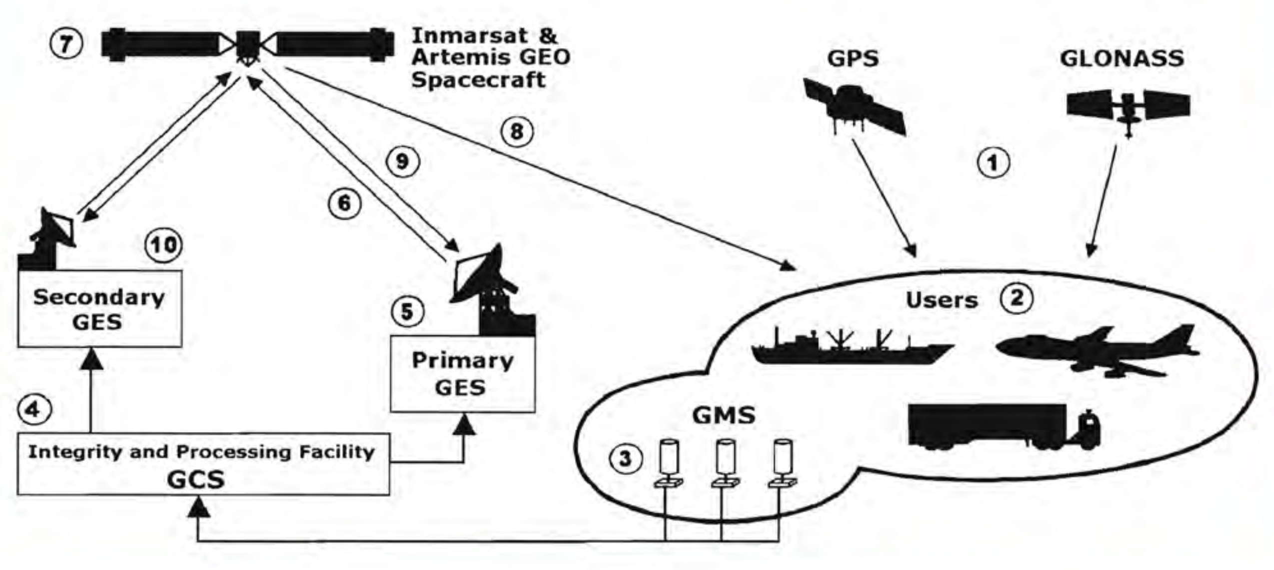
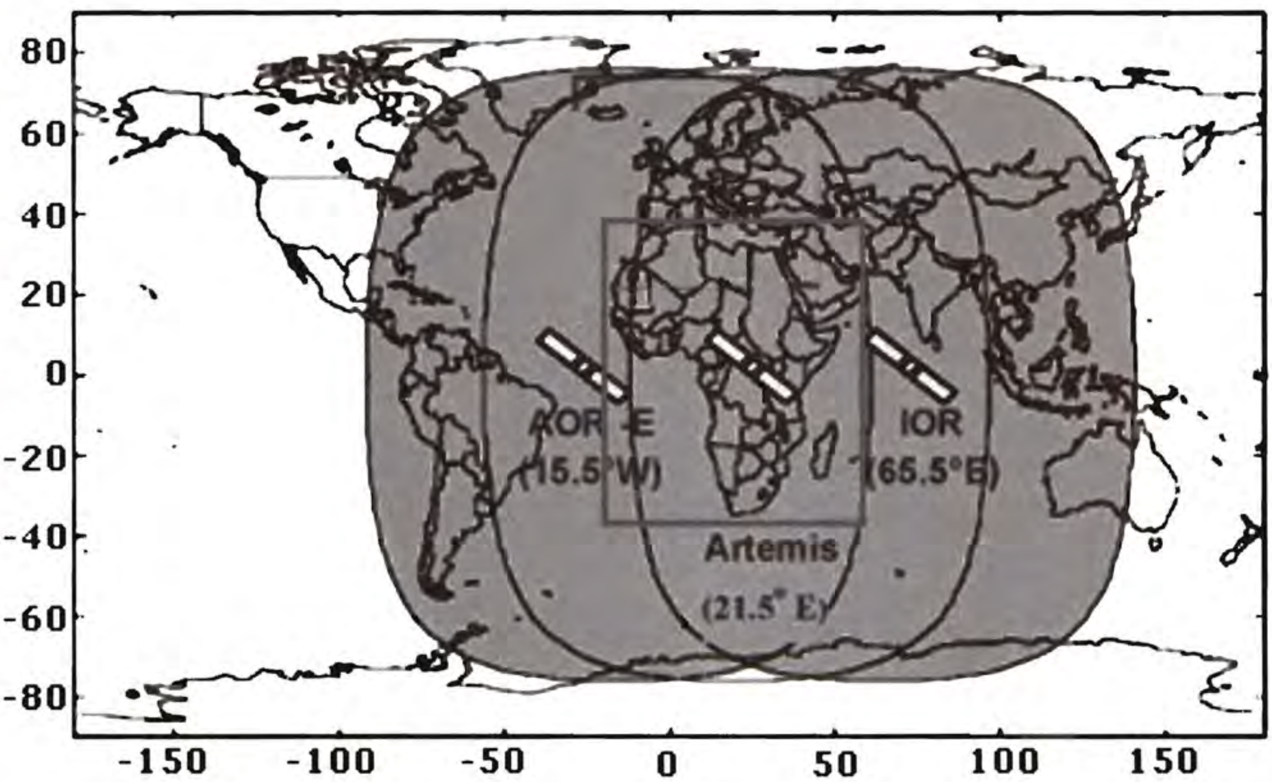


Figure 2: ASAS space segment



for Maritime Traffic Control (MTC) and Maritime Traffic Management (MTM) during course operations such as ocean crossings, navigation at open and close seas, coastal navigation, channels and passages, approachings to anchorages and harbours, and inside of seaports. Finally, it will improve Land Traffic Control (LTC) and Land Traffic Management (LTM) for land (road and railways) solutions.

First, the African Satellite Test Bed (ASTB) that includes all the parties mentioned in conclusion has to be established, then a minimum 28 ATSB GMS over the African continent and, perhaps, both existing Inmarsat GES in new uplink centre Maadi in Egypt and Jeddah in Saudi Arabia. In addition, it is possible to establish one GES in the west part of Africa, one in South Africa or to utilise service of the existing CSIR Satellite Centre with adequate NovAtel equipment for satellite uplink.

The TAB can initiate a 3-phase developmental approach to complete the ASAS network:

1. Phase 1 (2007-2010) will start with initial ASAS commissioned by 28 GMS (total number of GMS will be 44), three GCS uplinks and three GEO using GPS look-alike signal at the L1 (1575.42 MHz) GPS RF.

2. Phase 2 (2010-2014) will initiate with full ASAS service and add additional GMS, GCS and GEO birds.

3. Phase 3 (2014-2017): full constellations of GPS/GLONASS satellites with second and third RF signals, using 1227.60MHz (L2) frequency and a third civil signal at 1176.45MHz (L5) available for ASAS and LWAS.

ASAS Network Configuration

The ASAS network will be intended to provide the following services:

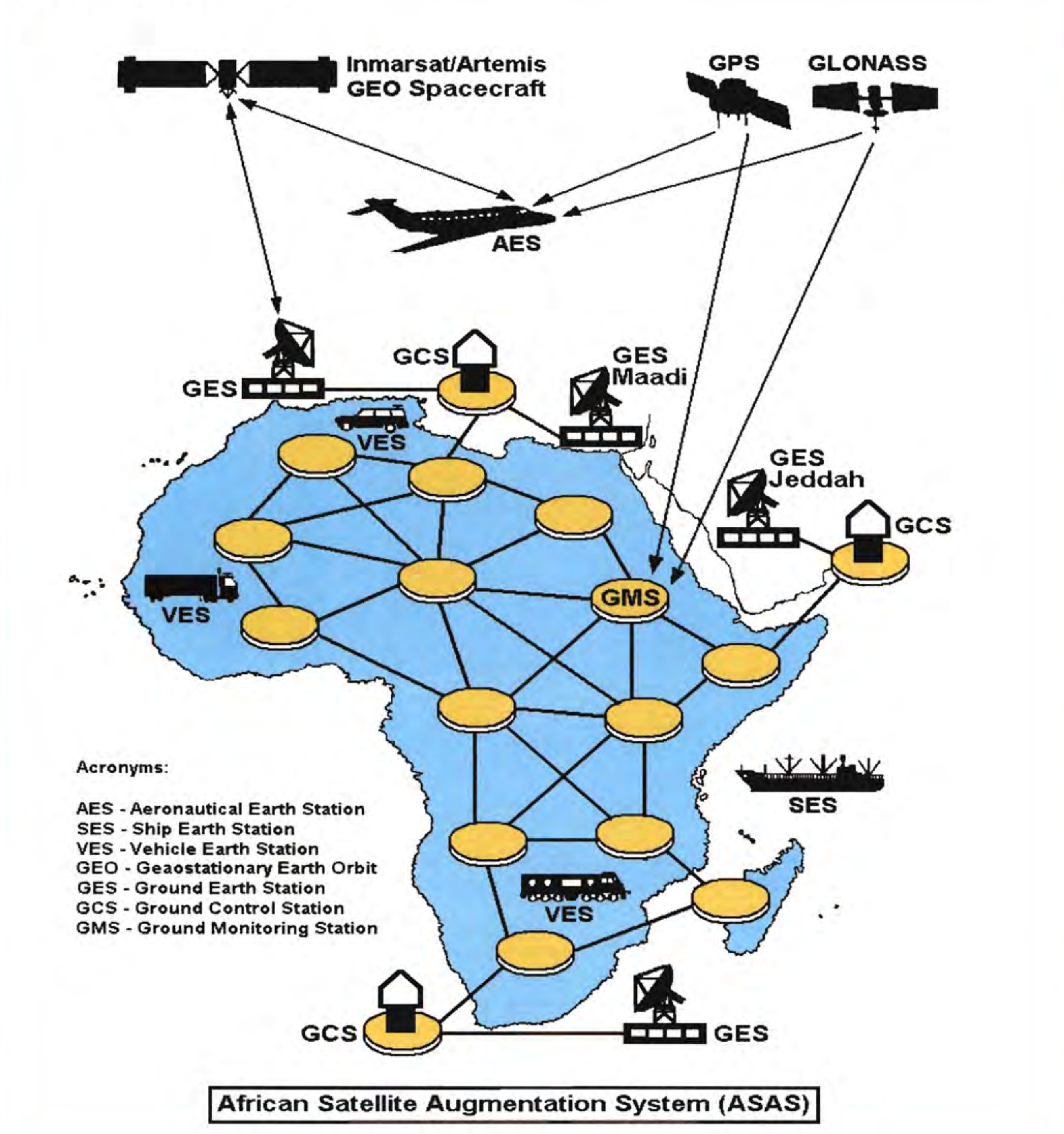
1) The transmission of integrity and health information on each GPS bird in real time to ensure all users do not use faulty satellites for navigation. This feature has been called the GNSS Integrity Channel (GIC).

