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REGULARS

36
Optimal Testing Practices

44
Tips & Tricks

FEATURES

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PREDICTIONS FOR
ENTERPRISE
OPERATING SYSTEMS IN
2012

IT initiatives tend to either promote long-term efficiency or growth. In 2012, we at Red Hat see technology advancements trending to drive efficiency while providing the foundation for new business growth initiatives.

As the global economy meanders through continued malaise, IT organisations will be faced with the pressure of doing more with less. This is hardly a new theme. Doing more with less has been a driving force in organisations for the past decade. The economic challenges mean that IT budgets will likely remain flat or grow modestly, creating situations where new initiatives can only begin if costs are removed from other business areas. The good news is that there are several ways to help organisations become more efficient to free up budget and resources for higher-value, critical IT projects. These include:

- Resource utilisation improvements through continued consolidation and virtualization;
- Automation and self-service in areas such as provisioning and identity management; and
- Initiatives that reduce the costs for power, cooling and physical facilities.

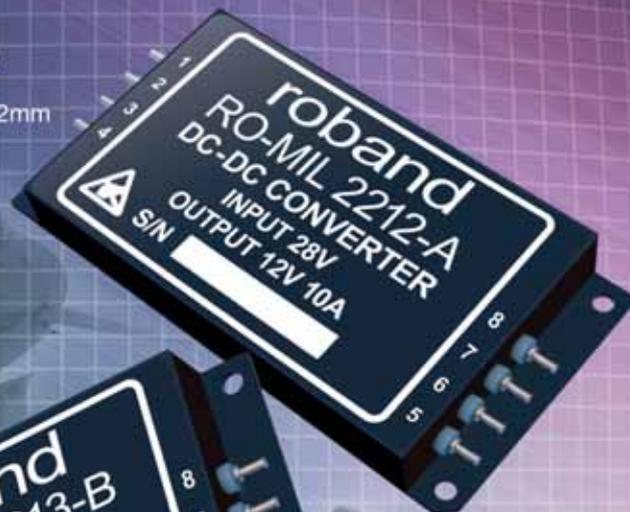We see three irrefutable requirements continuing to drive the IT organization: the ever-growing demand for increased computing capacity, application performance and data volumes. Moore's, Kryder's and Butter's laws that predict compute, storage and network capacity growth over time have proven true. Scale-out architectures have recently become a popular approach to keep up with these exploding demands. In 2012, we believe the predominant driver of scale-out architectures will be big data resulting from the explosion of mobile, commerce and indexed unstructured data. A scale-out approach will drive additional requirements for the operating system.

Hype would suggest all enterprises have implemented operating environments that are fully virtualized or deployed in cloud infrastructure. Red Hat believes the reality is quite different. In 2012, we expect organisations to continue to adopt new infrastructure patterns and add them

> **The economic challenges mean that IT budgets will likely remain flat or grow modestly, creating situations where new initiatives can only begin if costs are removed from other business areas**

incrementally while maintaining existing investments. The result will be hybrid environments with traditional 'silo' style workloads on physical servers, virtualized resource pools and private cloud infrastructures. Even organisations planning to leverage public cloud services will do so as an extension to their existing infrastructure patterns to result in hybrid operating models. These new models will define new requirements for developing, deploying and managing hybrid environments.

For many organisations, 2012 may be a year of breaking the shackles of vendor lock-in. Despite repeated efforts by the IT organisation, vendor lock-in has not gone away and it is still a limiting factor in their ability to control their own destiny. With the adoption of new approaches based on open source software, scale-out architectures, virtualization, SOA and cloud technologies, organisations can now truly use open and modular approaches to implement infrastructure, if done right. This can limit their dependence on any single vendor or even set of vendors.

In addition, the developer landscape will continue to change in 2012. Application models are moving to lightweight and 'componentised' architectures that need multi-platform and web-oriented programming languages and frameworks. This includes tools, services and components to develop applications for mobile, cloud and the enterprise to embrace the evolving nature of usage and delivery paradigms. And, we believe a broader adoption of PaaS (Platform as a Service) models will take place in 2012 to enable overall agility.

In summary, choice, freedom, flexibility and community-based open source development may prove to be additional 2012 themes for the enterprise operating system industry.

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SURREY ENGINEERS USE GAMES CONSOLE TECHNOLOGY TO MAKE "SPACE BUILDING BLOCKS"
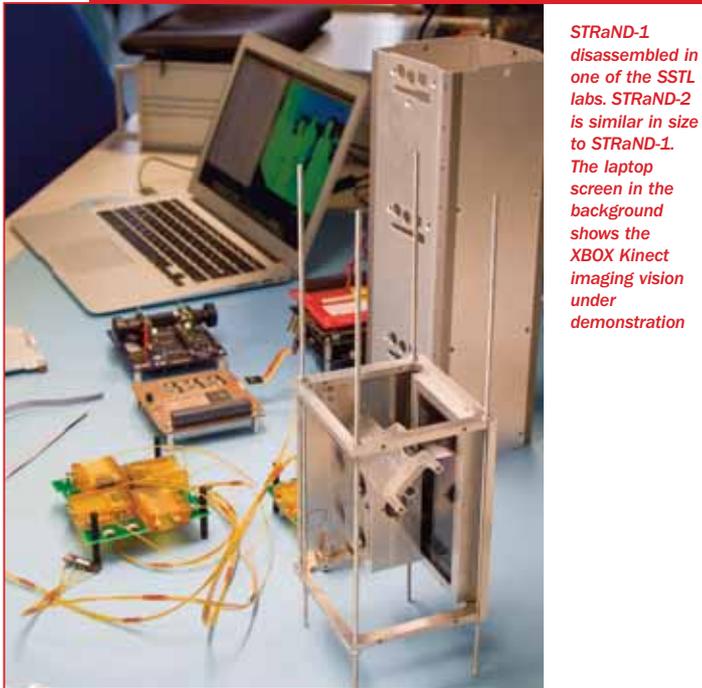
STRaND-1 disassembled in one of the SSTL labs. STRaND-2 is similar in size to STRaND-1. The laptop screen in the background shows the XBOX Kinect imaging vision under demonstration

Space innovators at the University of Surrey and Surrey Satellite Technology Limited (SSTL) are developing 'STRaND-2', a twin-satellite mission to test a novel in-orbit docking system based upon XBOX Kinect technology that could change the way space assets are built, maintained and decommissioned.

STRaND-2 is the latest mission in the cutting edge STRaND (Surrey Training, Research and Nanosatellite Demonstrator) programme, following on from the smartphone-powered STRaND-1 satellite that is near completion. Similar in design to STRaND-1, the identical twin satellites will each measure 30cm (3 unit Cubesat) in length, and utilise components from the XBOX Kinect games controller to scan the local area and provide the satellites with spatial awareness on all three axes.

Docking systems have never been employed on such small and low cost missions and are usually reserved for big-budget space missions to the International Space Station (ISS), or historically, the Mir space station and the Apollo program. The STRaND team sees the relatively low-cost nanosatellites as intelligent "space building blocks" that could be stacked together and reconfigured to build larger modular spacecraft.

"We were really impressed by what MIT had done flying an autonomous model helicopter that used Kinect and asked ourselves: Why has no-one used this in space? Once you can launch low cost nanosatellites that dock together, the possibilities are endless – like space building blocks,"

said SSTL Project Lead Shaun Kenyon.

The STRaND-2 twins will be separated after launch. After the initial phase of system checks, the two satellites will be commanded to perform the docking procedure and, when in close proximity, the Kinect-based docking system will provide the satellites with 3D spatial awareness to align and dock.

"Our low cost nano-satellites could dock to build large and sophisticated modular structures such as space telescopes. Unlike today's big space missions, these could be reconfigured as mission objectives change, and upgraded in-orbit with the latest available technologies," said Dr Chris Bridges, SSC Project Lead.

Other applications include the safe removal of space debris and spacecraft maintenance, with a low cost "snap-on" nanosatellite providing backup power, propulsion or additional on-board computing capability.

Analog Devices And TSMC Collaborate On New Analogue Process Technology Platform

Analog Devices (ADI) and TSMC announced they have jointly developed analogue process technology platform for precision an analogue integrated circuits (ICs).

The new platform significantly improves analogue performance for a number of devices, including A/D and D/A converters, power management devices and audio coders/decoders that are widely used in consumer, communication, computer,

industrial and automotive applications. Performance enhancements achieved with the 0.18 micron, 5V process include an order of magnitude noise improvement, 70% lower standby leakage current, 50% improvement in linearity and 50% better capacitor and resistor matching.

Recently introduced ADI products developed with the new platform include isolated CAN (Controller Area Network) transceivers, a HART (Highway

Addressable Remote Transducer) modem IC, an ECG (electrocardiogram) AFE (Analogue Front-End); a series of digital potentiometers and an audio codec.

TSMC's 0.18-micron, BCD process supports a range of operating voltages and provides cost-effective operation with a minimal footprint and a high degree of energy efficiency. It lends itself to many computer, industrial and consumer applications.

"The close, long-term technology relationship between Analog Devices and TSMC has enabled the development of this new industry-leading analogue technology platform for" said David Robertson, vice president, Analog Technology at Analog Devices. "The combination of an optimised process along with circuit and architecture innovation is key for our high-performance converter and linear products. This TSMC process provides a valuable addition to ADI's process technology portfolio."

MIT Researchers Produce 3D Configurations That Could Lead To New Microchips

Researchers at MIT have found a new way of making complex three-dimensional structures using self-assembling polymer materials that form tiny wires and junctions. The work has the potential to usher in a new generation of electronic devices made up of submicroscopic layers.

Although similar self-assembling structures with very fine wires have been produced before, this is the first time the structures have been extended into three dimensions with different, independent configurations on different layers, the researchers say.

Semiconductor researchers are particularly interested in finding ways to produce chip features that are much narrower than the wavelength of light and as such much narrower than what can be achieved using present light-based fabrication systems, so self-assembly based on polymers

has been an active area of research.

Researchers have created an array of tiny posts on a substrate of silicon, and coated the surface with materials called block co-polymers, which have a natural tendency to assemble into long cylindrical structures. By carefully controlling the initial spacing of the posts, the researchers were able to set the spacing, angles, bends and junctions of the cylinders that form on the surface. Each of the two layers of cylinders can be independently controlled using these posts to make complex 3D configurations.

Earlier attempts to make self-assembly structures have used complex processes with many steps, and had failed to control the resulting configurations well. The MIT system is hailed simpler but it is still allowing controlled alignment of the wires and sharp bends and junctions at precisely
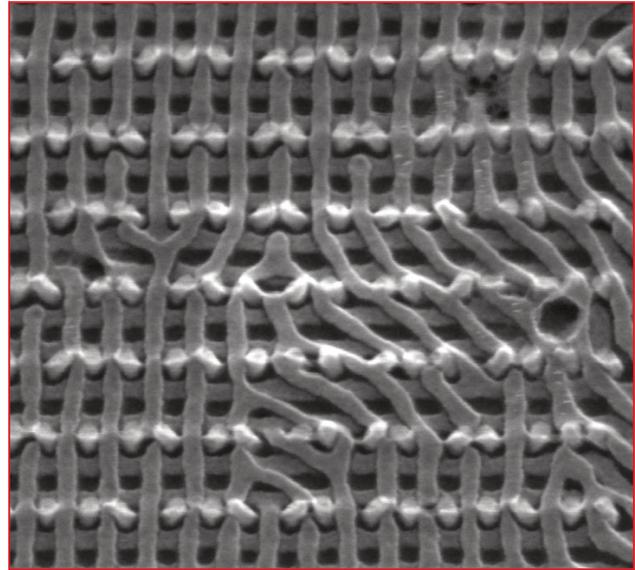
determined locations.

"It wasn't expected to be possible," said MIT graduate student Kevin Gotrik. "We stumbled upon it, and then had to figure out how it works. It was a surprising result."

The electron microscope image shows two layers of nanowires produced through the MIT team's self-assembly process, illustrating how deviations in the pattern and connections between the layers can be included in the design

DISTRIBUTION SECURES CENTRAL ROLE IN ELECTRONICS DESIGN THROUGH ONLINE INVESTMENT

Ten years ago, few could have imagined the pervasive impact of the Internet, which has revolutionised the nature of electronics design and the work patterns of engineering teams. With its surfeit of information, sourcing products on the Internet can be an overwhelming and time-consuming experience, however. Wedged between the supplier and the customer, the distributor has a natural role to play in easing this process for engineers and purchasing professionals. Exploiting the power of the Internet, RS Components embarked some two years ago on a dynamic eCommerce strategy that is now firmly at the heart of the business and brings incalculable value to the supply chain.

The persistent push by RS to add more than 5000 new electronics products a month from leading suppliers to its online offering, coupled with the many online initiatives developed within its eCommerce framework, are transforming the ways in which customers find, design and buy products for their projects.

FIND

RS' new online linecard now covers the company's entire range of more than 550,000 electronics and maintenance products from around 2500 leading suppliers, all available direct from stock. This huge conglomeration of products negates the need for customers to search multiple sites, and the user can navigate simply and quickly around the RS site aided by an advanced parametric search tool that combines a comprehensive set of product data with an intuitive interface to ease product selection. Additionally, the new RS Partsfinder accelerator tool allows the user to instantly search the RS database on the web for any RS stock number, manufacturer's part number, or keyword.

DESIGN

As any engineer knows, finding the right products is crucial, but is only the first step in a complex design process. Every penny and second saved in that process could mean the difference between failure and success. It is not surprising, then, that RS' online DesignSpark community has seen tens of thousands of electronics designers flock to the RS website to take advantage of a host of free online design resources, technical information, user reviews and tools developed to support engineers in their efforts to hasten their designs to market.

DesignSpark PCB, the company's multi-award-winning PCB design software, has proved particularly popular, drawing more than 140,000 engineers to the RS website to download the free, professional tool, which is provided without licence restrictions or time limitation. Similarly, the provision of an extensive library of free, downloadable 3D CAD models in multiple file formats for importing into most CAD suites, and easily identified with the RS part number when ordering, speeds up product integration.

BUY

RS recently upgraded its online quote system to enable customers to upload a spreadsheet bill of material (BOM) and match products according to the part descriptions, as well as to the RS or manufacturer's part number. Every customer order is important, irrespective of quantity, which is why RS supplies more than 75,000 electronic components in a range of packaging, from small pack sizes to industry-standard production reels. Its flexible pricing structure also offers customer discounts for bulk purchases.

INVESTMENT

RS has pledged continued investment in its eCommerce strategy, setting a precedent in the industry that is already seeing the distributor play an increasingly central role in electronics design, from concept to production.

**RS Component
Birchington Road
Corby, Northants
NN17 9RS
United Kingdom
Tel: 08457 201201**

For more information visit: www.rswww.com.com

High-Tech R&D – Drowning in Data but Starving for Information

JENS POPP AND **DIRK ORTLOFF** FROM PROCESS RELATIONS GMBH HIGHLIGHT THE DATA SEARCHING ISSUES AFFECTING EVERYDAY R&D ENGINEERS

High-tech is a term that is widely used to describe a device or system being state of the art. So high-tech can be applied to the cutting edge such as nanomaterials but also to some "old" industries like paint production for example. What all these industries have in common is a production process that has multiple steps, many parameters or both. And that is where the R&D part of the title comes from. The production process needs to be developed or improved. Experiments need to be executed and measurements must be taken. Thanks to the increasing variability of tools to generate measurement results there are lots of images, graphs or plain measure-

> *As engineers join and leave the company and as naming conventions for partially finished experiments change, a lot of sheets are generated*

ment data to look at and evaluate. And with advances in physics there are new hard disks available so that today it is not a problem to have storage with dozens of terabytes for very little money.