2) The continuous transmission of ranging signals in addition to the GIC service, to supplement GPS, thereby increasing GPS signal availability. Thus, increased signal availability also translates into an increase in Receiver Autonomous Integrity Monitoring (RAIM) availability, which is known as Ranging GIC (RGIC).

3) The transmission of GPS wide area differential corrections has to increase the accuracy of GPS signals, in addition to the GIC and RGIC services. This service is called Wide Area Differential GNSS (WADGNSS).

The combination of the Inmarsat overlay services and Artemis spacecraft will be referred to as the ASAS network illustrated in **Figure 1**. As observed in this figure all mobile users (2) receive navigation signals (1) transmitted from GPS and GLONASS satellites.

Figure 3: ASAS space and ground segment



These signals are also received by all reference GMS terminals of integrity monitoring networks (3) operated by governmental agencies in many countries of the African continent. The monitored data are sent to a regional Integrity and Processing Facility of GCS (4), where the data is processed to form the integrity and WADGNSS correction messages, which are then forwarded to the GES (5). At the GES, the spread spectrum navigation signal is precisely synchronised to a reference time and modulated with the GIC message data and WADGNSS corrections. This composite signal is transmitted to a satellite on the C-band uplink (6). On board the Inmarsat or Artemis spacecraft (7), the navigation signal is frequency-translated to the mobile user on L1 and new L5 (8) and to the C-band (9), which is used for maintaining the navigation signal timing loop.

The timing of the signal is done in a very precise manner in order that the signal will appear as though it was generated on board the satellite as a GPS ranging signal. At any rate, the secondary GES (10) functions as a hot standby in the event of failure at the primary GES.

ASAS Space Segment

The ASAS Space Segment can be designed by using own project of GEO satellite constellation, what is more expensive solution, or by leasing existing GEO Inmarsat-3 and/or Artemis spacecraft (see **Figure 2**). The operational system can use three GEO satellites: Inmarsat-3 IOR at position 64°E and ESA ARTEMIS at 21.5°E over equator.

In the future, it will be possible to integrate new satellite systems in ASAS network such as already mentioned Inmarsat-4 space configuration and forthcoming Galileo GNSS-2 system.

The navigation payloads on these GEO spacecraft are essentially bent-pipe transponders, so that a data message uploaded to a satellite is broadcast to all users in the GEO broadcast area of the satellite over entire African continent (see **Figure 3**).

The ASAS system can use service of existing Geostationary Ranging Station (GRS), implementing a wide triangular observation base for ranging purposes with the stations in Aussaguel (France), Kourou (French Guiana) and Hartebeeshoeck (South Africa).

In general, navigation payloads of GEO spacecraft for augmentation systems must fulfill two key roles:

1) Transmission of a spread-spectrum timing and ranging signal on one or two navigation L-band RF;

2) Relay in near-real-time of data originated on the ground and for use in user Rx to improve performance (reliability, accuracy) with GPS and GLONASS signals.

ASAS Ground Segment

The ASAS service will correct GPS or GLONASS signals from the 24 or 21 orbiting satellites, respectively, which can be in error because of satellite orbit and clock drift or signal delays caused by the atmosphere and ionosphere, or can also be disrupted by jamming.

The ASAS network, shown in Figure 3, can be based on minimum 44 GMS covering all countries on the African continent and 13 countries in the Middle East, which will monitor GPS data. In such a manner, signals from GPS are received and processed at 44 GMS, which are distributed throughout the African territory and the Middle East region linked to form the ASAS network.

Each of this precisely surveyed monitoring reference station receives GPS signals and determines if any errors exist, while minimum two GCS collect data from these GMS reference terminals assess signal validity, compute all corrections and create the ASAS correction message. Data from the GMS are forwarded to the GCS, which process the data to determine the differential corrections and bounds on the residual errors for each monitored satellite and for each Ionospheric Grid Points (IGP).

The bounds on the residual errors are used to establish the integrity of the ranging signals. Hence, the corrections and integrity information from the GCS are then sent to each GES and unlinked along with the GPS navigation message to the GEO communication satellite. The GEO downlinks this data to the users via the current GPS L1 frequency with GPS type modulation.

Therefore, the message is broadcasting on the same frequency as GPS to user receivers that are within the broadcast coverage area of the entire ASAS network. In fact, these three GEO communications satellites also act as an additional navigation constellation, providing supplemental signals for position determination. Each satellite covers a part of the hemisphere, except for both Polar regions. The user receiver, installed aboard a boat, ships, land vehicles or aircraft, combines the GPS signals with the ASAS message to arrive at a more accurate position.

Otherwise, each ASAS ground-based station or subsystem configuration of GMS and GCS communicates via the terrestrial landline TCS infrastructure or will use adequate satellite network.

Benefits Of The ASAS Network

The current radios and traffic control are based on 1960s' technology. In fact, there is no radar coverage over the ocean areas, so ship captains and aircraft pilots must report their positions verbally by voice or have them automatically sent through a relay station. For the controller, surveillance equipment – primarily radar – detects the position of the many moving ships, vehicles and aircraft in the traffic coverage area.

New tools, like satellite surveillance, have been developed as part of GSAS combined with surface radars; to help the ground controllers move more vessels, aircraft and land vehicles safely through the transportation augmentation system. In the proper manner, this additional navigational accuracy, now available on the ship's bridge and aircraft cockpit, will be used for other system enhancements and for surface control in area of ports and airports. This is the Automatic Dependent Surveillance System (ADSS), currently being evaluated and which is taking advantage of this improved accuracy of traffic control for all mobile applications.

Using this chain, the new GSAS ASAS network system and navigational message will improve the GPS or GLONASS signal accuracy from about 30-100 metres to approximately 3-7 metres. For example, the current US WAAS system provides 1-2 metres horizontal accuracy and 2-3 metres vertical accuracy throughout the contiguous US territory.

Unfortunately, to receive an ASAS or any GSAS GNSS signal, an ordinary GPS or GLONASS receiver must be capable of receiving and decoding ASAS signals. In some cases, the GPS-based receiver may be upgraded by using a special software modification or hardware adapters. Therefore, the ASAS system will improve CNS facilities for maritime, land and aeronautical applications to enhance mobile communication facilities in any phase of vehicle travelling, to enable better control of fleet, provide flexible and economic trip with optimum routes, to enhance surface guidance and control in sea or air port and to improve safety and security.

Just the top 20 world ships registers have about 40,000 units under their national flags. Above all, the biggest problem today is that merchant ships and their crews are targets of the types of crime traditionally associated with the maritime industries, such as piracy, robbery and, recently, a target for terrorist attacks.

Thus, IMO and flag states will have a vital role in developing International Ship and Port Security (ISPS).

The best way to implement ISPS is to design an Approaching and Port Control System (APCS) by special code augmentation satellite CNS, including tracking and monitoring of all vehicle circulation in and out of the seaport area. The land road and railway vehicles using ASAS will get better CNS, asset tracking, monitoring, logistics and management service between dispatchers and their fleet, including satellite signalisation for trains and traffic control on the railways.

The new CNS project will provide better regulation and minimise traffic jams on the roads and to help drivers to find easier their itinerary and destination. The world's commercial airways fleet is expected to double in the next 20 years. This will result in crowded routes leading to fuel wastage and delays, which could cost millions of dollars annually. The potential benefits will assist ATC to cope with increased traffic, as well as improving safety and reducing the infrastructures needed on the ground.

The problem of hijacking can be solved similarly as a piracy, robbery and terrorist attacks on ships developed by IMO. Namely, ICAO has to implement International Aircraft and Airport Security (IAAS) system and design an Approaching and Airport Control System (AACS) by special code augmentation satellite CNS, including tracking and monitoring of all vehicle circulation in and out of the airport area.

The problem of improvement of safety and security of flying and movement control on the airport surface is necessary to develop by ICAO new Global Aeronautical Distress and Safety System (GADSS).

In general, the development of new ASAS network will enable more economic, efecient, optimal and secure transportation communications, tracking, monitoring, control and management operations for the following applied GNSS solutions:

- Maritme (shipborne navigation and surveillance, seafloor maping and seismic surveying);
- Land (vehicleborne navigation, transit, tracking and surveillance, transportation steering and cranes); aeronautical (airborne navigation and surveillance and mapping);
- Agricultural (forestry, farming and machine control and monitoring);
- Industrial, mining and civil engineering;
- Structural deformations monitoring;
- Metoerological, cadastral and seismic surveying;
- Government and military determination and surveillance (police, intelligence services, firefighting); etc.

Forward Steps

The ASAS pilot project is the first step for the development of an independent African Satellite CNS system, with own ground network and leased space segment, which preliminary pilot project is already introduced in the South African "PositionIT" of July/August 2005.

The next step is to form Augmentation Standards Service (ASS), to establish Transport Augmentation Board (TAB) and to start with the first phase of the ASAS project. The TAB team will be responsible for providing the leadership role in coordinating the operational implementation of existing and emerging satellite CNS technologies into the African continent and Middle East region.

There are two solutions: first is to build own ASAS network with NovAtel reference products and, second, to integrate the Alcatel project with South African ATNS (Air Traffic and Navigation Service) in the new ASAS network.

PROJECT CHRONOLOGY

- **In May 2006, the Minister of South African (RSA) Department of Transport (DOT), Jeff Radebe, nominated his General Manager, Riad Khan, to discuss the project with Prof Ilcev and the establishment of TAB.**
- **On 20 May 2006 in Midrand they concluded that, at first, they have to meet people from NovAtel, supplier of reference equipment for a ground network, and to determine the most convenient prime contractors.**
- **On 25 August 2006, Khan and Prof Ilcev had a meeting with Rick Blighton of NovAtel to discuss the possibility of building together a similar ground network as the USA WAAS and with similar service as European EGNOS. Otherwise, in the near future, TAB has to chose one of the two above-mentioned solutions for the establishment of the ASAS network, to contact governments of Comesa, SADAC and other countries in the region, to nominate prime contractors and, finally, to find investors of the project.**

IS Marine Radio is likely to be sub-prime contractor as an initiator and designer of the ASAS project.

A Novel Current-Mode OTA-C Universal Filter

Here, we present a novel current-mode biquad circuit. It uses two single output, one multiple output Operational Transconductance Amplifiers (OTAs) and two grounded capacitors, and can realise lowpass, highpass, bandpass, notch, lowpass notch, highpass notch and allpass responses from the same topology. The parameters ω_o and ω_o / Q_o enjoy independent electronic tunability. Simulation results are included.

At present there is a growing interest in designing current-mode OTA based filters. This is attributed to their higher frequency capability, greater linearity, wider dynamic range, structural simplicity, electronic tenability and monolithic integratability. Thus, a number of circuit realisations for universal current-mode active filters using OTAs and grounded capacitors, widely known as OTA-C filters, were proposed.

Careful inspection of available literature on the subject shows that none of the available realisations can realise all the standard filter transfer functions: lowpass, highpass, bandpass, notch, lowpass notch, highpass notch and allpass responses from the same topology, while using only few number of OTAs. It is the major intention of this paper to present such a generalised current mode circuit using the three OTAs.

Proposed Circuit

The proposed circuit is shown in **Figure 1**. Routine analysis yields the transfer functions given by:

$$I_{out} = \frac{g_{m2}}{g_{m4}} \frac{N(s)}{D(s)} \quad (1)$$

where:

$$N(s) = s^2((g_{m3}V_{in3} + I_{in3}) - sg_{m3}(g_{m5}V_{in2} - g_{m6}V_{in4} + I_{in2})/C_1 + \frac{g_{m3}g_{m5}}{C_1C_2}(g_{m1}V_{in1} + I_{in1}) \quad (2)$$

and:

$$D(s) = s^2 + s\frac{g_{m3}g_{m6}}{g_{m4}C_1} + \frac{g_{m1}g_{m3}g_{m5}}{g_{m4}C_1C_2} \quad (3)$$

Equation 1 shows that the following current-mode responses can be obtained:

a. a non-inverted HPF with $I_{in1} = I_{in2} = 0$
b. a non-inverting LPF with $I_{in2} = I_{in3} = 0$
c. an inverting BPF with $I_{in1} = I_{in3} = 0$
d. a NF with $I_{in2} = 0$ and $I_{in1} = I_{in3}$
e. in case d above, a lowpass-notch and a highpass-notch can be obtained by adjusting the transconductances g_{m3} and g_{m4}
f. an APF with $I_{in1} = I_{in2} = I_{in3}$, and $g_{m1} = g_{m4} = g_{m6}$

Equation 3 shows that in all cases the paramete ω_o^2 and ω_o / Q_o are given by:

$$\omega_o^2 = \frac{g_{m1}g_{m3}g_{m5}}{g_{m4}C_1C_2} \quad (4)$$

and

$$\frac{\omega_o}{Q_o} = \frac{g_{m3}g_{m6}}{g_{m4}C_1} \quad (5)$$

Thus the parameter ω_o^2 can be controlled by adjusting the transconductances g_{m1} and/or g_{m5} without disturbing the parameters ω_o / Q_o. The parameter ω_o / Q_o can be controlled by adjusting transconductance g_{m6} without disturbing the parameter ω_o^2. Also, from **Equations 1** and **2** it shows that the gain associated with any transfer function can be controlled, without disturbing the parameters ω_o^2 and ω_o / Q_o by adjusting g_{m2} and/or g_{m7} for output voltage, or by adjusting the transconductance for output current. Thus, the proposed circuit enjoys the attractive feature of independent electronic tunability of the transfer gain and the parameters ω_o^2 and ω_o / Q_o.

Using **Equations 4** and **5** it is easy to show that all the passive sensitivities of the parameters ω_o^2 and ω_o / Q_o are less than unity. Thus, the circuit parameters enjoy low passive sensitivities.

Simulation Results

The proposed circuit was simulated using PSPICE circuit simulation program. The OTAs were modelled using the model reported by J. Wu in "*Current-mode high-order OTA-C filters*" in the International Journal of Electronics, Vol. 76, 1994, pp.1115-1120. The results obtained from current-mode realisations with:

$$C_1 = C_2 = 1nF, g_{m2} = g_{m3} = g_{m4} = g_{m5} = g_{m6} = 1.0mA/V, g_{m1} = 0.1mA/V$$

are shown in **Figures 2** to **5**. These figures show also calculations made using Equation 1. It appears that the simulated and calculated results are in fairly good agreement.

While the simulation results confirm the theory presented in this paper, the discrepancies between the calculated and simulated results are attributed to the simplified model used in the analysis.

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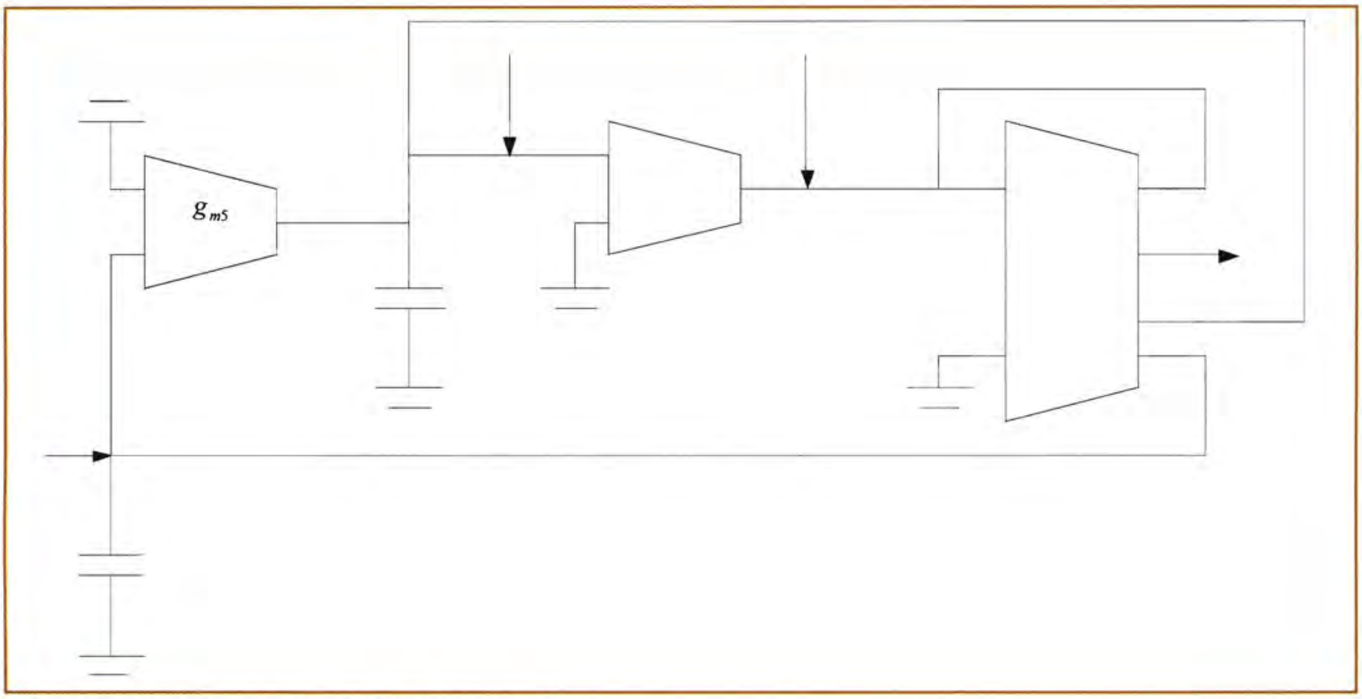