We can generate measurements; we can evaluate and store the results. So

is everything good? No, it isn't! The truth is, with today's IT, it is (in most cases) not a big problem to store large amounts of data. And that amount is growing every year by approximately 50% and this is the crux of it. The data can be stored. Many technologies and methods used are optimized for storage even if they are more than 30 years old. While that is fine for archiving results and fulfilling regulatory requirements, in R&D gaining information and knowledge out of that data is of importance. However, with drowning in that data and no effective way to retrieve it to generate knowledge for informed decisions, there's a problem – one that increases by 50% every year!
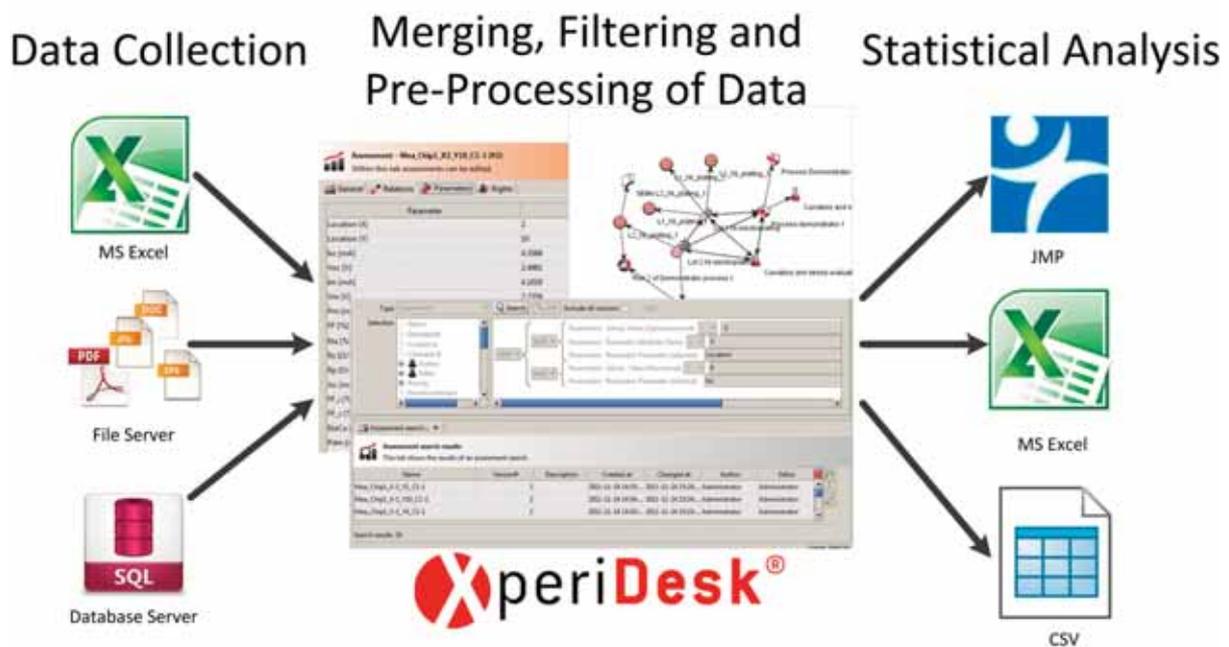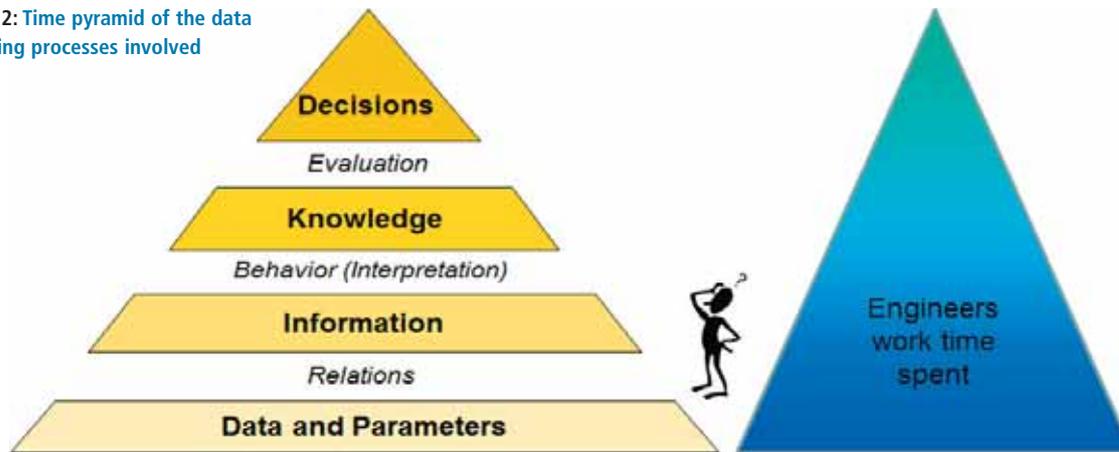
Figure 1: Data statistics

Figure 2: Time pyramid of the data searching processes involved

A Typical Case

Let's look at a typical medium-sized company with about 20 research engineers doing experiments. The engineers work in different R&D departments and rely on the work of other engineers. There is a template (MS Excel) for the experiments but, since we are talking R&D, this changes regularly (and every engineer has variants thereof).

Once the first stage is completed, the data is handed over to the engineer responsible for the next phase, who copies it into their own template. Finally a test engineer takes the results from the experiments and does some measurements, which are then stored in a separate sheet. The copy & paste not only introduces errors but also destroys the relations between the data. It is nearly impossible to find the source of

the values in the new sheet or to do a commonality analysis over more than one stage of R&D, especially when sheets are moved or renamed.

As engineers join and leave the company and as naming conventions for partially finished experiments change, a lot of sheets are generated. When a new project starts the old data is (or should be) reviewed. However that becomes increasingly difficult. The files are stored

on a file server sorted by stage and author. But that isn't helpful when looking for certain material. Even if the directory structure is changed and sorting by material is done, the problem remains. So if, say, the next project needs information involving "threshold voltage limit", searching for it is nearly impossible in the thousands of Excel sheets already accumulated on the file server. As a result current studies estimate that engineers spent 25-30% of their time just managing and rearranging data for various purposes (such as reporting and searching).

To summarize, there are the following deficiencies encountered in development organizations:

- Documentation on file servers, Excel, paper notebooks, etc;
- Untraceable and undiscoverable R&D results;
- Limited formalized data available;
- R&D data not interlinked or related.

At the end, experiments are repeated because the data (and information extracted from it) is not readily available.

A recent study of IDC Manufacturing Insights confirms that "as much as 40% of all R&D experiments are repeated unnecessarily and often inefficiently, delaying projects and increasing costs and risk". It is summarized that "45% of the resources allocated to product development and commercialization are wasted". This is a number that no company can ignore if it wants to survive in a global market.

Solutions

Data is raw and it can exist in many different forms. In R&D we are looking for information and knowledge; but how to gain that?

In the production area this problem is handled by a multitude of tools from categories such as Manufacturing Execution System (MES), Product Lifecycle Management (PLM) and Enterprise Resource Planning (ERP). These tools use a database as background to accumulate data, provide it for evaluation and to derive appropriate actions out of these evaluations. However, simply using a database instead of Excel to do a search will not help much, as contrary to production, in R&D data is changing constantly. New parameters are added daily and a big chunk of the data – such as images – is inherently unstructured and not suitable for database storage. Equally, information needs relational connections between the data and these connections are not always known at the beginning of R&D projects.

A system to manage R&D data must be a comprehensive repository for structured and unstructured data. It must provide multi-dimensional access possibilities. This is necessary to cater for multi-disciplined working environments as mechanical, electronics, electrical and other engineers need to be able to look at the same data from different perspectives. Furthermore, graphical navigation through historical data must be provided to enhance retrievability.

Other important requirements allow for data discovery are sophisticated searching capabilities. These need to allow searching structured as well as in unstructured data such as documents. While text-based unstructured data/files can be searched relatively easily using advanced index services, structured data management needs to be equipped with physical awareness. This means that searching for a 'voltage' only searches voltage parameters to comprehensively retrieve the information. Both means of searching must be able to be combined and the system must also be able to use freely definable relations in the searches.

However, two of the most important parts of such a system are import and export. A data management system for R&D must provide means to import data from existing data sources (Excel sheets, file servers, SQL databases, etc) and also means to export, e.g. search results into other tools (Excel, statistical software, ERP, MES, etc) for further processing. It must enable engineers to spend more time evaluating rather than managing data.

PDES (Process Development Execution Systems) like XperiDesk from Process Relations aim to fill this role. They provide a centralized platform to collect, evaluate and export data in a multidisciplinary research facility. PDES are geared to cope with the ever changing structured and unstructured data that is seen in R&D organizations.

Scratching the Surface

This article just scratched the surface of the problem. There are many more issues to consider, such as data security, regulatory requirements and IP protection – in short, the complete issue of information governance for R&D facilities (Ortloff, 2011).

The important message though is that companies must manage their R&D data and processes with the same rigour as they do for production, supply chain and sales & marketing. The initial investment in training and establishing of new procedures is nothing compared to the potential gain in reduced costs and improved time-to-market and might be the deciding factor to make a company ready for tomorrow's development challenges. ●

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• Ortloff, D. (2011). Information Governance in MEMS/NEMS process development. COMS 2011, Greensboro.

Proud of
WHAT?

MYK DORMER IS SENIOR RF DESIGN ENGINEER AT RADIOMETRIX LTD
WWW.RADIOMETRIX.COM

I am an RF engineer. I cannot fail to be aware that the little cul-de-sac of electronic design that I inhabit can – from the outside – seem somewhat obtuse.

Despite the strenuous attempts of simulation software vendors, the design processes remain very practical, and despite textbook-print-acres of theory, real product design relies on experience, a degree of empirical "feel" and an awful lot of prototyping and measurement.

Our workbenches groan with a bewildering range of highly specialised test devices, and a successful design can rely as much on the shape and positioning of its circuit board traces as the actual components soldered onto them.

But it isn't magic. It doesn't require special mental gifts, abnormal abilities or the bite of a radioactive spider to "become" an RF engineer. It's just a skill that is learned by study, application and practice. The longer you work at it, the better you become,

but the rudiments of it are not actually that difficult to grasp.

It's no different in other branches of engineering. Our machine-age society sits on top of a mountain of existing work, study and publication, and through study, teaching or even just surfing the Internet this information is available to us all. A ten-day crash course won't make you into the designer of the world's next favourite transatlantic airliner, but it will give you a basic understanding of the principles involved. Everything comes out of the same basic principles: the physics of our world are there to be understood and applied. Basic understanding, and the basic capabilities that such understanding gives, makes us all engineers.

Or, rather, it *should*.

Unfortunately, something in this (to me) obvious process has come unstuck, and if I'm not mistaken, may well be getting worse.

I frequently hear this excuse: "I'm sorry, but I'm not technical". I hear it used as an excuse for inability, incompetence or laziness in a whole spectrum of areas, from managers in

industry to reluctant amateur DIY practitioners. I hear it too often, but most worryingly of all, I hear it spoken without embarrassment, sometimes even preceded with a little giggle, frequently almost with pride.

This is nothing to be proud of. Failure to understand the basic technologies used in the products your company makes is no cause for pride. Inability to perform basic mechanical repair tasks, or understand the principles behind the operation of your vehicle, or the simple machines in your home, is no cause for pride. It should be a source of embarrassment.

I am not arguing for the return of the "renaissance man". Our society is complicated, and gaining a complete professional grasp of a specific technical discipline can take a lifetime, but it is not specific knowledge that is lacking. It's any knowledge at all. We all should be able to grasp fundamental mechanical, electrical and other scientific principles and apply them in simple real-world situations, and to understand the working of that which surrounds us. We should be honest enough to admit (to ourselves) when we don't know something, but then do something about that absence. Learn, and not be shy of learning.

Isaac Newton once made a lofty claim to "stand on the shoulders of Giants". In ignorance we run the risk of falling off.●

> *Failure to understand the basic technologies used in the products your company makes is no cause for pride*

USING MEMS ACCELEROMETERS IN AEROSPACE AND DEFENCE ELECTRONICS

PROFESSOR DOGAN IBRAHIM OF THE NEAR EAST UNIVERSITY IN CYPRUS DESCRIBES THE OPERATING PRINCIPLES AND APPLICATION AREAS OF MEMS ACCELEROMETERS IN THE AEROSPACE AND DEFENCE FIELDS. THE ARTICLE ALSO INCLUDES A DESIGN OF A MEMS ACCELEROMETER BASED INCLINOMETER

MEMS (Micro-Electro-Mechanical-Systems) are tiny devices used in intelligent systems as sensors or actuators. Their small sizes, reliability, robustness and low cost make them suitable for use in harsh environments in the aerospace and defence sectors.

MEMS sensors are used to gather information on temperature, force, pressure, acceleration, speed, position and angle. This information, together with actuators is processed by microcontrollers and used to create intelligent miniature systems.

A NATO executive summary report (MEMS Aerospace Applications, RTO Educational Notes, EN-AVT-105) identified six possible aerospace research and application fields for the MEMS devices:

● Active control of thin boundary layer flows to enhance aerodynamic performance;
● Single-chip inertial and navigation systems;
● Fusing/safety and arming systems;
● Generation of micro power using micro fuel cells and micro engines;
● Applications in harsh environments;
● Applications for autonomous inventory and storage monitoring.

The US Department of Defence conducted an assessment of MEMS (*A Review of Some Current Research in Microelectromechanical Systems (MEMS) with Defence Applications, Dept of Defence, DSTO-GD-0316*) in which it was said that "MEMS will create new military capabilities, make high-end functionality affordable to low-end military systems and extend the operational and lifetimes of existing weapons platforms". Twelve defence applications were identified, grouped under the major areas of inertial measurement applications, distributed sensing and control applications, and information technology applications.

THE SMALL-SIZED MIGHTY FORCE

Today, MEMS technology has developed into multi-billion dollar market with applications in commercial, industrial, consumer, aerospace and defence electronics. The MEMS market grew as expected at a rate of 5% annually between 2006 and 2011 (Sensors Mag, August 2007). Just the MEMS gyroscope and accelerometer market has expanded by 55% from 2005 to 2006. The major part of the market comes from automotive applications with Bosch and ST Microelectronics holding 35% of the MEMS accelerometer market share together (Research and Markets, June 2009).

Military MEMS applications are numerous and are addressed in the NATO RTO (Research and Technology Organization) MEMS Task Group. Perhaps one of the biggest advantages is the miniaturization where a number of sensors can all be placed on a single chip, resulting in higher reliability, less component count and reduced cost of fabrication. The MEMS market for defence and aerospace hit $265m by 2009 (Military & Aerospace Electronics, April 2006). The most established application of MEMS in defence has been in inertial measurement units for weapons, guidance, navigation and stabilization.

Consumer electronics	Mobile phones, notebooks, hand-held games, cameras, hard disks, home medical devices
Automotive electronics	Navigation, air bags, suspension control, engine control, engine performance analysis
Aerospace/defence	Navigation, missile guidance, range finders, flight control, gun control, situational awareness systems, power generation, enemy identification systems, aircraft performance analysis, weapon systems fusing and arming, micro propulsion systems, nano satellites, micro aerial vehicles, health monitoring of military systems
Medical	Blood pressure sensors, hearing aids, pacemakers, breathing control, kidney dialysis machines, respirators, insulin dispensing machines
Other	Humidity, ventilation, and air conditioning control, switches, relays, robotics, seismic studies, digital inclinometers, digital speed sensors, micro-mirrors, micro-pumps, micro-robotics, high sensitivity microphones

Table 1: Some high volume applications of MEMS devices

Description	G value
Earth's gravity at sea level	1
Elevator accelerating up	1.5
Commercial airline at take off	1.5
Passenger car cornering	2
Amusement park rides (max)	3.5
Death or serious injury	> 25
Sprint missile	100
Formula One piston acceleration	8600
9x19 mm handgun bullet (along the barrel)	31,000
9x19mm handgun bullet (peak)	190,000

Table 2: Some typical G values

Some of the commercial applications of MEMS devices include blood pressure sensors, tyre pressure sensors, airbag sensors, biomedical implantable sensors, optical switches, intelligent games, vehicle and aircraft dynamic performance analysis, and many other products. MEMS components are microscopic and some mechanical MEMS products are micro pumps, motors, valves, gears, pistons and many other micro size devices.

MEMS technology is also used in defence fields such as in ammunition guidance and solder survivability. An application of the MEMS technology in defence electronics is given here with an example – guidance and navigation are fundamental to military success. This is why the highly accurate GPS (Global Positioning System) system has been developed initially and mainly for the military use by the Department of Defence of the USA. Although the GPS system provides accurate guidance and navigation in military applications, it becomes useless in highly dense urban environments and in mountainous areas.

A list of some high volume applications of MEMS devices is given in Table 1.

A research team at the Carnegie Mellon University including the ICES (The Institute for Complex Engineered Systems), the Electrical and Computer Engineering department, the Robotics Institute and the NREC (National Robotics Engineering Centre) have been carrying out research for the development of portable localized guidance and navigation systems using MEMS technology products (ICES Newsletter, Fall 2008, www.ices.cmu.edu). Known as the "shoe-based sensors", it is reported that a complete GPS-free navigation and guidance system is implanted in a typical soldier shoe.

It is important to realise that MEMS is not just the miniaturisation of components. MEMS is the technology for creating highly complex electronic sensors and mechanical systems using batch fabrication techniques similar to those used in manufacturing integrated circuits. The materials used in MEMS technology are primarily based around silicon, because it is economically and readily available from the integrated circuit technology.

This article is about the MEMS accelerometers and their use in aerospace and defence applications. An example use of a MEMS accelerometer to create a microcontroller-based inclinometer is also described in detail.

MEMS ACCELEROMETERS

Accelerometers used to be large, clunky and expensive instruments and it was not practical to use them in defence/aerospace, or in portable embedded microcontroller-based applications. With the development of the MEMS technology it is now possible to manufacture accelerometer chips with footprints of less than 1cm³. Acceleration is sensed either on 2-axis

Figure 1: ADXL202 accelerometer chip

or 3-axis principle. 3-axis devices measure the acceleration on forward-backward, left-right and up-down.

MEMS accelerometers are tiny electronic chips used to measure the

Accelerometer	Manufacturer	Output	Max Range	Axis	Supply Voltage
MXD2020E	Memsic	Digital PWM	±1G	2	3V to 5.25V
MXD6025	Memsic	Digital PWM	±2G	2	2.7 to 3.6V
ADXL202	Analog Devices	Digital PWM	±2G	2	3V to 5.25V
ADXL210	Analog Devices	Digital PWM	±10G	2	3V to 5.25V
ADXL213	Analog Dervices	Digital PWM	±1.2G	2	5V
ADXL330	Analog Devices	Analog	±3G	3	1.8V to 3.6V
ADXL362	Analog Devices	Digital	±8G	3	1.6V to 3.6V
LIS244AL	STMicroelectronics	Analog	±2G	2	2.4V to 3.6V
LIS244ALH	STMicroelectronics	Analog	±6G	2	2.4V to 3.6V
Model 2420	Silicon Designs	Digital	±2G to ±200G	3	5V
LIS331DLH	STMicroelectronics	Digital	±8G	3	2.16V to 3.6V
MMA7455L	Freescale Semiconductor	Digital SPI/I2C	±8G	3	2.4V to 3.6V

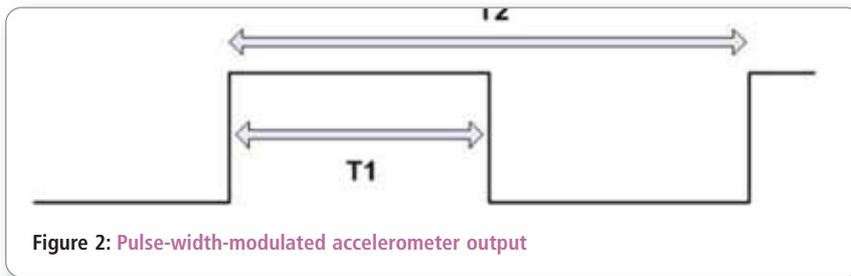**Table 3: Some popular MEMS accelerometer chips**

Figure 2: Pulse-width-modulated accelerometer output

Figure 3: ADXL330 accelerometer chip

Figure 4: MXD202E accelerometer chip (MEMSIC logo's arrow indicates the X-direction)

static or dynamic acceleration directly. By measuring the static acceleration due to gravity for example, we can find out the tilt angle of a device with respect to the Earth. By measuring the dynamic acceleration, we can analyse the way the device is moving. For example, in addition to measuring the

Figure 5: Model 2420 accelerometer

acceleration we can determine the speed and relative position of an object. Accelerometers provide outputs in units of "G", where 1G is equal to 9.81m/s² (or 32.2ft/s²), which is Earth's gravity at sea level. Some typical G values are given in Table 2 for reference.

Although accelerometers basically measure the acceleration due to gravity directly, we can use them to measure the speed and position of a moving object, or the tilt angle of an object. The speed can be measured by integrating the measured acceleration data, using a numerical integration technique (e.g. the trapezoidal rule). Once we obtain the speed, we can determine the position by integrating the speed data. It is important to realise that the sensor can accumulate and cause large errors in position calculations, making double integration useless without independent position check and position correction methods.

There are many types of accelerometer chips. Some of the commonly used ones are based on the principles of capacitive, piezoelectric, piezoresistive, magneto-resistive, or heat transfer mechanisms.

Table 3 gives a list of some of the MEMS accelerometer chips available in the market. ADXL 200 series (e.g. ADXL202) and the ADXL300 series (e.g. ADXL330) are popular accelerometer chips. Although both chips can be used to measure the acceleration, their operations are quite different.

ADXL202 is a 2-axis MEMS accelerometer chip in an 8-pin package (see Figure 1), measuring 10 x 0.9 x 5.5mm, and sensing acceleration in the range ±2G. It is based on capacitive principle where a polysilicon structure is suspended over a silicon wafer using polysilicon springs. A differential capacitor measures the deflection of the structure and this is translated into a pulse-width modulated output signal. Figure 2 shows a typical output signal of the ADXL202 accelerometer. The measured acceleration is expressed as a ratio between times T1 and T2 and is given by:

$$\text{X-axis Acceleration} = 8(T1X / T2) - 4 \quad (1)$$
$$\text{Y-axis Acceleration} = 8(T1Y / T2) - 4 \quad (2)$$

where T1X and T1Y are the waveforms of ON times output from channels X and Y respectively. When T1 = T2 = 0.5 the acceleration is nominally 0G. In microcontroller applications a timer/counter can be used to measure the lengths of T1 and T2. T2 does not need to be measured at every cycle. It should be updated when there are temperature changes. In addition, since the T2 time is shared between both X and Y channels, it needs to be measured by one channel only. Because the ADXL202 is a 2-axis accelerometer, acceleration perpendicular to the 2-axis cannot be detected. To measure acceleration in three dimensions, additional 2-axis accelerometers should be mounted at an angle to each other.

ADXL210 is similar in operation to ADXL202 and has the same pin configuration (14-pin DIL package), but it can be used to measure acceleration up to ±10G.

ADXL330 is a 3-axis solid-state accelerometer (see Figure 3) with a range of ±3G. The chip provides three analog outputs, one for each axis, and is available in 4 x 4 x 1.45mm 16-pin package. ADXL330 is a very low-power chip and operates with a supply voltage in the range
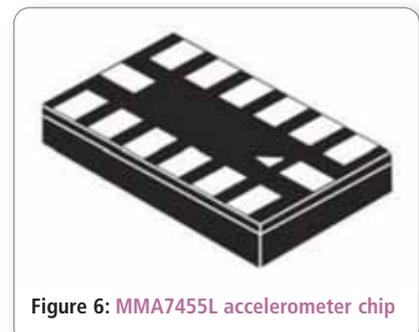

Figure 6: MMA7455L accelerometer chip

1.8V to 3.6V. The bandwidth of the device can be selected by connecting external capacitors to the output pins. The ADXL330 output is ratiometric, meaning that the sensitivity varies proportional to the supply voltage. At Vs = 3.6V, the output sensitivity is typically 360mV/G. At Vs = 2V, the output sensitivity is typically 195mV/G. The 0G output is also ratiometric, so the zero G output is nominally equal to Vs/2 at all supply voltages. It is recommended to calibrate the output at the working voltage for accurate results. The outputs of the ADXL330 are normally connected to the A/D converter inputs of a microcontroller. Then, knowing (or calibrating) the sensitivity of the device we can calculate the actual value of the measured acceleration in units of G.

ADXl362 is a 3-axis accelerometer measuring only 3 x 3.25 x 1.06mm in LGA-16 package, and operating with a supply voltage from 1.6V to 3.6V. The device consumes only 3µA while operating with 2V supply (300nA in wake-up mode and 10nA in standby mode) and in low-noise mode. The current increases to 10µA in ultra low-noise mode. 12-bit output resolution is provided with SPI interface to the outside world, making the device very easy to interface to microcontrollers with built-in SPI modules. Acceleration is measured with full-scale selectable from ±2G to ±8G. Two interrupt outputs are offered to increase the response time and to minimise the microcontroller loading.

MXD2020E is a 2-axis, 8-pin MEMS accelerometer (see Figure 4) chip manufactured by Memsic, measuring acceleration up to ±1G. The device measures 5 x 5 x 2mm and it provides digital PWM output similar to the ADXL202. MXD2020E operates with a supply voltage from 3V to 5.25V.

LIS244AL is a 2-axis accelerometer in LGA-16 package, manufactured by STMicroelectronics. The device operates with a supply voltage 2.4V to 3.6V and can measure acceleration up to ±2G. Two analog output voltages are provided, one for each channel. The device can operate with very low currents (680µA normal, 1µA power-down). A similar product, LIS244ALH can be used to measure acceleration up to ±G.
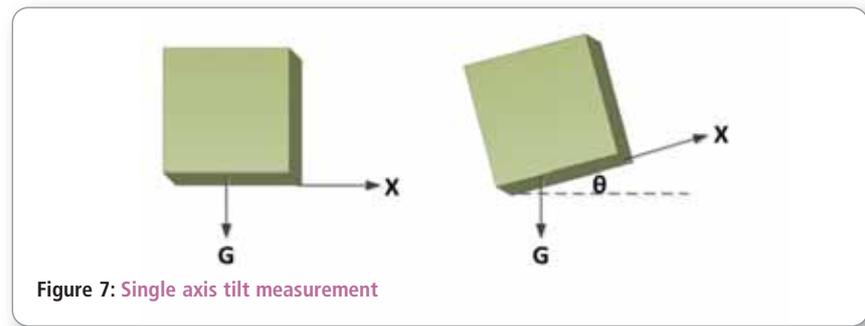
Figure 7: Single axis tilt measurement
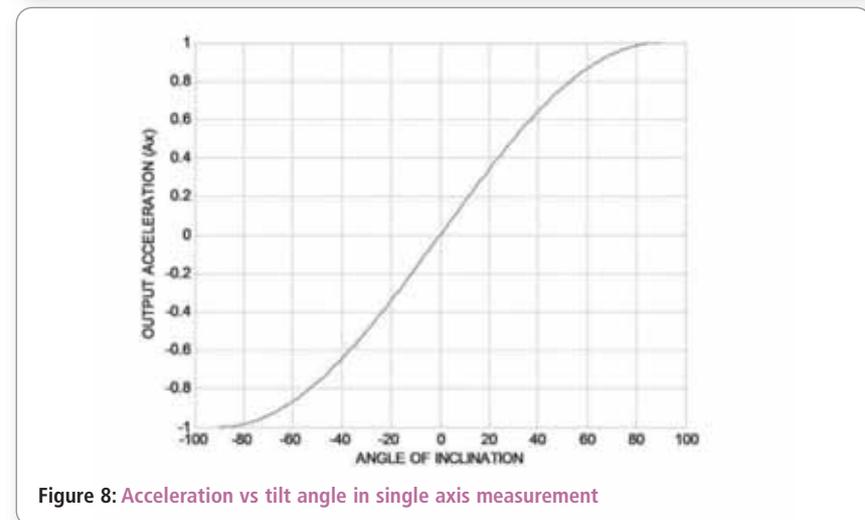
Figure 8: Acceleration vs tilt angle in single axis measurement
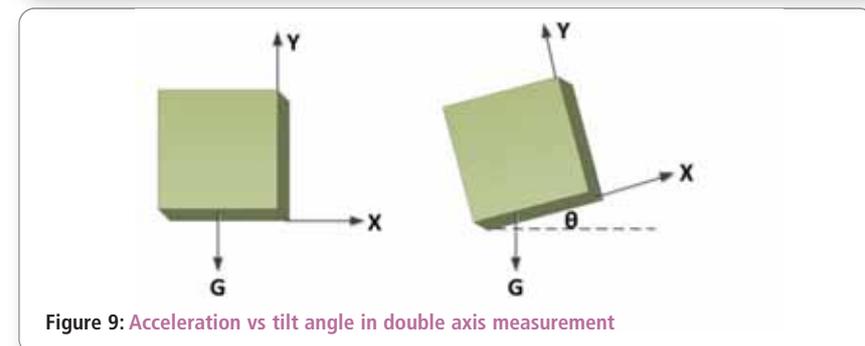
Figure 9: Acceleration vs tilt angle in double axis measurement

Model 2420 is a 3-axis accelerometer from Silicon Designs, supplied with a standard 9-pin D-type socket (see Figure 5), and operating with standard 5V. There are several models ranging from ±2G (Model 2420-2) to ±200G (Model 2420-200), all in a 25 x 25 x 21mm housing. The device produces three digital PWM signals where the number of pulses per second is proportional to the measured acceleration. The outputs are ratiometric to an input clock frequency and are independent of the supply voltage. The operating current is typically 6mA.

LIS331DLH is a 3-axis accelerometer that can be used to measure acceleration to up to ±8G. The device operates at 250µA (1µA in power-down mode), and is offered in LGA-16 package, measuring 3 x

3 x 1mm. The acceleration data is accessed via the SPI/I2C interface, thus making the device suitable for direct interface to a microcontroller.

MMA7455L is a 3-axis accelerometer (see Figure 6) from Freescale Semiconductor, capable of measuring acceleration up to 8G through selectable ranges, and providing SPI/I2C digital output. The device is offered in LGA-14 package, measuring 3 x 5 x 1mm. The operating voltage is 2.4V to 3.6V and consumes only 400µA in normal operating mode.

MEASURING THE TILT ANGLE
The measurement of the tilt angle is important in many defence and aerospace applications, such as rocket launch,
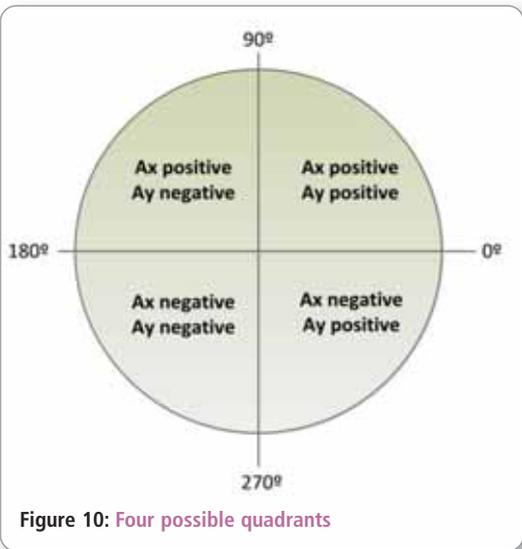
Figure 10: Four possible quadrants

navigation systems, aircraft control, military equipment performance analysis, military radar, space observations, satellite positioning, field artillery positioning, mortar positioning, mobile communication systems, intelligent mobile robotics, and so on.

In this section we will look at how the tilt angle of an object can be measured using a low-cost MEMS accelerometer chip. In the next section the design of a microcontroller-based tilt angle measuring device with LCD output is presented.

The tilt angle can be measured using single, double, or triple axis accelerometers. Single axis and double axis calculations are usually used in low-cost tilt angle measurements.

In single axis tilt measurement the acceleration in one direction only is considered and single, double, or triple axis accelerometers can be used for this type of measurement. Figure 7 shows the accelerometer before and after it is

tilted by an angle θ with respect to the X axis, where the horizon is taken to be the plane orthogonal to the gravity vector.

Referring to trigonometry, the output Ax from the accelerometer is given by:

$$Ax = G \times \sin\theta \qquad (3)$$

Then, the tilt angle in radians (θ) can be calculated from knowledge of the measured acceleration (Ax) and the acceleration due to gravity (G):

$$\theta = \arcsin(Ax / G) \qquad (4)$$

It is important to note that in single axis measurement the sensitivity depends on the angle of measurement and it approaches zero as the angle approaches ±90°. As shown in Figure 8, the measurement gives more accurate results when the angle is small, ideally between ±45°. Thus, single axis tilt measurement should only be used when it is required to measure angles not greater than +45° and not less than -45°.

The accuracy as well as the usable range of the tilt measurement can be increased greatly by introducing another axis to the measurement. This will require either a dual axis or a triple axis accelerometer. With dual axis measurement, when the angle in one direction is large and the measurement errors are high, the angle in the other direction will be small and thus the measurement errors will be small. As we shall see in the derivation, the angle in the second direction is a function of

trigonometric cosine which is more accurate at higher angles. Use of a second axis also enables us to distinguish between the four quadrants and thus to measure angles from 0° to up to 360°.

Figure 9 shows the accelerometer before and after it is tilted by an angle θ, causing both the X and the Y axis to be changed. Referring to trigonometry, the acceleration in both X and Y directions are given by:

$$Ax = G \times \sin\theta \qquad (5)$$
$$Ay = G \times \cos\theta \qquad (6)$$

Combining the two equations we get:
$$\tan\theta = Ax/Ay \qquad (7)$$

or, the tilt angle in radians is given by:
$$\theta = \arctan(Ax/Ay) \qquad (8)$$

Equation 5 can be used when the tilt angle is between ±45° and Equation 6 can be used for larger angles. As we shall see in the sensitivity analysis in the next section, by combining the two equations we can show that Equation 8 can be used to measure all angles accurately in the range 0° to 360°.

Once the acceleration is calculated in two axes, we can find in which quadrant the angle lies, and then calculate the actual angle. Figure 10 shows the four possible quadrants. Depending upon the quadrant, the angle in degrees is calculated as follows:

In Quadrant 1:
angle = (180/π) x arctan(Ax/Ay)
In Quadrant 2:
angle = (180/π) x arctan(Ax/Ay) + 180°
In Quadrant 3:
angle = (180/π) x arctan(Ax/Ay) + 270°
In Quadrant 4:
angle = (180/π) x arctan(Ax/Ay) + 360°

Using triple axis measurement enables us to measure the three rotational angles "yaw", "roll" and "pitch". Triple axis measurement is not covered in this introductory paper (interested readers can look at the Analog Devices Application Note AN-1057 for details).

We have seen in single axis tilt measurement (Figure 8) that the measurement is not sensitive to large tilt angles. The tilt sensitivity of an accelerometer is measured as mg/°. The tilt sensitivity at 0° is calculated by:
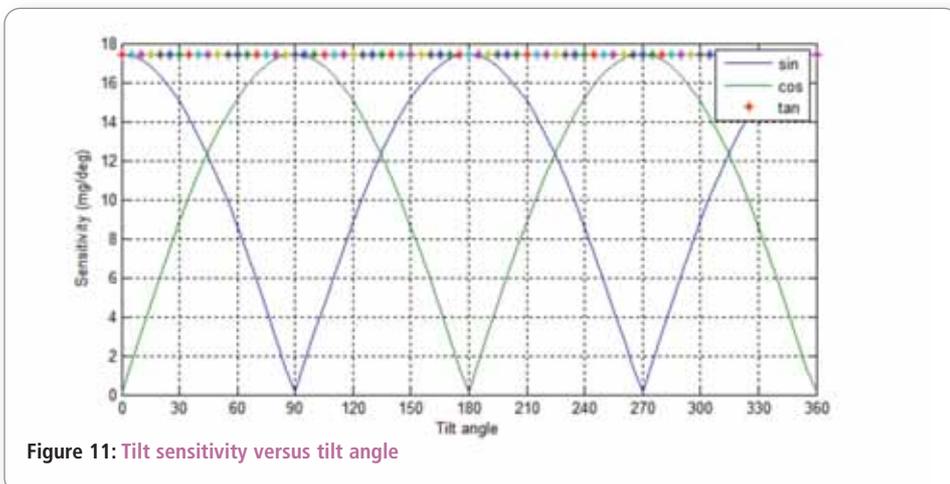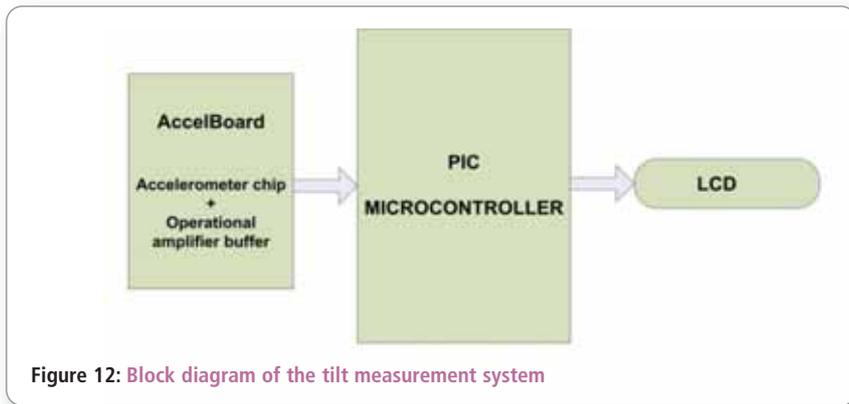

Figure 11: Tilt sensitivity versus tilt angle

Figure 12: Block diagram of the tilt measurement system

$$1000*[\sin(1) - \sin(0)] = 17.452\text{mg/}^\circ$$

Figure 11 shows the sensitivity versus the tilt angle for both single and dual axis measurements using all three Equations 5, 6 and 8, where the absolute value of the tilt sensitivity is taken. It is clear from this figure that using the arctan equation provides a constant sensitivity of 17.45mg/$^\circ$ for all angles from 0° to 360°.