Figure 1: *Proposed current-mode OTA-based universal filter*

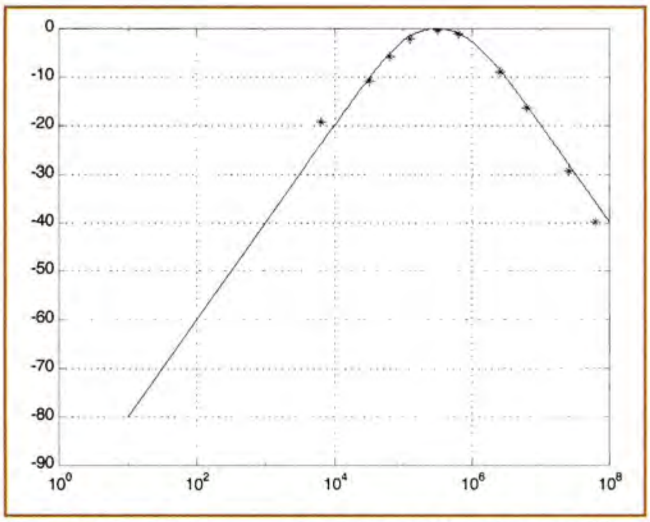

Figure 2: *Calculated (______) and simulated (**) bandpass filte*

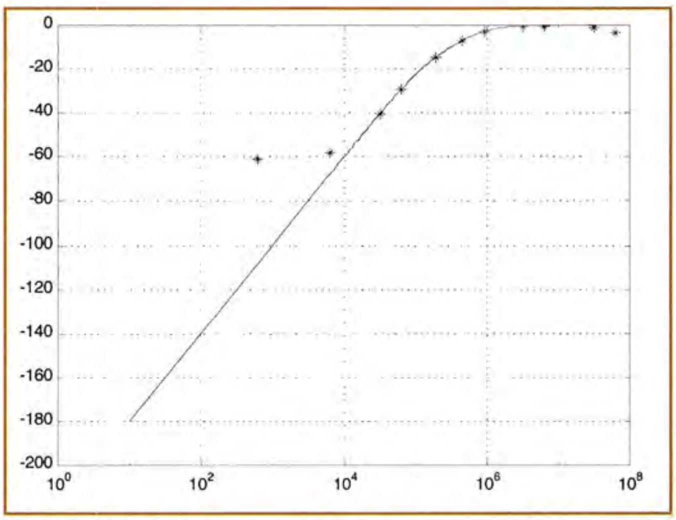

Figure 3: *Calculated (______) and simulated (**) highpass filter*

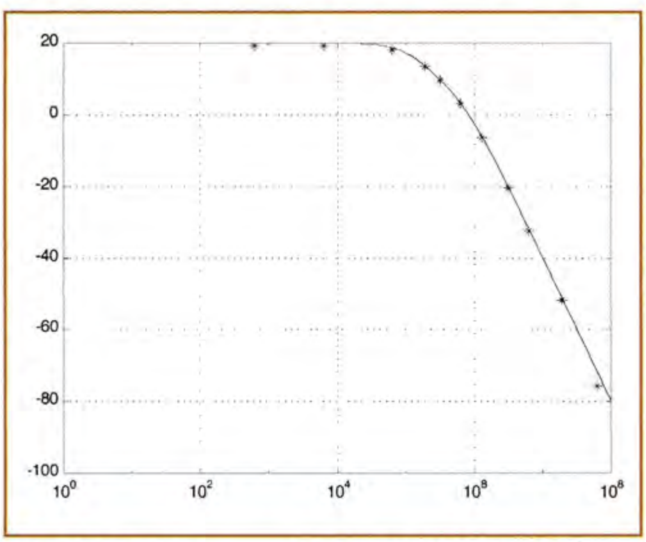

Figure 4: *Calculated (______) and simulated (**) lowpass filter*

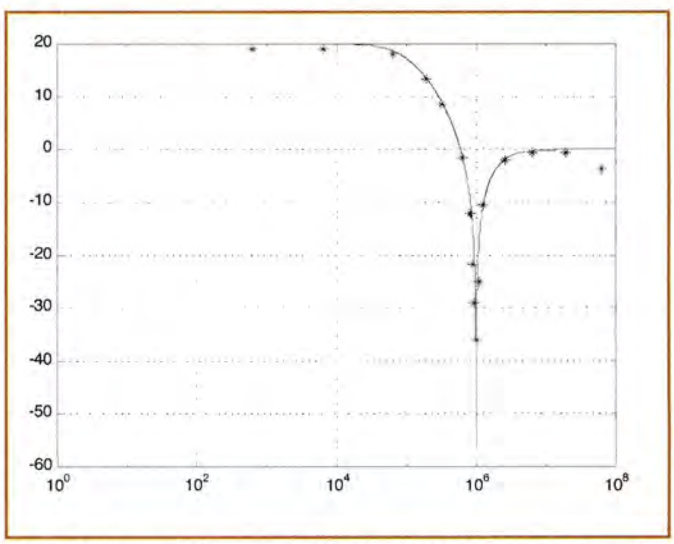

Figure 5: *Calculated (______) and simulated (**) lowpass notch filter*

A 150W A/B Amplifier

I come from a country that has diverse audio systems from the very cheap and shoddy to the very expensive and pleasing. All these systems sound different; some have poor bass response while others have very good bass response; some leave you with a good feeling while others leave your ears painful and uncomfortable. While I appreciate that manufacturing has a major impact on the resultant product, I also appreciate the role played by circuit topology and design. As a result, I have experimented with many amplifier circuit designs, trying to find out why some designs leave your ears feeling nasty and why others are okay.

The other point is: have you ever noticed the LEDs on any audio device flicker when the system is driven hard, meaning that there is voltage variation on the supply rail either due to high current drain or as a result of the supply capacitors not responding fast enough? In many amplifiers designers have tried to eliminate the effect of this phenomenon on the voltage gain stage of the amplifier using various methods, while others have simply ignored it. Some manufacturers, for example Sanyo in its STK series of amplifiers, minimise the effect of supply rail variation during heavy loading by using a 100Ω resistor and 100μF in the power supply between the current gain stage and the voltage gain stage. They are applying this in conjunction with a Darlington output stage, which minimises the effect on the signal from supply rail variations. Others have used a cascode in the voltage gain stage of the amplifier.

The Amplifier

There are many classes of amplifiers now: the analogue classes A, B, C; the more efficient digital classes D and H; and other classes. Analogue amplifiers are easier to construct and test than digital amplifiers and, as a result, small-scale equipment limited amplifier design favours analogue. The resulting amplifier shown in **Figure 1** is a result of careful solution formulation to address the various challenges encountered in A/B amplifier design.

Input Stage

The input stage is composed of a differencial/long tailed pair (that provides good DC linearity), composed of Q1 and Q2, and the current source provided by Q4 and Q3. Significance of the current source formed by Q3 and Q4 is that supply rail variations at the emitter of Q4 will be fed back and eliminated by the use of Q3. C13 protects the input from DC coupling. C2 provides high frequency feedback to limit high frequency gain. The suggested current source current is 2mA.

The suggested values and types for components in the input stage are:

C13: 2.2μF	R7: 680Ω
R28: 1K	Q3: BC546
R29: 33K	Q4: BC556
C12: 470pF	R6: 330Ω
R3: 1K	C3: 100μF
R27: 22K	R8: 1.5K
R5: 3.9K	C2: 2.2pF
Q1: BC546	R25: 33K
Q2: BC556	

Voltage Gain Stage

The voltage gain stage is a cascode stage composed of Q5 and Q6. The significance of this stage is that the supply rail variation presented at the emitter of Q5 is also presented at the base of Q6, thus overcoming the interference caused by supply rail variation. C4 provides high frequency feedback to limit high frequency gain.

The suggested values and types for components in the voltage gain stage are:

C4: 100pF	D7: 1N4148
Q5: BD140 (by choice)	D8: 1N4148
Q6: BD140 (by choice)	R9: 47K

Output Bias Stage

The output bias stage is composed of an amplified diode. C5 couples AC signal across the bias transistor. Q7 should be mounted on the heat sink so as to undergo the same thermal environment as the output transistors to safe guard against thermal runaway. The suggested values and types for components in the bias and bootstrap stage are:

R10: 2.7K	R12: 3.3K
R11: 1K	R26: 3.3K
Q7: BD139 (by choice)	C9: 220μF
C5: 47μF	

Output Stage

The output stage is composed of an emitter follower in Darlington configuration with protection diodes across the output to protect the output devices from over voltages. The benefit of such a stage is that it displays good immunity to supply rail variations. The output has a high frequency limiting network composed of C8, R20, R22 and L1.

The suggested values and types for components in the output stage are:

C8: 100pF	R17, R2: 150Ω
R20: 10Ω	C1: 22pF
R22: 4.7Ω	Q11: MJE340
L1: 2μH	Q14: MJE350
D5, D6: 1N4007	Q12, Q13: MJ15024
R19, R16, R15, R18: 0.27Ω	Q15, Q16: MJ15025