THE HARDWARE

The block diagram of the designed tilt measuring device is shown in Figure 12. The system is built around a PIC16F877 microcontroller (any other type of microcontroller can also be used if desired) and an ADXL330 type accelerometer chip. A small board known as AccelBoard (see Figure 13), manufactured by mikroElektronika is used to measure the acceleration and then the tilt angle is derived from the measured data. This board contains an ADXL330 type accelerometer chip and a MCP6284 type operational amplifier, configured as a voltage follower buffer. Use of a ready-built board such as the AccelBoard greatly simplifies the design of accelerometer-based projects since the actual accelerometer chip is tiny and as a result is hard to make connections to.

The circuit diagram of the project is shown in Figure 14. A PIC16F877 microcontroller receives the analog accelerometer data from the accelerometer through its analog ports RA0, RA1 and RA2. The tilt angle is calculated and displayed on an LCD connected to PORT B of the microcontroller.

THE SOFTWARE

The software was developed using the mikroC compiler. The accelerometer was calibrated before it was used and the calibration parameters were then used in

Figure 13: The AccelBoard

the program for calculating the acceleration. The operation of the tilt measurement device is simple and is described by the PDL given in Figure 15. ●

```
BEGIN
  Initialize A/D converter
  Initialize LCD
  Define accelerometer calibration parameters
DO FOREVER
    Read X, Y, Z acceleration
    Display "Tilt angle" on row 1 of LCD
    Calculate acceleration Ax
    Calculate acceleration Ay
    Calculate the tilt angle in degrees using
    Equation 8
    IF in Quadrant 2 or in Quadrant 3 THEN
        Add 180 to the calculated tilt angle
    ELSE IF in Quadrant 4 THEN
        Add 360 to the calculated tilt angle
    ENDIF
    Display the tilt angle on row 2 of LCD
    Wait 250ms
  ENDDO
END
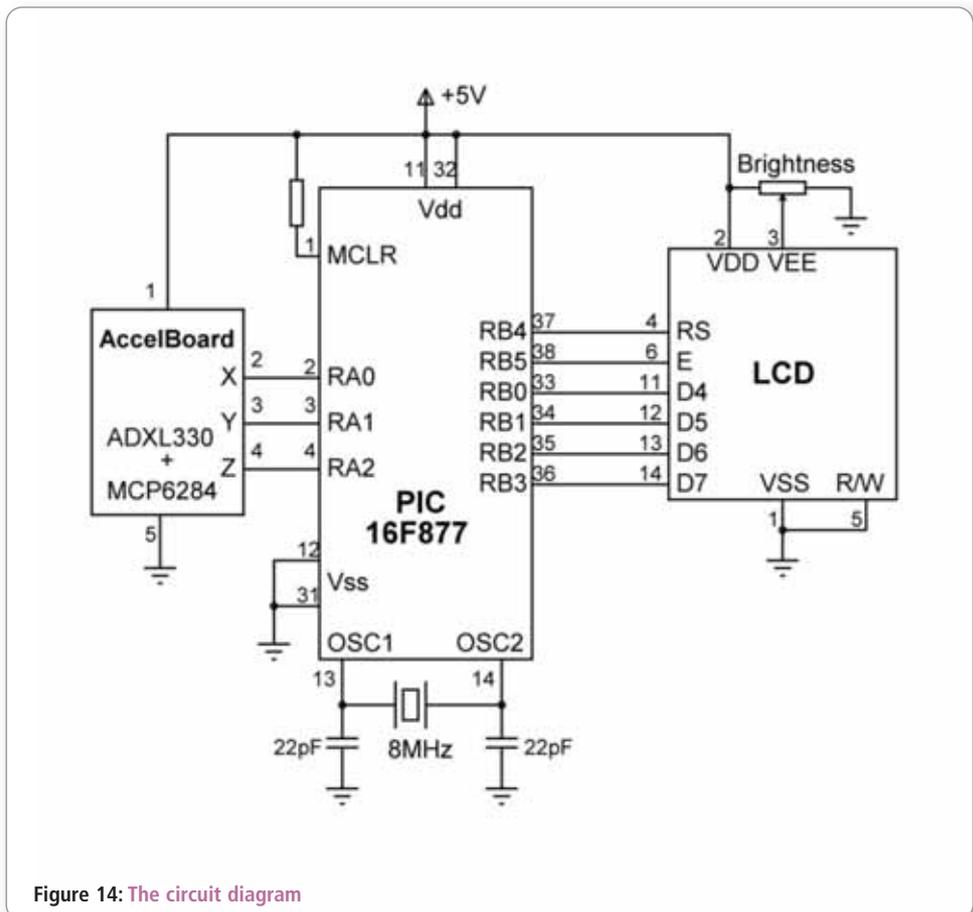```

**Figure 15: Operation of the tilt measurement device**



**Figure 14:** The circuit diagram

# MICROELECTRONICS AND EMBEDDED SYSTEMS
## FOR SPACE APPLICATIONS

**PROFESSOR TANYA VLADIMIROVA**, CHAIR IN ENGINEERING FOR THE EMBEDDED SYSTEMS RESEARCH GROUP AT UNIVERSITY OF LEICESTER, DETAILS THE CHALLENGES IN CREATING COMPUTATIONALLY-INTENSIVE EMBEDDED SYSTEMS FOR SPACE APPLICATIONS

**S**pace systems have changed our lives tremendously, enabling worldwide telephone service and giving users the ability to experience broadcast media in extraordinary audio and video quality, from the comfort of their home. Navigation devices assist us every day in finding our position accurately anywhere on Earth using signals from orbiting satellites. Most of all, satellites offer a unique tool for understanding and monitoring Earth at a global level, providing valuable data for preservation of the environment and security. As stated in the UK Civil Space Strategy 2008-2012 and beyond: "The immense utility that space-enabled systems and services provide to the citizen and the growing dependence on those systems will continue to increase in the future".

The space era started with the launch in orbit of the first artificial satellite of Earth, the Russian Sputnik-1, some 55 years ago in October 1957. Since then, the advances in spacecraft engineering have brought about extremely sophisticated spacecraft designs of different size and mass. Nowadays, small satellites, such as the UK TopSat satellite, are able to take high-quality low-cost images of Earth like the London's Dartford crossing image shown in Figure 1.

The UK has a thriving space sector, which is second only to the US in space science, accounting for around 7% of the global market according to the UK Space Innovation and Growth Strategy 2010 to 2030. Space is one of the highest value-adding industries in the UK contributing £6.5bn a year to the UK economy and supporting 68,000 jobs. Nearly 60% of its highly skilled workforce have at least a first degree. Its productivity figure of more than £100,000 per employee is nearly three times the national average. Space is also one of the most R&D intensive sectors, investing 12% of its GDP contribution in R&D, making it six times more R&D intensive than the UK average. It is predicted that the sector will be worth £40bn by 2030.

An illustration of the growth of the UK space activities is the success, achieved by the UK company Surrey Satellite Technology Ltd (SSTL) – a leading small satellite manufacturer in the world. It is now part of EADS, but SSTL started as a spin-out company of the University of Surrey in 1985. It has delivered 36 satellites to international customers, increasing to more than 40 by the end of 2012; it is the main payload supplier for the European GNSS programme.

## Challenges of Embedded Systems Design for Space

Advances in integrated circuit technology have enabled the integration of computation into devices for monitoring and control of physical processes via sensors and actuators, giving rise to the class of embedded computing systems. Embedded computing is everywhere: cars, mobile devices, washing machines, toys, robotic systems, aircraft, interplanetary rovers, spacecraft, etc.

Embedded systems are resource-constrained and a careful trade-off is needed to meet the design requirements in terms of performance, power consumption, cost, mass and so on. Therefore, carrying out high-performance computation in embedded systems is a great challenge. Embedded systems design for safety critical applications, such as space, require a high degree of reliability, adding another challenging dimension to the design process.

Embedded computing has become an integral part of spacecraft, being present in most platform subsystems and the payloads. The main on-board computer (OBC) is the kernel of the on-board data handling (OBDH) subsystem and behaves as a communications hub between all other on-board satellite modules and the various ground stations. Statistical data show that the trend is towards increasing the amount of embedded computing on board.

A recent study of spacecraft failures, published by the journal Acta Astronautica in 2009, reviewed 156 failures from 1980 to 2005 for both commercial and military spacecraft. It appeared that electrical/electronics failures are responsible



**Figure 1: TopSat image of London's Dartford crossing**

**Figure 2: System-on-chip based on-board computing platform**

for almost half of the failures (45%), ahead of the mechanical/thermal failures with a 32% share. This may seem unexpected, however, although electronic circuits would deteriorate less over time than mechanical components, there are much more electrical components than mechanical devices in modern satellites. In addition, space phenomena such as solar radiation and magnetic storm can heavily affect electronic boards.

Satellites are complex mechatronic devices, operating in a harsh environment, which are not available for repair after launch. Although power is harvested via solar panels, there is no power generation in eclipse and the electronics design is power-constrained. In addition, on-board electronics equipment and devices need to be protected from various space environmental hazards and, in particular, energetic hazards caused by radiation, including charged particles. This makes the design of the on-board embedded computing very challenging.

### Enhancing Reliability and Capability

The research projects, discussed in this section, originated and matured in the author's research group at the Surrey Space Centre in collaboration with SSTL. The research is at present being continued and extended at the University of Leicester, which the author joined in the spring of 2011. The work is aimed at:

(i)  increasing reliability of embedded systems via miniaturisation;
(ii)  improving reliability of on-board electronics through radiation hardening by design; and
(iii) acceleration of computationally-intensive digital signal processing algorithms.

The System-on-a-Chip (SoC) design approach is particularly beneficial to

applications on board satellites, as it delivers miniaturisation but also has the effect of improving design reliability and power consumption.

The first SoC design aiming to miniaturise an on-board computer (OBC) was proposed by the author and Hans Tiggeler from SSTL. It was based on a modular design using soft Intellectual Property (IP) cores and made use of the LEON processor core, developed by the European Space Agency (ESA). The concept and an initial implementation were presented at the NASA conference on Military and Aerospace Applications of Programmable Logic Devices (MAPLD) in 2000. Following that, a SoC on-board computing platform concept, illustrated in Figure 2, was developed, aimed at a modular design of generic on-board controllers. The design flow is targeted at both Field Programmable Gate Arrays (FPGAs) and Application Specific Integrated Systems (ASICs) and includes optimisation and tailoring to specific subsystem and

mission requirements, enabling re-use of previous controller designs. The use of SRAM based high-density FPGAs as the implementation medium render this platform reconfigurable and make it suitable for realisation of partial run-time reconfiguration techniques on board satellites.

Radiation hardening by design (RHBD) is a CMOS device layout technique, which mitigates both total ionizing dose and single event phenomena, induced by radiation. The approach is based on transistor level modifications and additions, such as laying out the n-type transistors in an annular shape, however these lead to a significant increase in the area and power consumption. Research effort into reducing the power consumption of RHBD of VLSI circuits was carried out by Dr David Barnhart. A novel design approach was proposed, based on combining RHBD with a clockless asynchronous method of timing. The main advantage is saving power by almost 50%, and in addition, such an
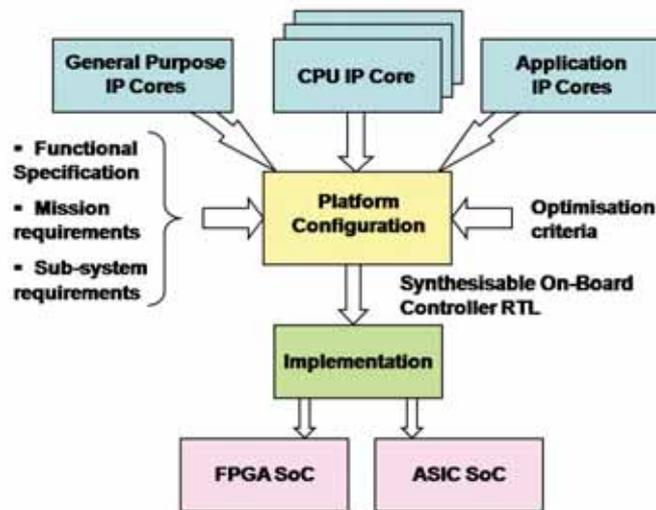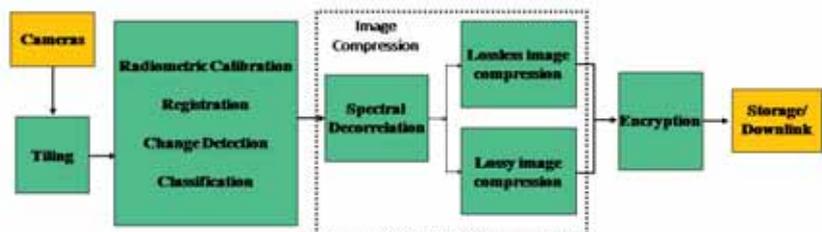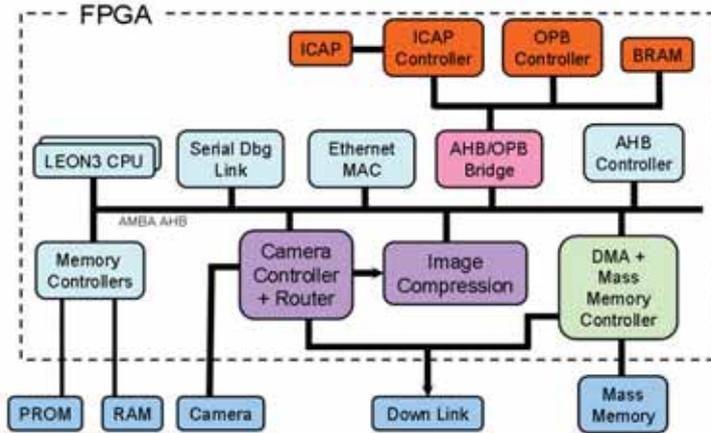


**Figure 3: Automatic on-board image compression system**

**Figure 4:** CCSDS lossless image compression system-on-a-chip design



asynchronous RHBD technique is more tolerant to process, voltage, temperature (PVT) extremes and features reduced electromagnetic interference (EMI).

The reduction of the energy penalty was verified through experimental work. An RHBD library for ASIC design was developed with radiation protection up to 100krad (Si). Three ASIC variations of a standard processor design were implemented in silicon: synchronous clocking/commercial gates, synchronous clocking/RHBD gates and asynchronous design/RHBD gates. This approach is applicable to all SoC applications (including bare die) in hostile environments.

In view of the growing amount of imaging data, acquired by observation satellites, it is extremely important to implement efficiently compression of satellite imagery on board. Figure 3 shows the block diagram of an automatic image compression system. After the images are pre-processed, they undergo spectral decorrelation and are then fed to the lossless or lossy spatial compression blocks before being encrypted and sent to ground. Dr Guoxia Yu applied the reconfigurable SoC platform concept in Figure 2 to lossless image compression of panchromatic and multispectral images captured by the SSTL Disaster Monitoring Constellation (DMC). A lossless compression scheme based on an algorithm, recommended by the Consultative Committee for Space Data Systems (CCSDS), CCSDS-LDC, was implemented as a hardware accelerator, which was incorporated in a SoC design using the LEON-3 processor core (Figure 4).

### Novel Architecture

Prototyping work based on the Xilinx FPGA devices Virtex4 LX25-12 and Virtex5 LX30-3 has shown that the SoC design is capable of real-time operation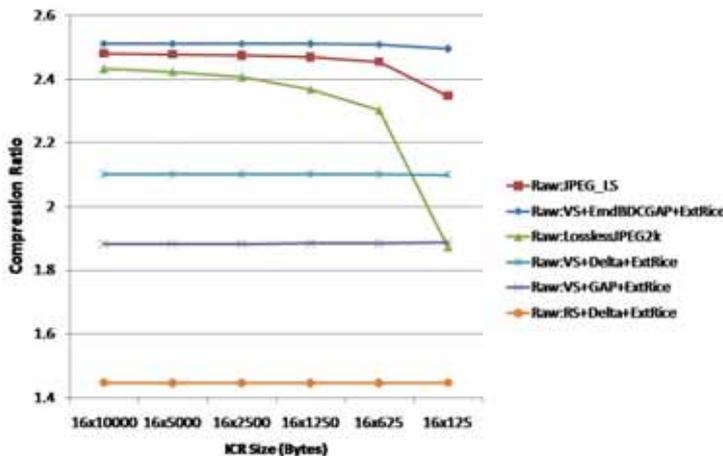 with pixel lengths of 8, 12 or 16bits/pixel. The performance of the algorithm was evaluated in terms of compression ratio for different sizes of the independent compression region (ICR), which controls the error resilience of the algorithm.

ICR defines the image area, within which an eventual error can propagate. Figure 5 shows a comparison with existing lossless compression algorithms, where the proposed algorithm (represented by the blue line) gives the highest ratio independently of the ICR byte size, while the top of the range JPEG-LS algorithm (represented by the red line) underperforms at the small ICR end. This evaluation was carried out using multispectral images from the SSTL UK-DMC satellite with 32m resolution.

Work on the implementation of the spectral decorrelation block in Figure 3 is in progress to cater for three dimensional (3-D) hyperspectral images. Hyperspectral imaging is a collection of measurements in a

> " The UK has a thriving space sector; one of the highest value-adding industries in the UK, contributing £6.5bn a year to the economy and supporting 68,000 jobs. It accounts for around 7% of the global market second, second only to the US in space science

large number (100s) of contiguous spectral bands. Among the possible decorrelating transforms the Karhunen-Loève Transform (KLT) provides the best performance. While KLT achieves lossy compression, the Integer KLT, which is a KLT approximation based on matrix factorization, is capable of lossless spectral decorrelation. Both KLT and the Integer KLT are extremely computationally-intensive, containing a large number of matrix multiplications and transformations, which are performed on matrices of a very large size, equal to the number of spectral bands. The aim of the research at present is to investigate if these algorithms are suitable for on-board use.