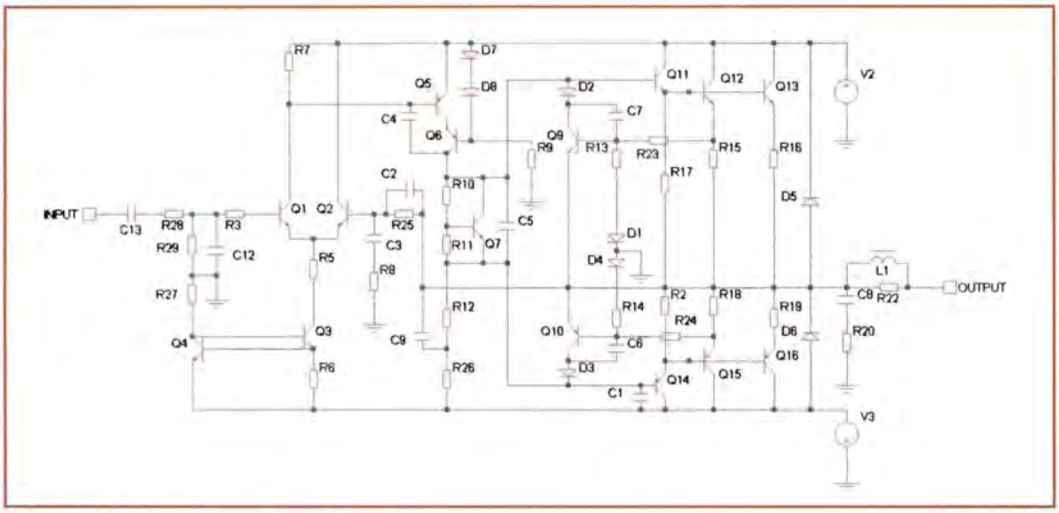

Figure 1

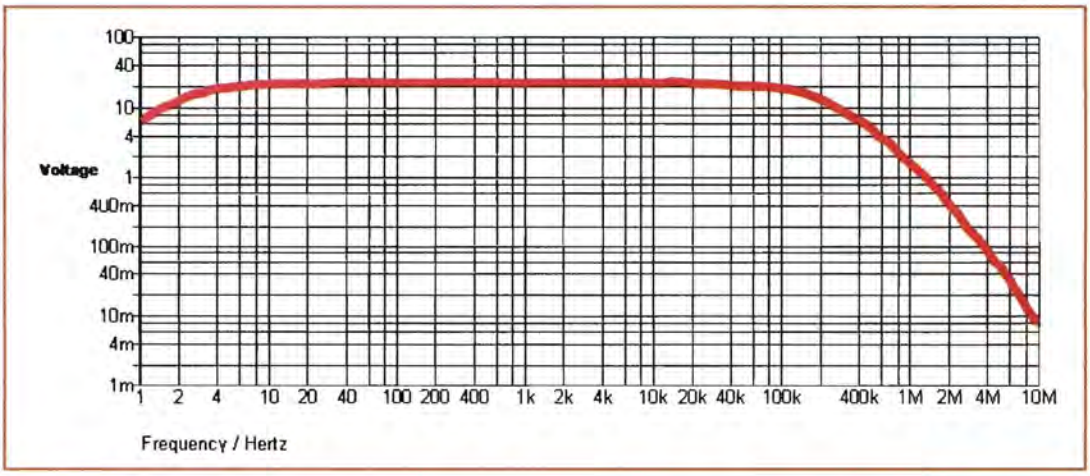

Figure 2

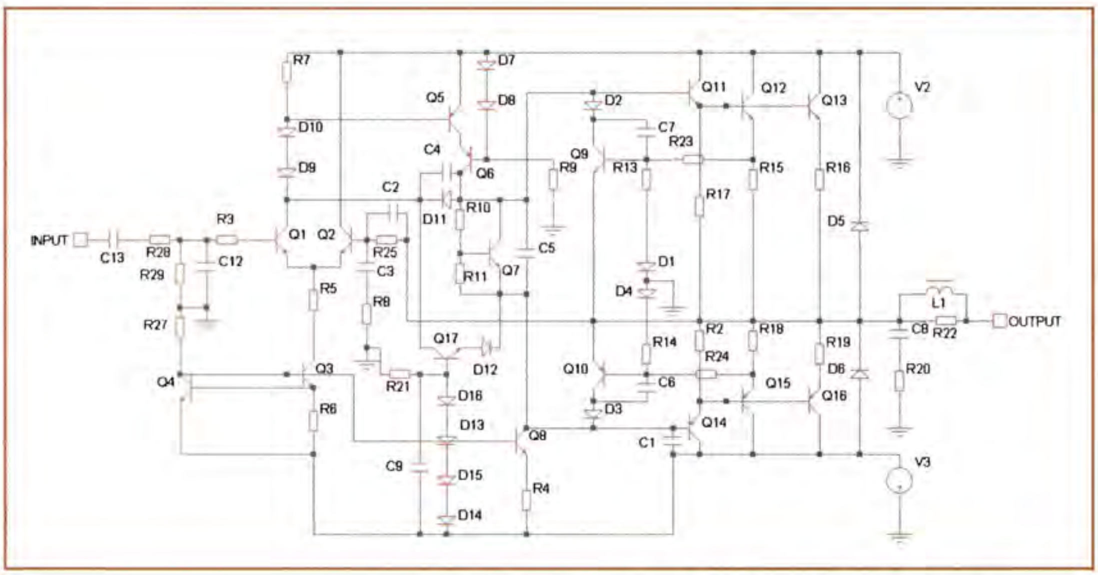

Figure 3

Output current limiting

The output current limiting is provided by the components D2, C7, R13, R23, D1, Q9 and Q10, D3, C6, R14, R24, D4. C7 and C6 provide high frequency feedback to Q9 and Q10 respectively. The suggested values and types for components in the output current limiting stage are:

D2: 1N4148
C7: 22nF
R13: 5.6K
R23: 220Ω
D1: 1N4148
Q9: BC546
Q10: BC556
D3: 1N4148
C6: 22nF
R14: 5.6K
R24: 220Ω
D4: 1N4148
Suggested supply rail voltage V2, V3: +/- 50V

The simulation software used was SIMetrix Intro 5.1
Some derived measurements:

- Transient distortion: 0.2%
- Frequency response: -3dB low pass 150kHz, -3dB high pass 2.5Hz (the frequency response curve is shown in Figure 2)
- DC offset < 90mV

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Letters

Done before

With regard to the November cover article in Electronics World magazine on Class-XD in "*A New Kind of Power Amplifier*" by Douglas Self (p20), I published this principle as 'class half-A' last year in the February issue 2005 of Electronics World magazine (please see below).
There are no patents on it, however.

"Hot debate

*With audio power amplifier distortion mechanisms currently hotly debated, I would like to add to it by proposing an audible distortion reducing mechanism I call **'class half-A'**.*

The idea is to trade some large signal power handling in return for the elimination of small signal crossover distortion. With a class AB power output stage, up to 25% of the stage's maximum power output may usefully be turned to partially bias the AB output stage as a small signal class-A amplifier. Crossover distortion may thereby be removed from the dynamic range of small signals.

*With a typical audio amplifier design, an output pull-down is a simple way to achieve this effect. **A pull-down resistor tied between the output node and the negative supply rail is the crudest approach, but a constant current pull-down gives more usable class-A power.** The pull-down current should be designed not to steal too much power when the output stage is giving its full pull-up voltage. For the more adventurous, it may be possible to adjust an amplifier's feedback to achieve a similar effect."*

Allan Campbell, UK

8-pin FLASH PICmicro Microcontrollers

Microchip's PIC12F/16F of devices with on-chip voltage comparators merge all the advantages of the PICmicro MCU architecture and the flexibility of Flash program memory with the mixed signal nature of a voltage comparator. Together they form a low-cost hybrid digital/analogue building block. The following series of Tips 'n' Tricks can be applied to a variety of applications to help make the most of discrete voltage comparators or microcontrollers with on-chip voltage comparators.

TIP 1: LOW BATTERY DETECTION

When monitoring an external sensor, it is often convenient to be able to determine when the signal has moved outside a pre-established safe operating range of values or window of operation. This windowing provides the circuit with an alarm when the signal moves above or below safety limits, ignoring minor fluctuations inside the safe operating range.

To implement a window comparator, two voltage comparators and three resistors are required (see **Figure 1**).

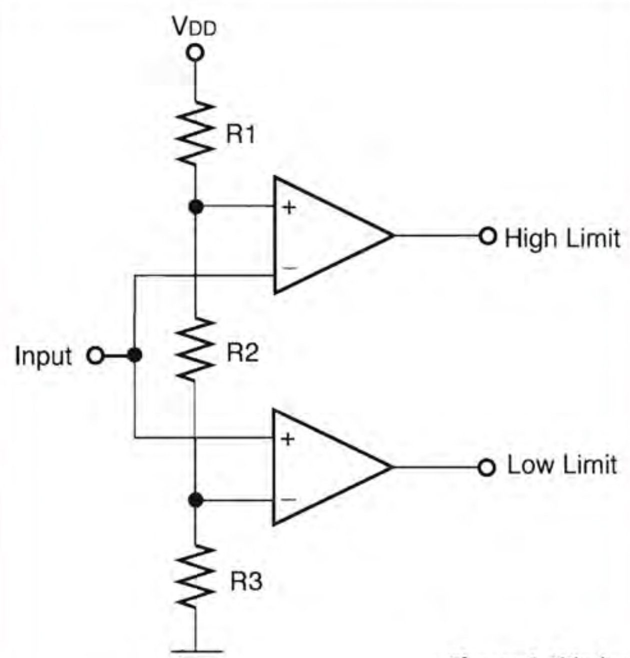

Figure 1: *Window comparator*

Resistors R1, R2 and R3 form a voltage divider, which generates the high and low threshold voltages. The outputs HIGH LIMIT and LOW LIMIT are both active high, generating a logic one on the HIGH LIMIT output when the input voltage rises above the high threshold, and a logic one on the LOW LIMIT output when the input voltage falls below the low threshold.

To calculate values for R1, R2 and R3, find values that satisfy **Equation 1** and **Equation 2** (see below).

Note: A continuous current will flow through R1, R2 and R3. To limit the power dissipation in the resistors, the total resistance of R1, R2 and R3 should be at least 1k. The total resistance of R1, R2 and R3 should also be kept less than 1MΩ to prevent offset voltages due to the input bias currents of the comparator.

$$V_{TH\text{-}HI} = \frac{V_{DD} * (R_3 + R_2)}{R1 + R2 + R3} \qquad (1)$$

$$V_{TH\text{-}LO} = \frac{V_{DD} * R_3}{R1 + R2 + R3} \qquad (2)$$

Example:

- VDD = 5.0V, VTH = 2.5V, VTL = 2.0V
- R1 = 12k, R2 = 2.7k, R3 = 10k
- VTH (actual) = 2.57V, VTL (actual) = 2.02V

Adding hysteresis:

To add hysteresis to the HIGH LIMIT comparator, follow the procedure outlined in TIP #3 from last month's edition. Use the series combination of R2 and R3 as the resistor R2 in TIP #3 from last month's issue.

To add hysteresis to the LOW LIMIT comparator, choose a suitable value for Req, 1k to 10kΩ, and place it between the circuit input and the non-inverting input of the LOW LIMIT comparator. Then calculate the needed feedback resistor using **Equation 3** and **Equation 4**.

$$D_R = \frac{(V_{TH} - V_{TL})}{V_{DD}} \qquad (3)$$

$$R3 = R_{EQ}\ [(\frac{1}{D_R}) - 1] \qquad (4)$$

TiP 2: DATA SLICER

In both wired and wireless data transmission, the data signal may be subject to DC offset shifts due to temperature shifts, ground currents or other factors in the system. When this happens, using a simple level comparison to recover the data is not possible because the DC offset may exceed the peak-to-peak amplitude of the signal. The circuit typically used to recover the signal in this situation is a data slicer.

The data slicer shown in **Figure 2** operates by comparing the incoming signal with a sliding reference derived from the average DC value of the incoming signal. The DC average value is found using a simple RC low-pass filter (R1 and C1). The corner frequency of the RC filter should be high enough to ignore the shifts in the DC level, while low enough to pass the data being transferred.

Resistors R2 and R3 are optional. They provide a slight bias to the reference, either high or low, to give a preference to the state of the output when no data is being received. R2 will bias the output low and R3 will bias the output high. Only one resistor should be used at a time and its value should be at least 50 to 100 times larger than R1.

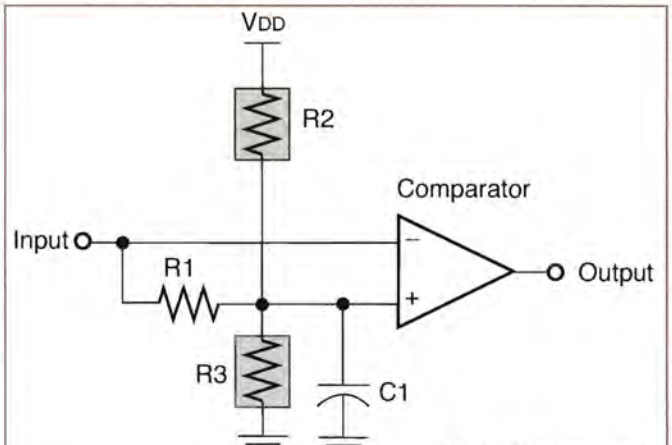

***Figure 2:** Data slicer*

Example:
Data rate of 10kbit/s. A low-pass filter frequency of 500Hz: R1 = 10k, C1 = 33µF. R2 or R3 should be 500k to 1MB.

TiP 3: ONE-SHOT

When dealing with short duration signals or glitches, it is often convenient to stretch out the event using a mono-stable, multivibrator or one-shot. Whenever the input pulses, the one-shot fires, holding its output for a preset period of time. This stretches the short trigger input into a long output, which the microcontroller can capture.

The circuit is designed with two feedback paths around a comparator. The first is a positive hysteresis feedback, which sets a two level threshold, VHI and VLO, based on the state of the comparator output. The second feedback path is an RC time circuit.

The one-shot circuit presented in **Figure 3** is triggered by a low-high transition on its input and generates a high output pulse. Using the component values from the example, the circuit's operation is as follows.

Prior to triggering, C1 will have charged to a voltage slightly above 0.7V due to resistor R2 and D1 (R1 << R2 and will have only a minimal effect on the voltage). The comparator output will be low, holding the non-inverting input slightly below 0.7V due to the hysteresis feedback through R3, R4 and R5 (the hysteresis lower limit is designed to be less than 0.7V). With the non-inverting input held low, C2 will charge up to the difference between the circuit input and the voltage present at the non-inverting input.

When the circuit input is pulsed high, the voltage present at the non-inverting input is pulled above 0.7V, due to the charge in C2. This causes the output of the comparator to go high, the hysteresis voltage at the non-inverting input goes to the high threshold voltage and C1 begins charging through R2.

When the voltage across C1 exceeds the high threshold voltage, the output of the comparator goes low, C1 is discharged to just above the 0.7V limit, the non-inverting input is pulled below 0.7V and the circuit is reset for the next pulse input, waiting for the next trigger input.

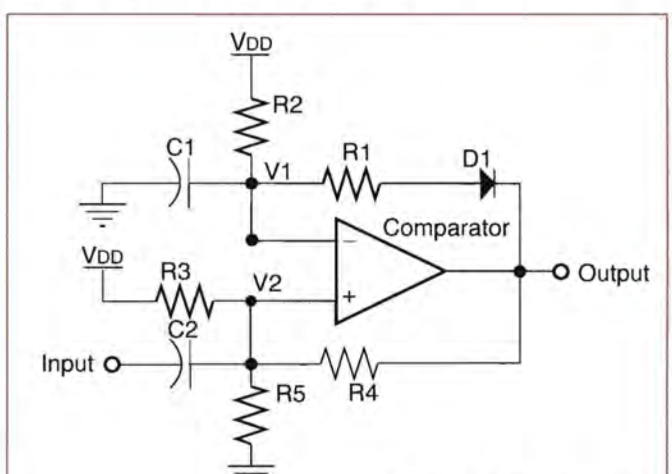

***Figure 3:** One-shot circuit*

To design the one-shot, first create the hysteresis feedback using the techniques from TIP #3 from last month's edition. Remember to set the low threshold below 0.7V. Next, choose values for R2 and C1 using **Equation 5**.

$$T_{PULSE} = \frac{R2 * C1 * \ln(V_{TH}/V_{TL})}{4} \qquad (5)$$

D1 can be any low voltage switching diode. R1 should be 1% to 2% of R2 and C2 should be between 100 and 220pF.

Example:

- VDD = 5V, VTH = 3.0V, VTL = 2.5V
- From TIP #3, R4 = 1k, R5 = 1.5k and R3 = 12k
- TPULSE = IMS, C1 = .1µF and R2 = 15k
- D1 is a 1N4148, R1 = 220Ω and C2 = 150pF

Win a Microchip PICDEM.net Lite Internet/Ethernet Demonstration Board

Electronics World is offering its readers the chance to win a Microchip PICDEM.net Lite Demo Board and MPLAB ICD 2 Debugger.

The PICDEM.net Lite demonstration board is an Internet/Ethernet demonstration board using the PIC18F452 microcontroller and TCP/IP firmware. The board supports any 40-pin DIP device that conforms to the standard pin-out used by the PIC16F877 or PIC18F452.

The PICDEM.net board is used to experiment with Microchip's various TCP/IP solutions. The user has immediate network access after the initial set up of the IP address. The Flash microcontroller allows modifications to the demonstration program to add application software.

The breadboard area includes a regulated 5V power supply for the addition of sensors or custom circuits for testing. Other standard or custom stack control software can be loaded for evaluation.

The board now uses the free Microchip TCP/IP stack, which is available in Application Note AN833 (DS00833). Please refer to this document for code samples.

The Microchip TCP/IP stack is a suite of programs that can either provide services to standard TCP/IP-based applications (HTTP server, Mail Client, etc) or be used in a custom TCP/IP-based application. Potential users do not need to know all of the intricacies of the TCP/IP specifications to use it, and those interested only in the accompanying HTTP server application need not have specific knowledge of TCP/IP.

The TCP/IP stack is implemented in a modular fashion, with all of its services creating highly abstracted layers, each layer accessing services from one or more layers directly below it. The stack is written in the C programming language, intended for both Microchip C18 and HI-TECH PICC 18 compilers, and is designed to run on Microchip's PIC18 family of microcontrollers only.

Although, this particular implementation is specifically targeted to run on Microchip's PICDEM.net Internet/ Ethernet demo board, it can be easily retargeted to any hardware equipped with a PIC18 microcontroller. The PICDEM.net supports Ethernet and RS-232 interfaces. With a standard web browser such as Microsoft Explorer, HTML web pages generated by the PICmicro MCU can be viewed. The initial board configuration is performed via the RS-232 port using a standard terminal program to configure the IP, Ethernet, addresses etc for the board. The demo board is also equipped with a 6-pin modular connector to interface directly with the MPLAB ICD 2 In-Circuit Debugger. With MPLAB ICD 2, the developer can now modify or re-program the onboard Flash-based PICmicro device to meet the specific needs.

A generous breadboarding area is also available to add special circuits for experimentation. The area is large enough to add an embedded modem to provide for dial-up capability. Several status indicators and user interface devices are provided, including a 16 x 2 LCD indicator and LEDs.

For the chance to win a these development kits, please log onto **www.microchip-comp.com/ew-picdem**

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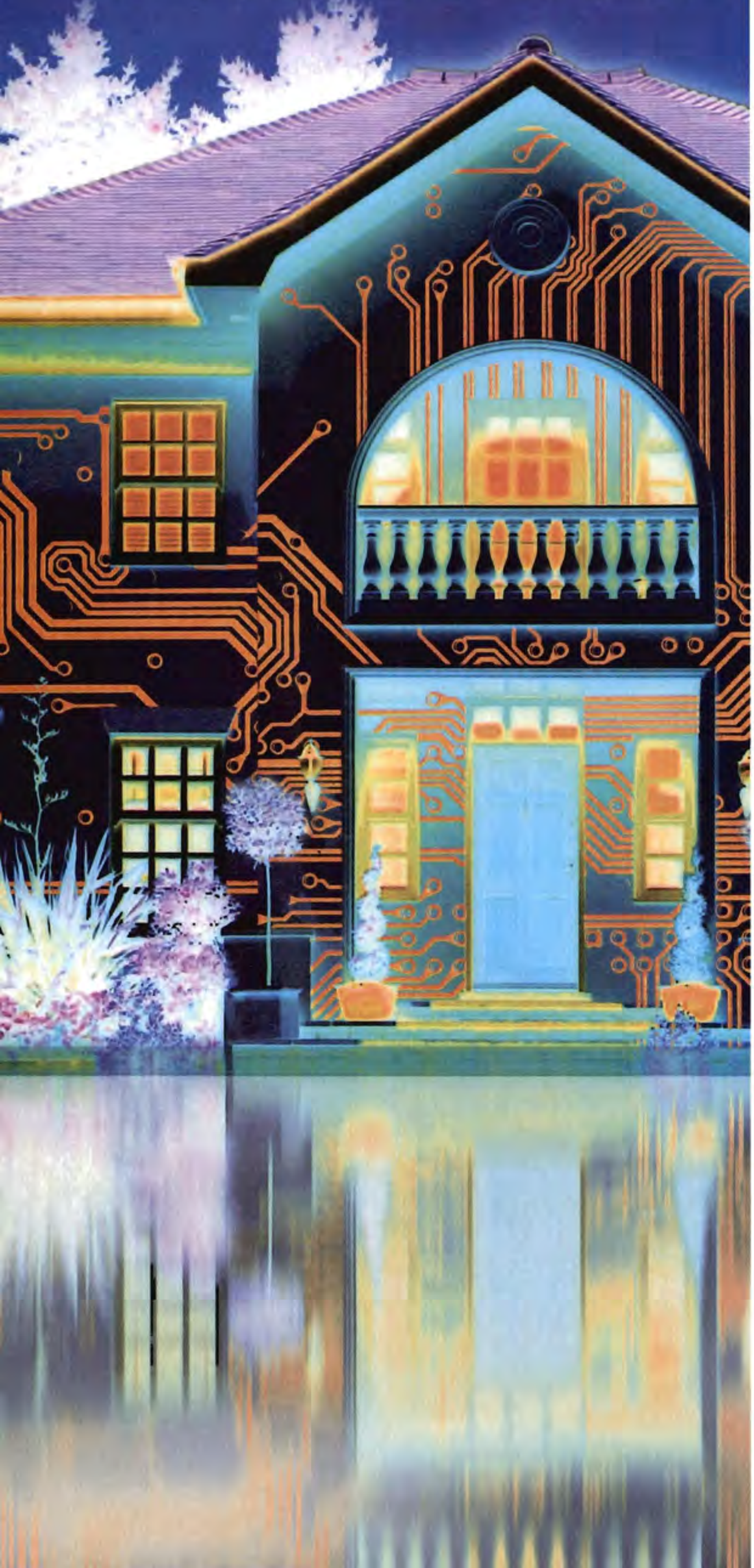

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Book Review

Automotive Electrics, Automotive Electronics
Robert Bosch Gmbh

This book is now at the 4th edition. Building over a long-standing tradition of authoritative, well informed and in-depth technical content, this new edition adds a lot of material about electronics and the application of electronic devices (in the form of microprocessors and sensors) to the contemporary car.

This reflects a trend of ever increasing adoption of electronic "intelligence" in the design of a car, both for management of core functions (engine, transmission, brakes) and entertainment/passenger convenience function. Citing from the book, in a typical car today, about 20% of its value is comprised of electronic equipment.