A novel SoC architecture for a KLT computational system was developed and prototyped on the Actel SmartFusion SoC platform by Chafik Egho, featuring a speedup of more than 54% compared with
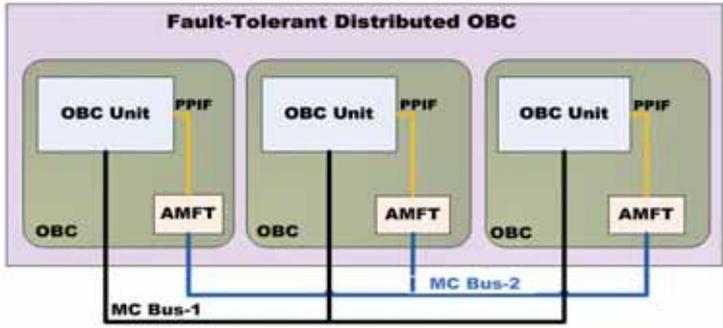


**Figure 5:** Lossless compression algorithm validation with DMC images

**Figure 6:** Fault-tolerant distributed on-board computer

the Cortex M-3 processor and power consumption of less than 225mW in the case of 32 spectral bands. The proposed hardware solution is scalable with respect to the number of spectral bands. Clustering and tiling techniques aimed at reducing the complexity of the Integer KLT and understanding their impact on performance have been investigated by Nor Rizuan Mat Noor. The airborne AVIRIS images (224 bands) and spaceborne EO-1 Hyperion images (242 bands) are used for testing. The Integer KLT is implemented and evaluated on the TI OMAP-L137 EVM board. Overall,

it takes around 3 to 5 minutes to encode the 224 bands of the AVIRIS hyperspectral images and from half-a-minute to 4 minutes for the Hyperion images. In an attempt to speed up the Integer KLT algorithm, parallelization using the OpenMP environment on a desktop PC is also accomplished, which reduces the execution time by 59% in average in the case of 4, 8 and 16 clusters of AVIRIS data.

The encryption block in Figure 3 was also implemented as a hardware accelerator by Dr Roohi Banu and can be incorporated in a SoC design. The accelerator is based on a

novel fault-tolerant model of the Advanced Encryption Standard (AES), which has an error detection and correction mechanism, built in its data path, allowing it to detect and correct an erroneous bit-flip, occurring during the encryption process.

## Fault-Tolerant, Distributed On-Board Computing

Current research at the University of Leicester is focused on fault-tolerant distributed computing architectures for reducing the impact of space debris on board observation satellites in low Earth orbit (LEO). The work is a part of the FP7 space project "*ReVuS: Reducing the Vulnerability of Space Systems*", coordinated by EADS Astrium France. A novel fault-tolerant distributed OBC (FTD-OBC) system is proposed, which is comprised of multiple OBC units, each being monitored by a separate functional block referred to as adaptive middleware for fault tolerance (AMFT) (Figure 6).

The AMFT detects faults/failures in the OBC units, isolates them and reconfigures the FTD-OBC accordingly. After reconfiguration of the FTD-OBC, the master OBC processor re-allocates the failed processor tasks to the other healthy OBC units in the group.
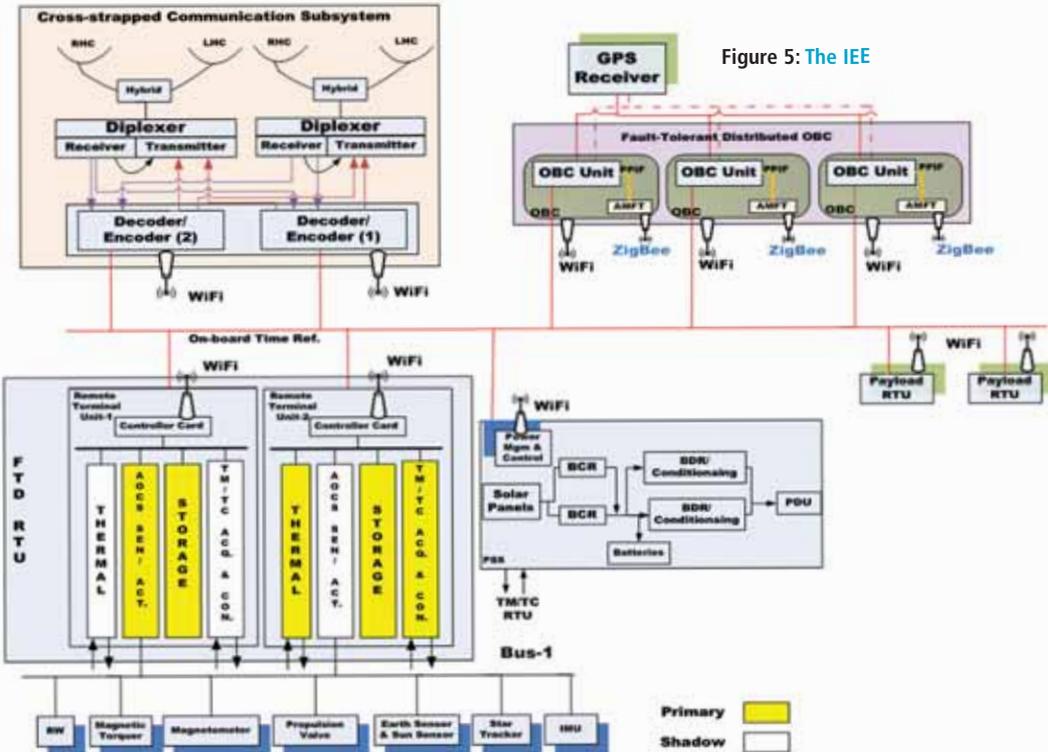
Wireless communication is less



**Figure 5:** The IEE

**Figure 7:** Wireless fault-tolerant distributed satellite platform architecture
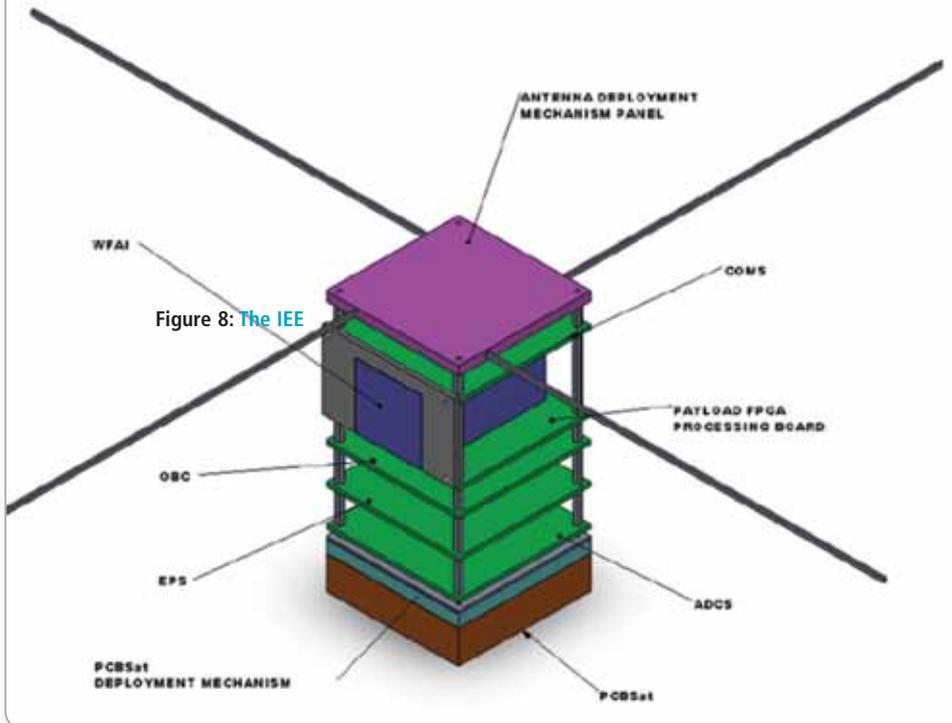
**Figure 8:** Leicester CubeSat model



Figure 8: The IEE

vulnerable to space debris impact than wired communication. A novel wirelessly connected satellite platform architecture, which is an extension of the FTD-OBC concept, is in a process of development (Figure 7). It features wireless communication links between all platform subsystems. WiFi (IEEE 802.11 a/g) communication links are introduced between the FTD-OBC and different platform subsystems and ZigBee (IEEE 802.15.4) is used for the communication between the AMFT blocks. ●

## THE UNIVERSITY OF LEICESTER CUBESAT PROJECT

The Department of Engineering and the Department of Physics & Astronomy of the University of Leicester are planning to develop a joint CubeSat mission for science and technology demonstration to participate in the European nanosatellite network project QB50, which aims to launch 50 CubeSats in 2015. A 3-D view of the CubeSat design is shown in Figure 8 (left). It will carry an innovative miniaturised ultraviolet Wide-Field Auroral Imager (WFAI) – a unique tool for high time resolution imaging of large areas of the auroral ovals that can provide crucial information improving our understanding of the dynamics of the terrestrial magnetosphere. In addition, the CubeSat will act as a mother-ship and will deploy a pico-satellite, referred to as satellite-on-a-printed circuit-board (PCBSat), which will be tethered to it, as shown in Figure 9.
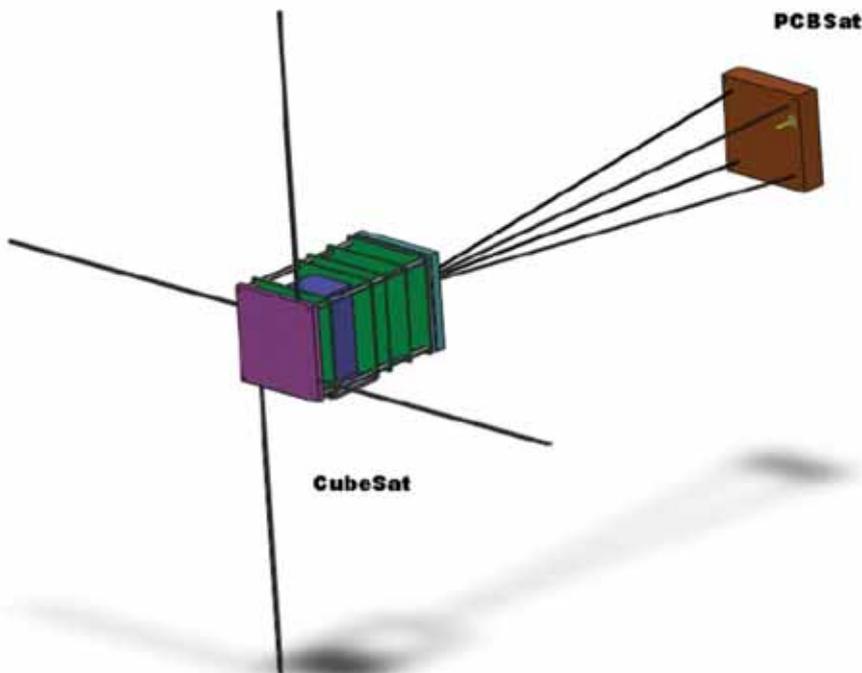
The pico-satellite will carry a miniaturised sensor for monitoring the plasma bubble phenomenon, which is known to cause communication and navigation satellite signal outages by scintillating the radio frequency (RF) signal between space and ground segments. The data, gathered by the pico-satellite, will be passed on to the CubeSat mother-ship via a wireless link for transmission to ground. There will be an advanced FPGA payload too, which will house a reconfigurable SoC design supporting high-performance computing and intersatellite communication. The SoC will be used to demonstrate a partial run-time reconfiguration in orbit.

At present the CubeSat team is in a process of looking for sponsorship to cover launch and development costs, following the acceptance of the proposed CubeSat mission for participation in QB50 on the condition that evidence of funding was obtained by the end of September 2012.

> **The CubeSat team is in a process of looking for sponsorship to cover launch and development costs, following the acceptance of the proposed CubeSat mission for participation in QB50**

**Figure 9:** Leicester CubeSat – deployed configuration

# AIRCRAFT STRUCTURES
# TAKE ADVANTAGE OF ENERGY HARVESTING IMPLEMENTATIONS

**TONY ARMSTRONG**, DIRECTOR OF PRODUCT MARKETING FOR POWER PRODUCTS AT LINEAR TECHNOLOGY CORPORATION, EXPLAINS THE IMPORTANCE OF HEALTH CHECKING AIRCRAFTS AND THE LOW-POWER SYSTEMS THAT HELP IN THIS PROCESS

Major incidents have been known to push mankind's awareness to the forefront.

On April 28th 1988 an Aloha Airlines Flight broke apart some 23 minutes after take-off. A small section on the left side of the roof ruptured, resulting in an explosive decompression that tore off a large section of the roof, consisting of the entire top half of the aircraft skin extending from just behind the cockpit to the fore-wing area. The electrical wiring from the nose gear to the indicator light on the cockpit instrument panel was also severed. As a result, the light did not illuminate when the nose gear was lowered, so the pilots had no way of knowing if it had fully extended. Fortunately, the crew was able to perform an emergency landing whereupon they deployed the aircraft's evacuation slides and evacuated passengers from the aircraft quickly. In all, there was one fatality and 65 people injured.

An investigation by the United States National Transportation Safety Board (NTSB) concluded that the accident was caused by metal fatigue exacerbated by crevice corrosion (the plane operated in a coastal environment, with exposure to salt and humidity). The root cause of the problem was failure of an epoxy adhesive used to bond the aluminum sheets of the fuselage together when the Boeing 737 was manufactured. Thus, water was able to enter the gap where the epoxy failed to bond the two surfaces together properly and started the corrosion process. The conclusion was that the age of the aircraft was the overriding factor in the accident, and that in order to prevent the likelihood of future occurrences, all aircraft should receive regular fuselage maintenance checks.

> " In an aircraft environment there are a number of "free" energy sources available to power such sensors

## Aircraft Health Monitoring

There can be no doubt that the structural fatigue of today's large fleet of aircraft is a serious issue and needs to be addressed. This is being accomplished through inspections, improved structural-analysis and tracking methods and by incorporating new and innovative ideas for assessing structural integrity. This is sometimes referred to as "health monitoring of aircraft". This process incorporates sensors, artificial intelligence and advanced analytical techniques to produce real time and continual health assessment.

Acoustic emission detection is a well-established method of locating and monitoring crack development in metal structures. It can be readily applied for the diagnosis of damage in composite aircraft structures. A clear requirement is a level form of 'go/no go' indications of structural integrity or the need for immediate maintenance actions. The technology comprises low profile detection sensors using piezoelectric wafers, encapsulated in polymer film, and optical sensors. Sensors are bonded to the structure's surface, which enables acoustic events from the loaded structure to be located by triangulation. Instrumentation is then used to capture and parameterize the sensor data in a form suitable for low-bandwidth storage and transmission.

Thus, although wireless sensor modules are often embedded in various airplane sections for structural analysis, wings or fuselage for example, powering them can be cumbersome. Therefore, these sensor modules are more convenient and efficient when powered wirelessly, or even when self-powered.

In an aircraft environment there are a number of "free" energy sources available to power such sensors. Two obvious methods are thermal energy harvesting and piezoelectric energy harvesting, each with its own pros and cons.

## Energy-Harvesting Basics

Transducers that create electricity from readily available physical sources, such as temperature differentials (thermoelectric generators or thermopiles), mechanical vibration or strain (piezoelectric or electromechanical devices) and light (photovoltaic devices), are viable sources of power for many applications. Numerous wireless sensors, remote monitors and other low-power applications are on track to become near "zero" power devices using
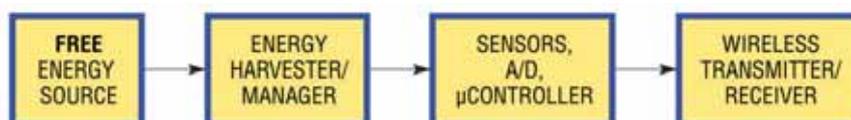


**Figure 1: The four main blocks of a typical energy-scavenging system**

only harvested energy.

Even though the concept of energy harvesting has been around for a number of years, the implementation of a system in a real world environment has been cumbersome, complex and costly. Nevertheless, examples of markets where an energy harvesting approach has been used include transportation infrastructure, wireless medical devices, tire pressure sensing and building automation.

A typical energy scavenging configuration or system (represented by the four main circuit system blocks shown in Figure 1), usually consists of a free energy source. Examples of such sources include a thermoelectric generator (TEG) or thermopile attached to a heat-generating source, such as an aircraft engine, or a piezoelectric transducer attached to a vibrating mechanical source, such as an aircraft airframe or wing.

In the case of a heat source, a compact thermoelectric device can convert small temperature differences into electrical energy. And where vibration or strain is available, a piezoelectric device can convert these small vibrations or strain differences into electrical energy. In either case, the electrical energy produced can be converted by an energy harvesting circuit (the second block in Figure 1) and modified into a usable form to power downstream circuits. These downstream electronics usually consist of some kind of sensor, an analog-to-digital converter and an ultra-low-power microcontroller (the third block in Figure 1). These components can take this harvested energy, now in the form of an electric current, and wake up a sensor to take a reading or a measurement and then make this data available for transmission via an ultralow power wireless transceiver – represented by the fourth block in the circuit chain shown in Figure 1.

Each circuit system block in this chain, with the possible exception of the energy source itself, has had its own unique set of constraints that have impaired its economical viability until now. Low cost and low power sensors and microcon-trollers have been available for a couple of years; however, it is only recently that ultra low power transceivers have become commercially available. Nevertheless, the laggard in this chain has been the energy harvester.

Existing implementations of the energy harvester block typically consist of low performing discrete configurations, usually comprising 30 or more
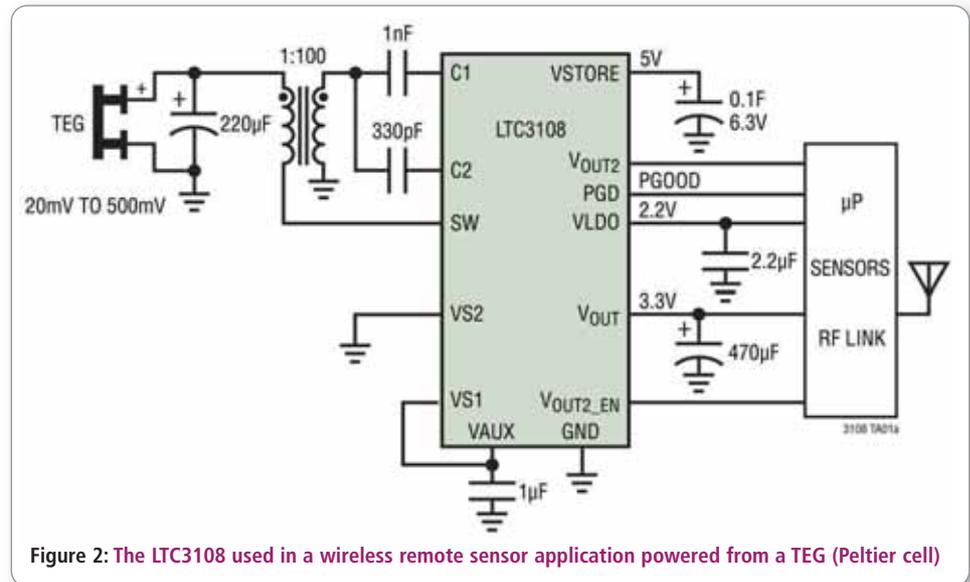


Figure 2: The LTC3108 used in a wireless remote sensor application powered from a TEG (Peltier cell)

components. Such designs have low conversion efficiency and high quiescent currents. Both of these deficiencies result in compromised performance in end-systems. The low conversion efficiency increases the amount of time required to power up a system, which in turn increases the time interval between taking a sensor reading and transmitting the data. A high quiescent current limits how low the output of the energy-harvesting source can be, since it must first overcome the current level needed for its own operation before it can supply any excess power to the output.

## Energy-Harvesting Transducers and ICs

The core component of a thermoelectric device is a thermocouple, which consists of an n-type and a p-type semiconductor connected by a metal plate. Electrical

> In the case of a heat source, a compact thermoelectric device can convert small temperature differences into electrical energy

connection at the opposing ends of the p- and n-type material complete an electric circuit. Thermoelectric generation (TEG) occurs when the couple is subjected to a thermal gradient, in which case the device generates a voltage and causes current to flow, thereby converting heat into electrical power by what is known as the

Seebeck effect. A thermoelectric module is then formed from arrays of these thermocouples connected in series. If heat is flowing between the top and bottom of the module, a voltage will be produced and an electric current will flow.

In the case of a typical airplane engine, its temperature can vary anywhere from several hundred degrees Celsius to 1,000ºC and even 2,000ºC. Although most of this energy is converted in mechanical energy (from combustion and thrust), a portion is dissipated purely as heat. Since the Seebeck effect is the underlying thermodynamic phenomenon that converts thermal heat to electric power, the main equation to take into consideration is:

$$P = \eta Q$$

where P is electrical power, Q is heat and $\eta$ is efficiency.

Larger TEGs that use more heat, Q, produce more power, P. Similarly, the use of twice as many power converters naturally produces twice the power, given that they can capture twice the heat. Larger TEGs are created by putting more P-N junctions in series; however, while this creates more millivolts per delta T (mV/dT), it also increases the series resistance of the TEG. This increased series resistance limits the power available to the load. Therefore, depending on the application requirements, it is sometimes better to use smaller TEGs in parallel rather than a larger TEG. Regardless of which choice is used, TEGs are commercially available from a number of suppliers, including Tellurex Corp.

Figure 3: **The LTC3108 block diagram**

Piezoelectricity can be generated by applying stress to an element, which in turn creates an electric potential. The piezoelectric effect is reversible in that materials exhibiting the direct piezoelectric effect (the production of an electric potential when stress is applied) also exhibit the reverse piezoelectric effect (the production of stress and/or strain when an electric field is applied).

In order to optimize a piezo transducer, one needs to characterize its source for vibration frequency and displacement. Once these levels have been determined, a piezo manufacturer can design a piezo that is mechanically tuned to the specific vibration frequency and size it to provide the necessary amount of power. The vibration in the piezo material activates the direct piezo effect, which results in the accumulation of charge on the output capacitance of the device. This is usually pretty small so the AC open circuit voltage is high – of the order of 200V in many cases. Since the amount of charge generated from each deflection is relatively small, it is necessary to full-wave rectify this AC signal and accumulate the cycle-by-cycle charge on an input capacitor. Once again, there are a number of piezoelectric transducers available from a number of suppliers, including AmbioSystems, MIDE Technology Corp and Advanced Cerametrics Inc.

However, what has been missing until now is a highly integrated, high efficiency

DC/DC converter solution that can both harvest and manage the energy from either a thermal or piezoelectric source. Linear Technology's LTC3108 and LTC3588-1 will greatly simplify the task of harvesting surplus energy from a variety of sources.

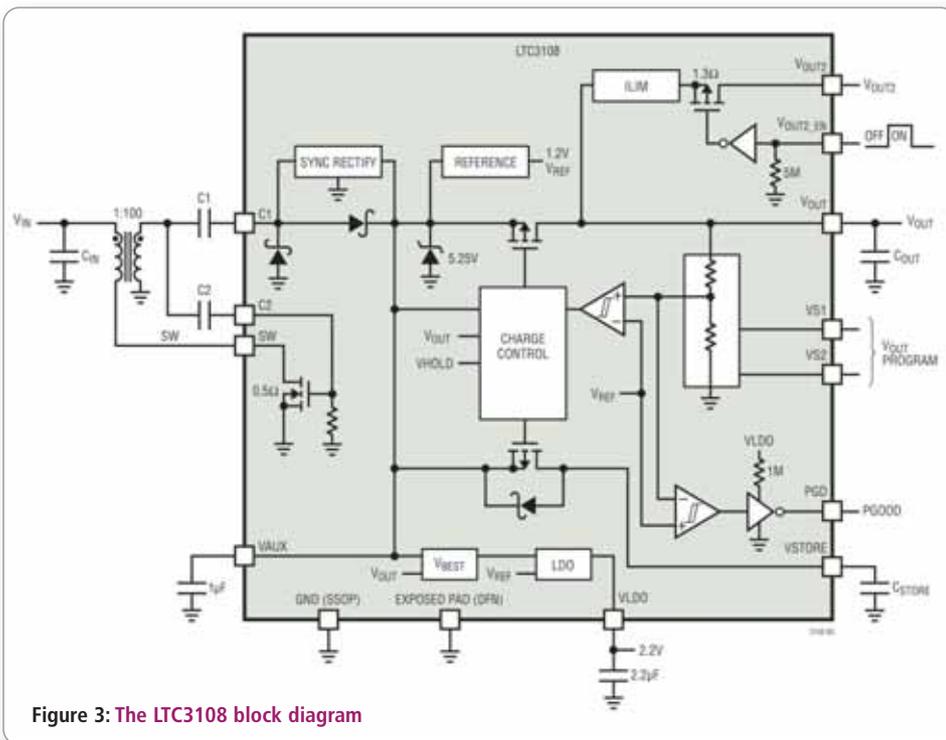The recently introduced LTC3108 is an ultra-low voltage step-up converter and power manager, specifically designed to greatly simplify the task of harvesting and managing surplus energy from extremely low input voltage sources such as thermopiles, thermoelectric generators (TEGs) and even small solar panels. Its step-up topology operates from input voltages as low as 20mV. This is significant since it allows the LTC3108 to harvest energy from a TEG with as little as 1°C temperature differential – something a discrete implementation struggles to meet due to its high quiescent current.

The circuit shown in Figure 2 uses a small step-up transformer to boost the input voltage source to a LTC3108 which then provides a complete power management solution for wireless sensing and data acquisition. It can harvest small temperature differences and generate system power instead of using traditional battery power.

The LTC3108 utilizes a depletion mode N-channel MOSFET switch to form a resonant step-up oscillator using an external step-up transformer and a small coupling capacitor. This allows it to boost

input voltages as low as 20mV, high enough to provide multiple regulated output voltages for powering other circuits. The frequency of oscillation is determined primarily by the inductance of the transformer's secondary winding and input capacitance of the LTC3108 and is typically in the range of 20kHz to 200kHz.

For input voltages as low as 20mV, a primary-secondary turns ratio of about 1:100 is recommended. For higher input voltages, a lower turns ratio can be used, since it will provide greater output power. These transformers are standard, off-the-shelf components, and are readily available from magnetic suppliers.

Linear's compound depletion mode N-channel MOSFET is what makes 20mV operation possible. As can be seen in Figure 3, the LTC3108 takes a "systems level" approach to solving a complex problem. It can convert the low voltage source and manage the energy between multiple outputs.

The AC voltage produced on the secondary winding of the transformer is boosted and rectified using an external charge pump capacitor (from the secondary winding to pin C1) and the rectifiers internal to the LTC3108. This rectifier circuit feeds current into the VAUX pin, providing charge to the external VAUX capacitor and then the other outputs.

The internal 2.2V LDO can support a low-power processor or other low power ICs. The LDO is powered by the higher value of either VAUX or VOUT. This enables it to become active as soon as VAUX has charged to 2.3V, while the VOUT storage capacitor is still charging. In the event of a step load on the LDO output, current can come from the main VOUT capacitor if VAUX drops below VOUT. The LDO output can supply up to 3mA.

The main output voltage on VOUT is charged from the VAUX supply and is user programmable to one of four regulated voltages using the voltage select pins VS1 and VS2. The four fixed output voltages are: 2.35V for supercapacitors, 3.3V for standard capacitors and RF or sensor circuitry, 4.1V for lithium-ion battery termination and 5V for higher energy storage and a main system rail to power a wireless transmitter or sensors – thereby eliminating the need for multi-meg-Ohm external resistors. As a result, the LTC3108 does not require special board

coatings to minimize leakage, as do discrete designs where very large value resistors are required.

A second output, VOUT2, can be turned on and off by the host microprocessor using the VOUT2_EN pin. When enabled, VOUT2 is connected to Vout through a P-channel MOSFET switch. This output can be used to power external circuits such as sensors or amplifiers that do not have low power sleep or shutdown capability. An example of this would be to power a MOSFET on and off as part of a sensing circuit within a building thermostat.

The VSTORE capacitor may be a very large value (thousands of microfarads or even farads) to provide holdup at times when the input power may be lost. Once power-up is completed, the main, backup and switched outputs are all available.

If the input power fails operation can still continue, operating off the VSTORE capacitor. The VSTORE output can be used to charge a large storage capacitor or rechargeable battery after VOUT has reached regulation. Once VOUT has reached regulation, the VSTORE output is allowed to charge up to the VAUX voltage, which is clamped at 5.3V. Not only can the storage element on VSTORE be used to power the system if the input source is lost, but it can also be used to supplement the current demanded by VOUT, VOUT2 and the LDO outputs if the input source has insufficient energy.

A power-good comparator monitors the VOUT voltage. Once VOUT has charged to within 7% of its regulated voltage, the PGOOD output will go high. If VOUT drops more than 9% from its regulated voltage, PGOOD will go low. The PGOOD output is designed to drive a micro-processor or other chip I/O and is not intended to drive a higher current load such as an LED.

The circuit shown in Figure 4 utilizes a small piezoelectric transducer to convert mechanical vibration into an AC voltage source that is fed into the LTC3588-1's internal bridge rectifier. It can harvest energy from small vibration sources and generate system power instead of using traditional battery power.

The LTC3588-1 is an ultralow quiescent current power supply designed specifically for energy harvesting and/or low current step-down applications. It can interface directly to a piezoelectric or alternative AC power source, rectify the voltage waveform and store harvested energy in an external
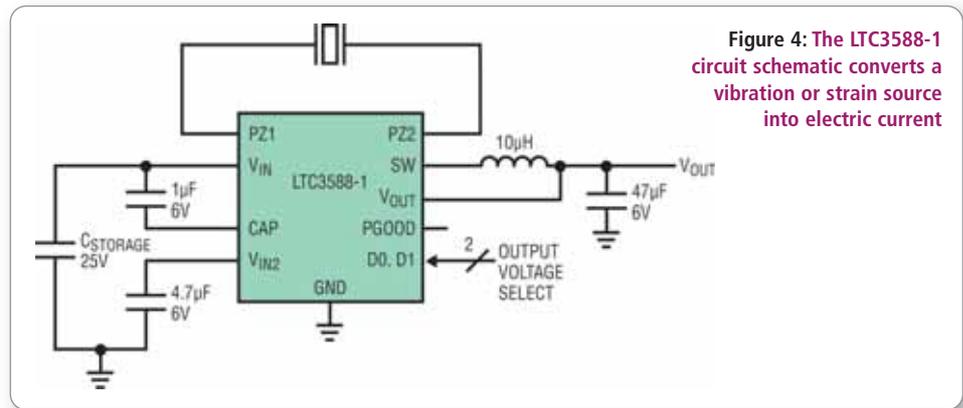
capacitor, bleed off any excess power via an internal shunt regulator and maintain a regulated output voltage by means of a nanopower high efficiency buck regulator.

The LTC3588-1's internal full-wave bridge rectifier is accessible via two differential inputs, PZ1 and PZ2, which rectify AC inputs. This rectified output is then stored on a capacitor at the VIN pin and can be used as an energy reservoir for the buck converter. The low-loss bridge rectifier has a total voltage drop of about 400mV with typical piezo generated currents, which are normally around 10µA. This bridge is capable of carrying up to 50mA of current. The buck regulator is enabled once there is sufficient voltage on VIN to produce a regulated output.

The buck regulator uses a hysteretic voltage algorithm to control the output through internal feedback from the VOUT sense pin. The buck converter charges an output capacitor through an inductor to a value slightly higher than the regulation point. It does this by ramping the inductor current to 260mA through an internal PMOS switch and then down to 0mA through an internal NMOS switch, thereby efficiently delivering energy to the output capacitor. Its hysteretic method of providing a regulated output reduces losses associated with FET switching and maintains an output at light loads. The

buck converter delivers a minimum of 100mA of average load current when it is switching.

## Best Methods

With respect to the energy source choice, there are trade-offs between thermal and piezoelectric sources. Table 1 summarizes the pros and cons between these two methods.

With analog switchmode power supply design expertise in short supply around the globe, it has been difficult to design an effective energy harvesting system, as illustrated in Figure 1. However, with the introduction of the LTC3108 and LTC3588-1 that's about to change. These devices can extract energy from almost any source of heat or mechanical vibration, both of which are commonly found in an airplane environment. Furthermore, with their comprehensive feature sets and ease of design, they greatly simplify the hard-to-do power conversion design of an energy harvesting chain. This is good news for the designer of aircraft health monitoring systems because their high integration, including power management control and off-the-shelf external components, make them the smallest, simplest and most easy-to-use solutions available to complete the energy harvesting chain. ●

| | Pros | Cons |
|---|---|---|
| Thermal | Able to continuously supply DC power. | Temperature differentials can be difficult to implement in enclosed environments (see note below). |
| Piezoelectric | Does not need to be manually charged. The aircraft provides plenty of vibrational force. | Each element has to be manually tuned to the aircraft's vibrational frequency. |

Table 1: Pros and cons of thermal and piezoelectric method.
Note: The best opportunity for temperature differential in an aircraft is between the aircraft 'skin' on the inside of the cabin and the internal cabin temperature

# CIRCUIT MODELLING

ANYONE WHO HAS USED SPICE SOFTWARE WILL BE WELL AWARE THAT EVERY SOFTWARE PACKAGE CONTAINS A LARGE LIBRARY OF CIRCUIT MODELS, ANY OF WHICH CAN BE INSERTED INTO THE CIRCUIT DIAGRAM UNDER DEVELOPMENT. HOWEVER, THE PURPOSES TO WHICH CIRCUIT MODELLING CAN BE APPLIED IS MUCH WIDER THAN MOST DESIGNERS REALISE. BY **IAN DARNEY**

**I**n mechanical engineering, the equation of motion for a mass on a spring, as illustrated by Figure 1, can be set out as:

$$f = m \cdot \ddot{y} + r \cdot \dot{y} + s \cdot y \qquad (1)$$

This equation can be correlated with the response of the LCR circuit of Figure 2:

$$V = L \cdot \frac{dI}{dt} + R \cdot I + C \cdot q \qquad (2)$$

where the parallels are:

| f | force | voltage | V |
|---|---|---|---|
| y | displacement | charge | q |
|   | velocity | current | I |
|   | acceleration | rate of change of current |   |
| m | mass | inductance | L |
| s | compliance | capacitance | C |

This type of correlation was put to practical use in the sixties during the design of the dynamic control system for the Rapier rocket.

## Transformer Model

The same approach can be adopted to analyse the magnetic coupling between two independent circuit loops. Figure 3 depicts an assembly of four parallel conductors, configured as two separate loops. Loop 1 has a sinusoidal source applied to the near end, and the terminals at the far end are short circuited. Terminals at both ends of loop 2 are short circuited.