Overall, I can suggest this book to every engineer involved with electronics and electrics in cars, both as a designer of cars or a designer of components, systems or appliances intended to be used on board a contemporary car

The book is published in the context of the "*Automotive Technology*" series of reference works. As such, it is intended as a tool for everybody involved with car electrics and electronics, both as designers of overall systems and designers of individual components. It can be used as a handy reference work by the seasoned engineer or also as a support for everyone who wants to study and understand the basics of car electrical systems.

The authors, most of them employees of Robert Bosch Gmbh, are well conversant with the subject, and each chapter/paragraph is written by a specialist in each field. This gives the book an extended information content but, here and there, the biggest limit of this book also shows: notwithstanding the length of the work (503 pages), the background of each theme is only sketched. As a consequence, the book demands of the reader a basic knowledge of electricity and electronics, and some background of car technology. This might be a limit in its use as study material for absolute beginners in the field.

This is especially true in the first part, devoted to the traditional electrical systems. The second part, devoted to electronic components and systems, tries to start from the most basic concepts. However, considering that the field of electronics today is so wide in scope, those concepts are only touched upon briefly, leaving the reader confused. From one perspective, it seems this part is oriented to absolute beginners; from another, those who read and use this book as reference work will find the introductory paragraphs too condensed and already well known.

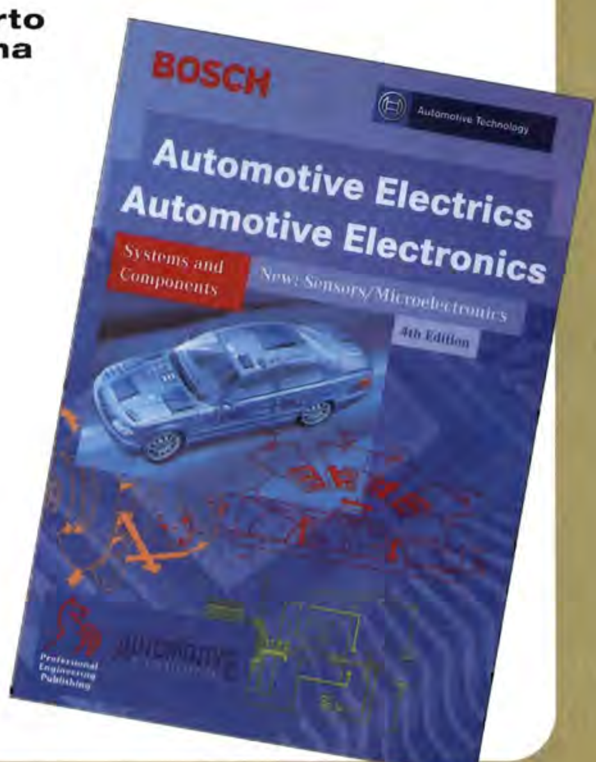
The look-and-feel of the book is one typical of reference books and publications from Robert Bosch; the diagrams and illustrations are made in its well-known style.

The large catalogue of components and products from Bosch – covering almost every aspect of the use of electricity in a car – provides an ample choice of examples. The description of each one is often done by the actual designers and it comes across as such from their detailed description.

The English edition is published by Professional Engineering Publishing and sponsored by the "*Automotive Engineer*" magazine. The translation is accurately done and only a couple of German words are left in.

Overall, I can suggest this book to every engineer involved with electronics and electrics in cars, both as a designer of cars or a designer of components, systems or appliances intended to be used on board a contemporary car.

Alberto Lobina



Living with RoHS – the big questions

Q: I've heard a rumour about another exemption. Is this true?

A: Yes, the EC has accepted one of the exemptions that it was originally delaying making a decision on. The new exemption is number 22, *"Lead as impurity in RIG (rare earth iron garnet) Faraday rotators used for fibre optic communications systems"*. This brings the total number of exemption categories to 29. There is an up-to-date exemptions list at **www.rohs.info**.

Q: I'm concerned about being 'guilty by association' if someone in our supply chain is either deliberately or accidentally in breach of RoHS. As far as I'm aware, there have been no electronics distributors or manufacturers that have been fined for non-compliance in the UK as yet. But, if non-compliance is passed down the chain, would we be liable too? And how would we prove our case?

A: Firstly, you're right, NWML confirms that there have been no RoHS fines as yet in the UK. There were, however, two retailers fined in Ireland in respect of the WEEE Directive.

Secondly, in the EU it is the 'producer' of the finished product sold to end users who is legally responsible for compliance to RoHS. This is true in all EU States except the UK where, in theory, suppliers could also be prosecuted, although this is very unlikely according to the DTI.

It may be helpful to address each link in the supply chain. The distributor that supplies RoHS non-compliant parts in error would not be prosecuted as it is not the "producer" of the finished product. But, the producer could take legal action against its supplier for breach of contract, depending on contractual terms.

This questions if an equipment manufacturer or producer is prosecuted for non-compliance either due to an error, negligence or dishonesty on the part of a supplier. The view of consultants ERA Technology suggests other customers of this supplier who were sold the same non-compliant component may also have been making and selling the non-compliant finished products as a result.

At this time, all those parties should stop making and selling RoHS non-compliant products. They may even consider a recall and this would obviously have cost implications and a question mark would hang over whether this can be recovered from the supplier. It is unlikely that under these circumstances the authorities would prosecute other producers but, in theory, they could and might if any continue to sell non-compliant products after they are aware of the situation. The cause of this problem, the supplier in this case, is unlikely to be prosecuted as they are not the "producer". However, they would certainly lose customers.

The EU RoHS enforcement bodies have published the procedures that they will be using (**www.rohs.gov.uk**) and this is based on documentation. However, analysis will be expected where there is a significant risk of non-compliance.

The key is due diligence. Using suppliers that have the BSI Kitemark and offer certificates of compliance is a good place to start. It gives producers confidence that suppliers are following suitable procedures and that they are being audited.

In some EU States it will be an offence not to be able to provide the documentation that shows compliance. If documentation is available and is in order but the product still does not comply due to an error in the supply chain, then it will be illegal to sell this product. The question is: would the producer be prosecuted for this? And the answer really is, that depends. In the UK the producer probably wouldn't be, but in certain other States it is a possibility, especially if the producer is a large household name brand that the authorities might want to make an example of.

Q: Do products such as semiconductors, connectors and resistors fall into RoHS?

A: It is not illegal to sell non-compliant components as these items are not included in any of the eight RoHS categories. Such non-compliant products can still be used to maintain, repair and upgrade equipment placed on the market prior to July 1st. Any new equipment after that date must be compliant, unless an exemption comes into play.

Q: Are solder stations within scope?

A: Yes, category 6.

Q: What is the RoHS and WEEE position on batteries?

A: All batteries are excluded from RoHS as they are covered by the batteries directive. The current batteries directive requires certain labelling for toxic substances and bans mercury in batteries, except button cells. The proposed new batteries directive is likely to have additional substance restrictions but, as yet, it is not decided what these will be.

As far as WEEE is concerned, this requires batteries to be removed from equipment at end of life and separately recycled. When providing sales data to WEEE registration bodies, the producer can exclude the weight of batteries if they are also registering for the battery directive.

It is worth noting, however, that battery chargers do fall within RoHS, the category being determined by the application for example, a charger for a mobile phone would be category 3 (IT and telecommunications equipment) or category 6 (Electrical and Electronic tools) for a power drill.

Gary Nevison is chairman of the AFDEC RoHS team, board director at Electronics Yorkshire and head of product market strategy at Farnell InOne. As such he is our industry expert who will try and answer any questions that you might have relating to the issues of RoHS and WEEE. Your questions will be published together with Gary's answers in the following issues of Electronics World. Please email your questions to EWeditor@nexusmedia.com, marking them as RoHS or WEEE.

14 Channel Clock Generator With 2.8GHz VCO

Analog Devices (ADI) is introducing what is claims is the industry's first clock IC to combine low phase noise clock generation with 14-channel clock distribution at jitter levels below 1ps. The AD9516 series integrates an integer N synthesiser, two reference inputs, a voltage-controlled oscillator (VCO), programmable dividers, adjustable delay lines and 14 clock drivers, including LVPECL, LVDS and CMOS.

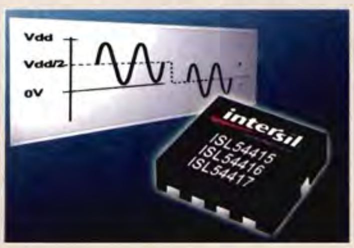
This level of integration replaces several discrete components and, as such, enables designers to reduce board space and bill-of-materials costs. In addition, integrating the VCO on-chip greatly reduces the risks associated with the failure of discrete oscillators, improving overall system reliability.

The AD9516 has five versions, each supporting a specific frequency range. On the high end, the AD9516-0 includes a VCO that tunes from 2.60GHz to 2.95GHz. The other parts cover lower frequencies, down to the AD9516-4's VCO range of 1.50GHz to 1.90GHz. Any of the AD9516 family may also be used with an external VCO up to 2.4GHz.

Each device features six LVPECL outputs, which operate up to the maximum VCO rate, as well as four/eight outputs which may be programmed to either LVDS (four outputs max) or CMOS (eight outputs max) levels. In LVDS mode the outputs operate to 1GHz and in CMOS mode the outputs operate to 250MHz.

www.analog.com

Multiplexers Eliminate Separate I/O Jacks For A/V



Intersil has introduced a family of dual 2:1 multiplexers that enable the transmission of quality audio, video and high-speed USB data through a single input/output port, eliminating up to two ports on each portable device.

The move to fewer I/O ports is well demonstrated by the recent launch of Apple's iPod Shuffle, which uses a single 1/8" jack for USB and headphone connections. Intersil's ISL54415/6/7 multiplexers give users the ability to display images on a TV from a portable media player, in addition to providing an audio output and still using a single I/O port to minimise cost and size.

The multiplexers combine high speed, low capacitance switches for data signals with low distortion, low capacitance switches for audio and video (A/V), so they can be used for data downloading or for A/V playback through a single port, without impacting performance in either mode of operation. This increases available board space, reduces external components and lowers the manufacturing cost of portable devices that need to connect to other equipment such as TVs, flat screen monitors, headphones, speakers and PCs.

The ISL54415/6/7 multiplexers can switch between USB, other digital data and A/V signals in personal media player applications. The family is designed to reduce the number of connectors and cables required to connect personal media players, digital still cameras, camcorders and other consumer electronics products to other equipment such as TVs, flat screen monitors and PCs.

Negative signal swing capability on the audio and video inputs of the multiplexers allows these signals to be AC coupled, preventing battery discharge of the portable device if left connected to a powered-down piece of equipment.

www.intersil.com

High-Temperature Automotive Driver ICs

Atmel has announced the availability of three new driver ICs for high-temperature applications (AECQ100, Grade 0). The ATA6824, ATA6827 and ATA6832 are designed using Atmel's new high-voltage SMARTIS technology, which is based on SOI (Silicon-On-Insulator) substrate and which enables chip temperatures of up to 200°C. As a result, ambient temperatures of up to 150°C can be achieved, allowing the use of these devices in hot environments.

In mechatronic solutions, such as turbochargers or exhaust gas recirculation systems, many flaps have to be controlled by DC-motor driver ICs, which are located very close to a hot engine. To design a complete motor control system solution, designers can combine the new driver ICs with Atmel's well-known family of ATmega 8-bit AVR Flash microcontrollers qualified for high-temperature automotive applications.

The small and low-cost ATA6827 is a fully-protected triple half-bridge driver with integrated power stages to control up to three different loads by a microcontroller. Each of the three high-side and three low-side drivers are capable of driving currents of up to 1A.

The ATA6827 supports the application of H-bridges to drive DC motors very well. The operation modes reverse, brake and high impedance are controlled by the SPI interface. The enhanced version, ATA6832, provides an additional PWM functionality with up to 25kHz, enabling a DC motor control to be generated without any audible noise caused by the PWM signal.

www.atmel.com

Digital-to-Analogue Audio Converter

With the introduction of the CS4352 digital-to-analogue converter (DAC), Cirrus Logic has developed a highly competitive converter that offers a strong combination of audio performance and feature integration.

With its on-chip line driver and analogue low-pass filter, the CS4352 gives designers of mainstream consumer audio products, such as flat-panel digital televisions, DVD recorders, set-top boxes, game consoles and sound cards, the ability to eliminate external components, reduce design complexity and overall system costs.

Specifically, the on-chip line driver and analogue low-pass filter directly drives a 2Vrms consumer line level audio output, eliminating the need for an operational amplifier and as many as 10 passive components within system designs. The integration and ability to directly drive the output of the end product greatly simplifies analogue output stages and reduces costs. Automatic sample-rate detection, which uses proprietary Cirrus Logic techniques, further simplifies designs by automatically configuring the CS4352 into the appropriate operational mode.

The CS4352 utilises a multibit Delta-Sigma architecture, operates from a 9V or 12V power supply and is hardware configurable. It is also pin compatible with Cirrus Logic's CS4351 DAC, ensuring an easy upgrade path for existing customers. It features Cirrus Logic's Popguard technology for control of clicks and pops during power cycling.

The CS4352 is available in a 20-pin, lead-free TSSOP package and is currently sampling to customers. The CS4352 is priced at $1.60 in quantities of 10,000.

www.cirrus.com

Push-Push-Pot For Lighting And Motor Control

Lorlin Electronics, the UK-based switch manufacturer, is now offering the new MDSP push button dimmer switch. The UK manufactured MDSP is a push-on, push-off switch with a potentiometer mounted on the same spindle. Widely used in domestic lighting dimmer controls, the MDSP is now also finding acceptance in industrial and professional switching and control applications.

The MDSP offers a wide range of potentiometer resistance values, including non-linear, and is available with either printed circuit terminals, in line or staggered terminals. Switch operation force is nominally 15N, with optional tactile feel and other switch forces being available. All moulded components are in UL 94V-0 rated materials. A 4mm or 6mm diameter polyamide or 4mm metal spindle may be specified at any length. Secure panel mounting is provided by an M10 x 1mm bush thread.

The switch offers a single pole change over, rated at 10A (2.5A @250VAC resistive) and life expectancy is greater than 25,000 cycles. Operating temperature range is –25°C to +100°C and the unit has a withstand voltage of 2,500VAC.

The potentiometer has a track life of over 50,000 cycles, operates over a 270° range and may be specified to give 0Ω to maximum resistance, or maximum resistance to 0Ω over its clockwise rotation. The MDSP is fully approved to international safety standards including EN61058 by VDE, SEMKO, NEMKO, DEMKO and FEMKO.

www.lorlin.co.uk

ZigBee 15.4 Application Kit

Rabbit Semiconductor has released its ZigBee/802.15.4 Application Kit. The kit interfaces a RabbitCore module with MaxStream XBee wireless ZigBee modules. Adding ZigBee technology to an Ethernet-enabled Rabbit embedded control device offers a low-cost, robust wireless infrastructure that allows users to monitor remote devices within a sophisticated wireless network, exchange data between devices and control I/O from a secured PC on the Internet.

Rabbit's ZigBee/802.15.4 Application Kit is a reference application that comes complete with the hardware and software for implementing a ZigBee wireless control network in the various topologies such as point-to-point and point-to-multipoint. The configuration software allows users to set up a network, discover nodes and establish communications between similar ZigBee devices.

The RabbitCore module acts as the network coordinator to monitor and manage two other battery-powered XBee-equipped node devices. This allows users to access and control a ZigBee/802.15.4 network from anywhere in the world. The RabbitCore module is equipped with Ethernet and 512K Flash, 256K SRAM, 1MB serial flash and 33 GPIO lines, and has the ability to act as both an intelligent control device or as an Ethernet gateway.

www.rabbit.com

Versatile Multipin Connector Series

New from ITT Electronic Components is one of the most versatile multipin connector series. The VEAM CIR series can function as an electrical, optical or pneumatic connector, and it is also available in high voltage, twin or tri-axial, hermetic and EMC versions.

Designed originally for the hostile environment of mass transit applications, CIR connectors are also suitable for use in military, commercial, medical, geophysical, entertainment, nuclear and aerospace applications. The design parameters were based on MIL-C-5015, however, its unique positive lock and quick disconnect coupling surpasses the environmental requirements of this military specification.

Coaxial CIR connectors accept most popular RG cables. Fibre styles are available with single or multiple fibre terminals. Devices can include a range of insert/grommet materials to provide superior resistance to fuel oils, solvents and elevated temperatures; alternatively they can be supplied with glass to metal hermetic seals in lieu of elastomeric inserts.

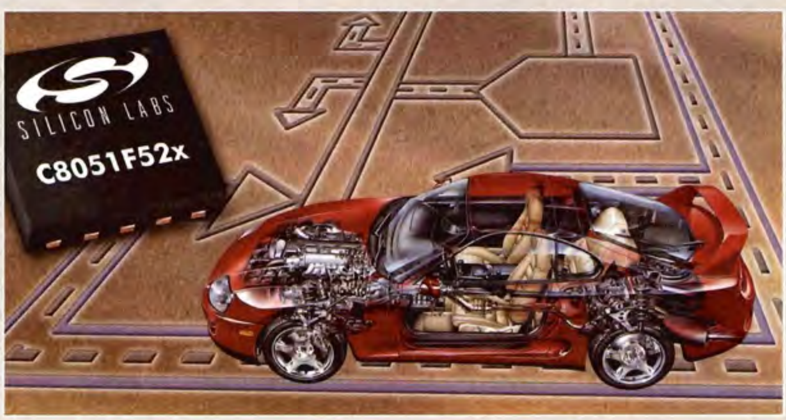
Other configurations include: high voltage, twin- or tri-axial size four or eight contacts and RFI/EMI – grounding fingers on plug connectors provide superior plug-to-receptacle (360°) shield integrity. Filtered devices are also available incorporating tubular or planar filter networks.

CIR connectors have also been designed for pneumatic operation. Various insert arrangements with size 4, 8 or 12 cavities accept pneumatic contacts to pass liquid or air, at pressures of up to 110 PSI. Flow valves are additionally available.

CIR connectors are available with various thermocouple material contacts including chromel, alumel, copper, constantan and iron.

www.ittcannon.com

Highly Integrated Automotive MCU



Silicon Laboratories launched its highly-integrated MCU family designed specifically for the automotive sector. The C8051F52/3x offers high-performance, mixed-signal MCUs with small footprint and high functional density.

The C8051F52x MCU family is the first to combine a ±0.5% integrated precision internal oscillator with 8K Flash, 25MIPS, 12-bit ADC, dedicated LIN 2.0 controller, 16-bit timers/PWM, SPI, UART and six I/O lines in a small 3 x 3 mm QFN package. The C8051F53x MCU family has the same feature set but adds ten additional I/O lines and is offered in 20-pin QFN and TSSOP packages.

Both families integrate additional analogue features, such as programmable comparators, voltage regulators and on-board temperature sensors to further reduce design complexity. This highly integrated architecture enables automotive electronics designers to simplify the design process and reduce bill of materials.

The C8051F52/3x MCU family provides automotive electronics applications with greater functionality, sensing and control. For example, the integrated LIN 2.0 controller, combined with the ultra-high precision internal oscillator enables designers to implement LIN master-mode communication networks without the need for external timing components, further reducing overall system cost.

The C8051F52/3x MCU family also includes power-on-reset, brown-out protection and a watch-dog timer reset, helping designers to create reliable and durable electronics systems. In addition, Silicon Laboratories's patented MCU technology has been field tested and optimised for rigorous automotive specifications and maintains full performance over the complete automotive temperature range -40°C to +125°C.

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http://www.microchip.com/
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MicroRobotics

www.microrobotics.co.uk
Micro-Robotics is a Cambridge-based manufacturer of custom and off-the-shelf embedded control solutions and components. The company's VM-1 credit-card-sized control computer is ideal for a wide range of applications.
When used with the Micro-Robotics proprietary Venom-SC object-oriented programming language, the VM-1 controller can handle analogue and digital I/O, graphical user interfaces, communication protocols, data and text files and many other functions.
This combination of powerful processor, easy to use application software and comprehensive I/O resources will make the VM-1 highly suitable for applications such as intelligent instruments, hand-held devices, industrial automation and process control systems, security systems and similar other applications.

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