Magnetic field theory can be used to define the partial voltage components in each of the four conductors in terms of the geometry of the assembly, and then to simplify the relationships to create a pair of loop equations:

$$V_1 = j \cdot \omega \cdot L_{1,1} \cdot I_1 + j \cdot \omega \cdot L_{1,2} \cdot I_2$$
$$0 = j \cdot \omega \cdot L_{2,1} \cdot I_1 + j \cdot \omega \cdot L_{2,2} \cdot I_2 \qquad (3)$$



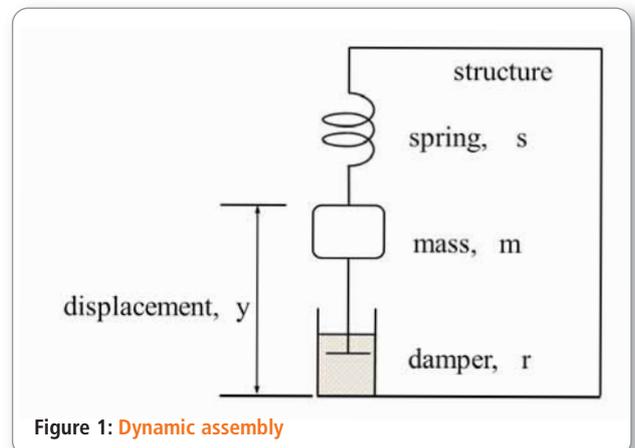**Figure 1: Dynamic assembly**



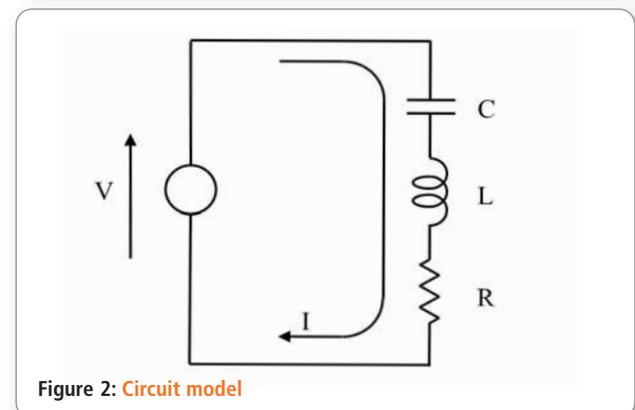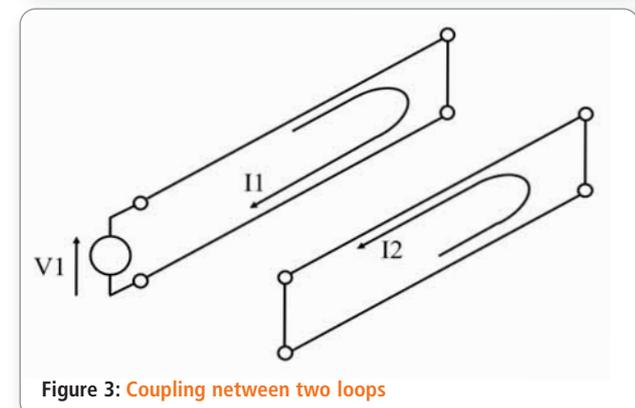**Figure 2: Circuit model**



**Figure 3: Coupling netween two loops**
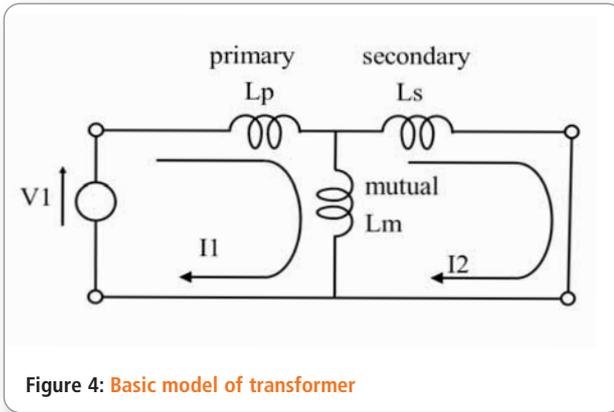
Figure 4: **Basic model of transformer**



Figure 5: **Coupling over ground plane**

I1 and I2 are the loop currents, L1,1 is the inductance of loop 1, L1,2 is the mutual inductance, and L2,2 is the inductance of loop 2.

It is possible to hypothesise the existence of a circuit model which can be used to formulate a similar pair of equations (Figure 4). Applying mesh analysis to this model gives the circuit equations:

$$V_1 = j \cdot \omega \cdot (Lp + Lm) \cdot I_1 - j \cdot \omega \cdot Lm \cdot I_2$$
$$0 = -j \cdot \omega \cdot Lm \cdot I_1 + j \cdot \omega \cdot (Ls + Lm) \cdot I_2 \quad (4)$$

Since the form of the two sets of equations is identical, it is possible to define the circuit parameters in terms of the loop parameters.

$$Lp = L_{1,1} - L_{1,2}$$
$$Lm = L_{1,2}$$
$$Ls = L_{2,2} - L_{1,2} \quad (5)$$

The circuit of Figure 4 is the basic model of any transformer; Lp is the primary self-inductance, Lm is the mutual inductance, and Ls is the self-inductance of the secondary.

## Underlying Concept

At this point it is well worth reflecting on the methodology involved in the creation of each circuit model. Figure 2 was introduced to allow the dynamic behaviour of a mechanical system to be simulated using an analogue computer. Figure 4 was created to simulate the interactions involved in magnetic field coupling. In both cases, the circuit model can be defined as a fictitious entity. In both cases, the use of a circuit model allows the physical behaviour of the system-under-review to be simulated using circuit theory.

In the case of the transformer model, it allows the complex inter-relationship of magnetic fields to be analysed using the much simpler mathematics of circuit theory. The basic rules of circuit theory are quite different from those of electromagnetic theory.

The circuit model can be regarded as the modern equivalent of the Arabic invention of the unknown variable. A diagram is used to define a set of differential equations.

## The Ground Conductor

A standard technique used in electromagnetic theory is the 'Method of Images', which exploits the known properties of conducting surfaces. The magnetic field due to a conductor routed over a ground plane can be analysed by assuming that the plane is replaced by an image conductor located below the plane. Figure 5 illustrates a configuration where two conductors are routed over such a conducting surface, as well



Figure 6: **Three-conductor model. Inductive coupling**



Figure 7: **Three-conductor model. Capacitive coupling**



Figure 8: **Electromagnetic coupling model**

**Figure 9: Signal link**



**Figure 10: Two-conductor transmission line – distributed parameters**



**Figure 11: Three-conductor transmission line – distributed parameters**
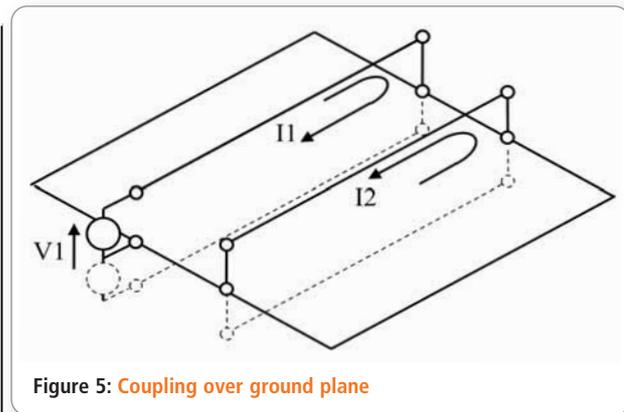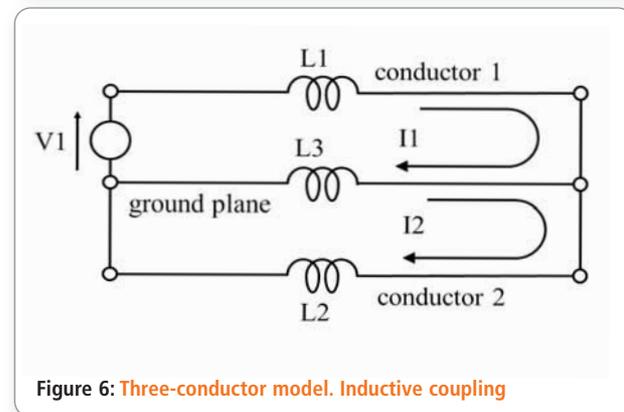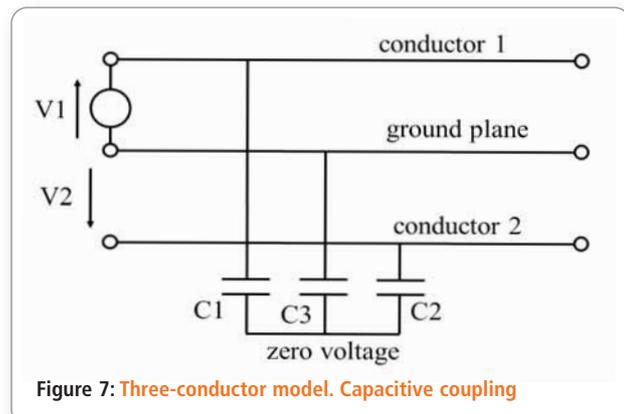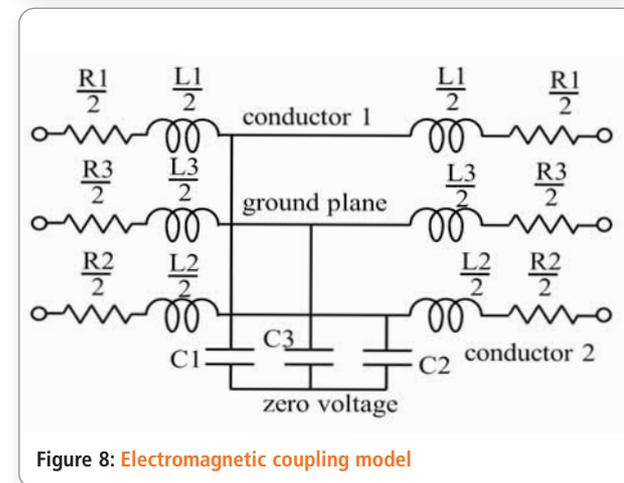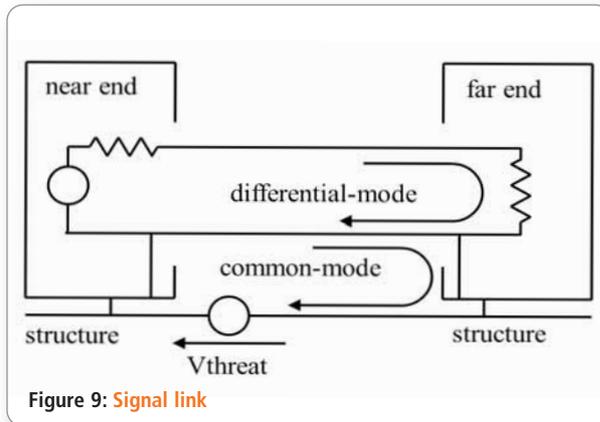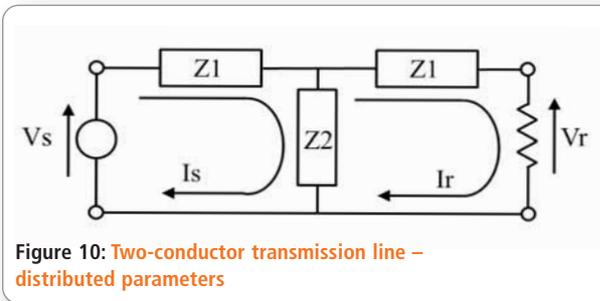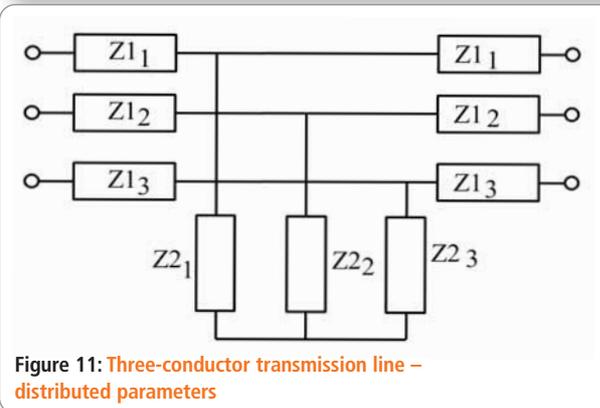
as indicating the location of the image conductors.

If the ground plane is replaced by the image conductors, the assembly reverts to that depicted by Figure 3; that used to analyse the magnetic coupling between two separate loops. It follows that the circuit model of Figure 4 can be used to analyse the coupling between two conductors over a ground plane. This time there is a clear correlation between the conductors of the assembly under review and the components of the circuit model, as illustrated by Figure 6. The values of the inductors L1, L2 and L3 can be evaluated by using data from the physical construction.

## Electric Field Coupling

Electric field coupling can be analysed in exactly the same way. If the short-circuits are removed from the terminations of the assembly of Figure 5, then the resultant circuit model would be as shown on Figure 7 and, again, the values of the three circuit components can be evaluated using data on the physical construction. The temptation to carry out a star to delta transformation is resisted, since such an action would cause the zero-volt terminal to disappear.

## Electromagnetic Coupling

Combining the models of Figures 6 and 7 leads to Figure 8, a circuit model which simulates the effect of both the magnetic field and the electric field. That is, it simulates the effect of the electromagnetic field. In almost every problem involving unwanted coupling, the highest amplitude of interference occurs at resonance. So it is essential for any analysis to consider the combined effects of inductance, capacitance and resistance.

A key feature of this model is the fact that each conductor is represented by a T-network. Invoking the concept of the equivalent circuit, the parallel combination of any two conductors can also be represented by a single T-network. Extending the concept further, the ground conductor of the model can be used to represent all the other conductors in the assembly-under-review. Where the structure itself is made from conducting material, the terms 'structure' and 'ground' become synonymous.

## Conducted Susceptibility

Given this assumption, it becomes possible to simulate the coupling between the common-mode loop and the differential-mode loop in assemblies such as that illustrated in Figure 8. In this configuration, the principle of superposition allows the combined effect of all external sources of interference to be represented by the voltage source Vthreat in series with the structure.

The applicability of the model of Figure 8 is limited to the simulation of frequencies well below that of quarter-wave resonance. But that does not mean that circuit models are incapable of simulating high-frequency effects.

## Transmission Lines

Transmission line theory caters for the fact that currents and voltages vary along the length of any conductor and introduces the concept of distributed parameters (Henrys per metre, Farads per metre, etc). Analysis of such a line results in the formulation of a pair of hybrid equations.

$$Vs = Vr \cdot \cosh(\gamma \cdot l) + Zo \cdot Ir \cdot \sinh(\gamma \cdot l)$$
$$Is = \frac{Vr}{Zo} \cdot \sinh(\gamma \cdot l) + Ir \cdot \cosh(\gamma \cdot l)$$

(6)

where:

$$\gamma = \frac{1}{l} \cdot \sqrt{(R + j \cdot \omega \cdot L) \cdot (G + j \cdot \omega \cdot C)}$$
$$Zo = \sqrt{\frac{R + j \cdot \omega \cdot L}{G + j \cdot \omega \cdot C}}$$

(7)

and where R, L, C and G are the resistance, inductance, capacitance, and conductance of the line, Zo is the characteristic impedance, ω is the propagation constant, and l is the length.

These equations allow the current and voltage at one termination to be related to the current and voltage at the other end, at any particular frequency. Since the propagation of energy along the conductors of any transmission line matches that of the associated electromagnetic wave, these hybrid equations are valid over the same range as that covered by electromagnetic theory.

If it is hypothesised that a circuit model exists which replicates the relationships of the hybrid equations, then that model can be used over the range of frequencies at which the Maxwell equations are valid. Figure 10 illustrates such a model.

A pair of loop equations can be formulated from an inspection of the model. Manipulating the relationships leads to a pair of hybrid
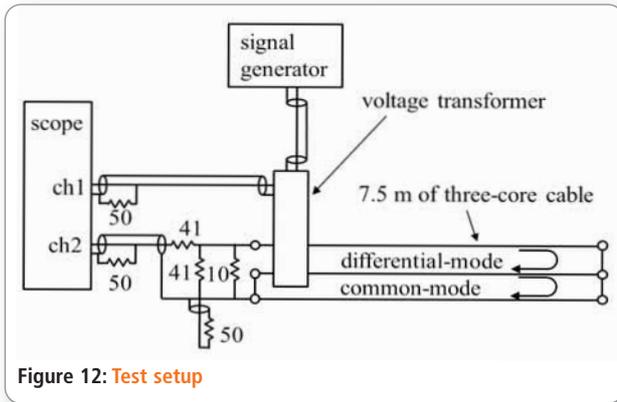
**Figure 12: Test setup**



**Figure 13: Transfer admittance of short-circuited line**



**Figure 14: Transfer admittance of open-circuited line**

equations which match those of equation set 6. Correlating the terms of the two sets of equations enables the impedances of the circuit model to be defined in terms of the characteristic impedance and the propagation constant.

$$Z1 = Zo \cdot \tanh\left(\frac{\gamma \cdot l}{2}\right)$$
$$Z2 = Zo \cdot \text{cosech}(\gamma \cdot l) \tag{8}$$

It may be that the impedances Z1 and Z2 are derived from an unconventional process, but the fact remains that they are impedances. Also, there is a clear correlation between the impedance values of Figures 8 and 10:

$$\frac{1}{2} \cdot (R + j \cdot \omega \cdot L) \rightarrow Z1$$
$$\frac{1}{G + j \cdot \omega \cdot C} \rightarrow Z2 \tag{9}$$

It is worth repeating that, since the hybrid equations are valid over the same range of frequencies as that covered by the Maxwell equations, then so is the model of Figure 10.

## Three-Conductor Transmission Line

Applying this transformation to the triple-T network of Figure 8 leads to the distributed-parameter model of a three-conductor transmission line: Figure 11. Although this model has been derived using an unconventional process, the fact remains that it is a circuit model. As such, it can be analysed using any of the techniques available in circuit theory.

The best way of confirming the validity of such a model is to carry out tests on a particular configuration and compare the test results with those derived from a simulation. So this was done.

Figure 12 illustrates the setup used to characterise a 7.5 metre length of flexible, three-core, mains cable. A wideband voltage transformer was used to inject a sinusoidal voltage into the common-mode loop and the amplitude of this voltage was monitored on channel 1 of the oscilloscope. The electromagnetic field caused by the current in the common-mode loop created a differential-mode signal, and this signal was monitored by channel 2.

By monitoring the peak-to-peak voltage of each channel, it was possible to calculate the ratio of the current in the differential-mode loop to the voltage induced in the common-mode loop; the transfer admittance, YT. By repeating the test at a number of spot frequencies, a graph was created which relates transfer admittance to frequency.

Component values were assigned to the model of Figure 8 using data on the physical construction of the cable, and components added to simulate the interface circuitry at the terminations. Then the response of the model, YTm, was compared to that of the actual hardware, YT2. The end result is illustrated by Figure 13.
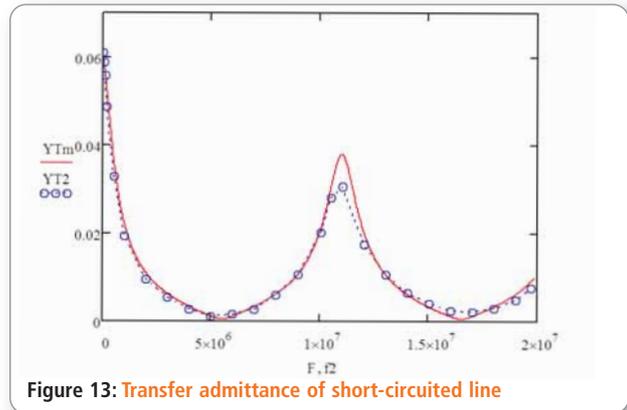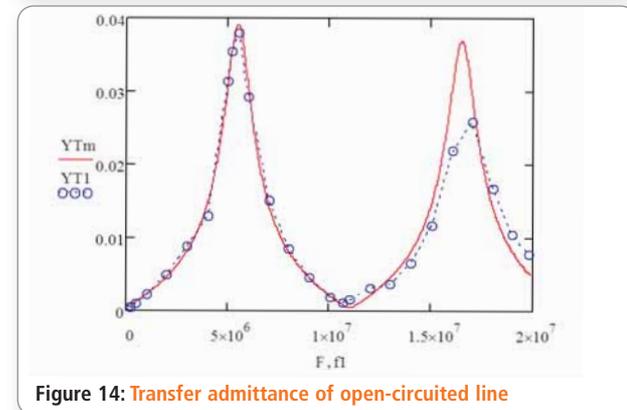
It is clear from the near coincidence of the two curves that the model is accurate at frequencies up to and beyond half-wave resonance; that is, the peak at 10.5MHz.

To double-check the validity of the model, the short-circuits were removed from the far end of the cable-under-test and the test was re-run. The same thing was done to the model and the simulation was re-run. Figure 14 illustrates the open-circuit responses of test and model.

The close correlation between test results and those of the model provides convincing evidence that this technique can simulate interference coupling over a range of frequencies which extends well beyond that of quarter-wave resonance.

The process of modelling and testing, as described above, can be applied to any signal link of the form illustrated by Figure 9, and can be used to assess conducted emission as well as conducted susceptibility.

## Valuable Analytical Tools

Electromagnetic fields are present in and around the internal workings of integrated circuits and printed circuit boards just as surely as they permeate the environment, but we do not use electromagnetic theory to analyse how these circuits perform.

Circuit theory is a development and simplification of electromagnetic theory. It has provided valuable analytical tools to designers over the past century in simulating the behaviour of complex signal processing equipment. With a little bit of development, circuit modelling can also be used to analyse and solve a wide range of interference problems. This enables system designers to assess the electromagnetic compatibility of equipment for themselves, without the need to rely on the advice of experts. ●

# OPTIMAL TESTING PRACTICES

**JEAN-LOUIS EVANS** FROM TUV SUD PRODUCT SERVICE GIVES A PRACTICAL AND USEFUL GUIDE ON WHEN IT IS AND IT ISN'T APPROPRIATE TO TEST A PRODUCT, AND WHERE TO USE SHORTCUTS IF POSSIBLE



Climatic testing – ice conditions

**T**he benefits for testing electrical products, both pre-production and as part of an ongoing audit process to ensure continued compliance, are obvious. While electrical testing is more critical than ever, to ensure that products are safe before they reach the end user it can be duplicated unnecessarily to 'cover all bases'.

It seems that confusion and fear are frequently ruling over common sense because there is such a range of electrical product safety standards, as well as many legal actions pending in various courts around the world. The result is that customers' demands regularly reflect a poor understanding of the intended environment and the specifications used to qualify it, if a product should be tested. Consequently, most designers and manufacturers err on the side of caution and often over test their products. This not only wastes money through unnecessary testing costs, but occasionally slows the launch of new products in a competitive market.

Before we look at over testing and how to address it, it's worthwhile reminding ourselves of the good reasons for testing products in the first place. These include a contractual requirement where the designer or supplier of a product is obliged by their purchaser to undertake particular tests. However, always bear in mind that this does not mean that those demands should not be refined or challenged.

## Price Reputation

Protecting a brand's reputation is a major factor for ensuring that tests are done correctly and are indeed a key reason why products undergo 'over testing'. Brand loyalty can be quickly lost if a product is defective, unreliable, or, in the worst case scenario, it injures someone. It is usually agreed that

effective testing and product development therefore helps to sustain brand loyalty.

Linked with brand reputation is the issue of warranties, as the cost of post-sale warranty returns is also another key driver for ensuring that the correct

> **"** Confusion and fear are frequently ruling over common sense because there is such a range of electrical product safety standards, as well as many legal actions pending in various courts around the world

tests are done to help reduce product failures. Warranty returns on a poor product can cause considerable problems and their importance is highlighted by the fact that many

serious complaints are usually handled at a high level within a business.

The warranty issue is linked closely with customer satisfaction. It's obvious that customers will have more confidence in their suppliers if they can prove that they have an effective test strategy in place. Also, in some markets advertising that the product is compliant to a particular standard gives it a marketing advantage over competitive offerings. Being able to demonstrate to customers that you are a diligent supplier, even if they do not require it contractually, will inevitably give them greater confidence in the product and in you as a supplier.

This brings us back to the issue of brand reputation, as customer satisfaction is also maintained if the product is reliable in service. I would like to say satisfaction is increased if a product is highly reliable. However, the truth is probably that satisfaction can only be maintained or lost because of good or poor reliability.

Another issue that drives a
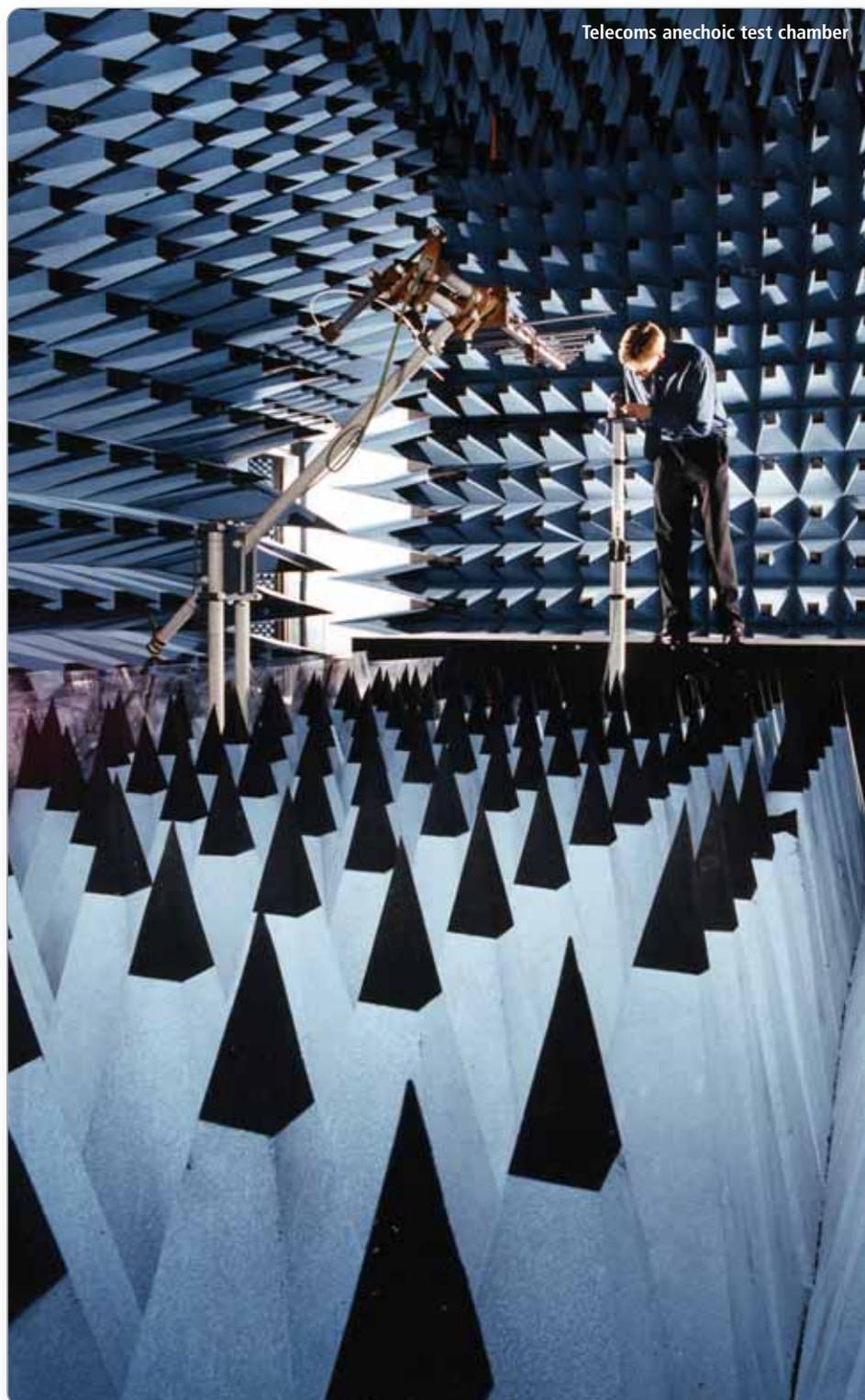
**Telecoms anechoic test chamber**

company's approach to product testing is its overall policy, which is potentially linked to a bad experience in the past that has had a significantly negative impact on the issues of brand, warranty and customer satisfaction. If a company has experienced this, it may be over cautious in terms of the amount of testing that its products are put through, in order to try and ensure that it never produces a poor product again.

## Which Way in Testing?

While we can see the good reasons for testing, these often lead to a blind spot in terms of how companies approach testing and, indeed, over testing. But, there are many considerations to take into account before embarking on a set of expensive tests.

Firstly, it is important to check if the product has been tested to another specification. Since there are a huge variety of tests and standards that have very similar specifications, taking a 'read across' may be appropriate. This is where test specialists compare two standards, identify where they differ and create an argument for partial testing or not testing at all.

It's also vital to consider if the product is similar to others that have already been tested, as a qualification by similarity may also be possible in this situation. If there is a lot of similarity between the current and a previous product it may also be possible to 'read across' from the previous product's test results to avoid some re-testing. For example, this would apply to product upgrades where it is the same product but with some additions. Likewise for a full product range, it may be possible simply to test the basic and top-end product without testing all of the model variations in between.

Equally, if an existing product is sold into a new market, do not ignore the value of good field-evidence where it is currently used. While it may not satisfy a very particular requirement in a completely new market, such as a significant change in temperature from its current use, it may have some value and a new customer may be willing to

accept the field record as proof.

Even if a product is vastly different from a previous model there may be constructional similarities which could reduce the requirement for embarking on specific tests, such as contamination. This could be the case where the materials used are the same as those on previous products. If this is

the situation, there will be no need to run the very specific requirements of contamination testing again. Likewise, if the material's performance characteristics are already known and are intrinsically resistant to the known contaminants and their conformance can be proven, there may be no reason to test. One example would be: it's well-known that plastics do not rust when wet. This might seem obvious, but we do regularly see unnecessary tests, wasting time and money.

### Country Requirements

Often, manufacturers test their products repeatedly to similar but slightly different standards in order to meet country specific requirements. Despite the existence of the IECEE CB scheme, we see many companies still applying for testing and certificates with a plethora of certification bodies to gain access to individual export markets.

The CB scheme is the world's first international system for the mutual acceptance of test reports and certificates for electrical and electronic components, equipment and products. Before the CB scheme, manufacturers' only option was to have their products tested and certified by many different national testing laboratories/ certification bodies –  a difficult, time-consuming and expensive process.

The CB scheme is essentially a passport that helps a product gain individual country approval. It does not eliminate the need for additional "in-country" approval or testing, but it does get you 85% there. The multilateral agreement reduces significantly the need for duplicate testing, is operational in 53 countries, and is being used by more than 15,000 manufacturers worldwide.

If you are selling products internationally, then the CB scheme is

for you, as many countries will now accept CB test reports and certificates without the need for local certification. The ability to carry out one test programme to gain many national marks faster and at a lower cost means that more manufacturers should take advantage of it.

> **"** If you are selling products internationally, then the CB scheme is for you, as many countries will now accept CB test reports and certificates without the need for local certification

### The Customer Is Not Always King

Frequently, we find that a customer's original requirements are flawed because of several reasons:

- Poorly understood environment – while the customers are aware of the intended environment, they do not necessarily capture all of the environments for every possible use, often concentrating on operational environments and neglecting transportation.
- Poorly defined test requirements – the test standards and methods that are defined by the customer show a misunderstanding and tests are incorrectly specified. A good example is that a customer once wanted to specify a gritty sand environment but actually mistakenly specified an environment simulated using soft, fine, talcum powder.

Exaggerated test parameters – there is always a temptation to be 'safe' with

test parameters, involving rounding up and adding safety margins. Be sure that this has only happened once, not once for each person involved!

### Time Saving

If it transpires that your product does require testing, very often the duration of tests can be cut to reduce costs. Historically climatic tests were run overnight starting at 5pm and ending a 9am, so a 16-hour dwell soon became a standard. If a product stabilises more quickly why would you pay for unnecessary laboratory time? Stabilisation plus two hours is now accepted.

It is also important to consider if combined tests satisfy two require-ments. For example an altitude test may satisfy both an altitude and a temperature requirement, thus significantly reducing test times and laboratory costs. Where there is already confidence that the product is sufficiently robust, operational tests may be combined.

### Best Advice

When a customer demands that certain tests are done, it is advantageous for both to assess if they are required, or determine if they can be reduced. Most importantly, first check that the standards relating to the product have been interpreted correctly. For example, has the environment been correctly interpreted and the test requirements properly defined? Also, do some research in the short term to make long-term savings by reviewing what testing has already been performed; look for similarity between products and consider those that are already in the field as performance evidence. If you do have to test, you will save time and money by looking at how to combine tests and reduce test durations where possible.

By spending some effort in the short term at the outset of a testing relationship and considering some of the advice outlined here, significant long-term cost savings can be made, and products can be released onto markets quicker. ●

**JEAN-LOUIS EVANS**

**IS MANAGING DIRECTOR AT TÜV SÜD PRODUCT SERVICE,**
a global product testing and certification organisation, and its sister company, British Approvals Board of Telecommunications (BABT), a radio and telecommunications certification body

# WHAT THE READERS SAY

## ANSWERING THE CATT QUESTION

On page 38 of the June issue Raymond Boute gives us "a snow job", defined as "Slang chiefly US and Canadian of overwhelming someone with elaborate talk".

Boute cannot resolve the problem that we see in the web page he cites (www.ivorcatt.co.uk/cattq.htm) that accredited experts totally contradict each other with their answers. Sir Michael Pepper, knighted for services to physics and now editing the top Royal Society journal, totally contradicts Boute, when he says "as the wave travels at light velocity, then charge supplied from outside the system would have to travel at light velocity as well, which is clearly impossible".

The challenge posed by "The Catt Question" is not to "answer" it. This has already been done many times. It is to get professors and textbook writers to resolve their contradictory answers. Today, no one with accreditation in electromagnetic theory will make any written comment whatsoever on "The Catt Question".

Whereas in his letter of February 2012, Ian Darney writes: "Ivor has never mentioned the existence of photons…".

True. I worked within the framework of classical electromagnetism for decades and later found flaws in it, leading to my exclusion of electricity. When a battery is connected to a lamp, classical electromagnetic theory had electric current, later morphing into electrons, travelling in the connecting wires. This is taught in schools and colleges. There are no photons involved. The electric current creates a field between the wires. My letter referred to by Ian Darney discusses problems with the classical model. Photons arrived decades later, and still today have never been involved in a battery lighting a lamp. If Ian Darney wants to resolve the flaws in classical theory by introducing photons, so be it. However, he needs to produce a properly structured theory involving photons helping a battery to light a lamp. His new theory will not have any bearing on my finding of flaws in classical theory.

Tony Callegari's letter [page 34, Letters, February issue] confuses my work with Liapunov, Korteweg and others who have nothing to do with electro-magnetism. The photographs in my articles do not exhibit soliton waves. "Solitons are caused by a cancellation of nonlinear and dispersive effects in the medium". (The term 'dispersive effects' refers to a property of certain systems, where the speed of the waves varies according to frequency.) This does not apply to my work with very narrow pulses, where, because they are TEM Waves, velocity is independent of frequency.

Last February I wrote: "Today's hijacking of the physical world by the limitations of mere mathematical analysis is disastrous".

**Ivor Catt**

## RADIATED TRANSIENTS

Ivor Catt's article 'The end of electric charge and electric current as we know them' in EW of January 2011 was quite thought-provoking. He reported the results of a 43-year old experiment where a short sharp pulse was injected into a stripline and its progress was monitored at three locations along the line. The oscilloscope traces show quite clearly that the pulse separates out into two components. Ivor identifies these as odd-mode and even-mode currents and concludes that they are propagating at different velocities.

Such a conclusion concurs with my own reasoning that the current in each conductor can be treated as the sum of a set of partial currents. In the initial traverse down the line, these are the differential-mode current and aerial-mode current. Aerial-mode current travels faster because it is concentrated on the outer surface of the conductors where the adjacent dielectric material is predominantly air with a relative permittivity close to unity. Differential-mode current propagates slower because it is concentrated on the adjacent surfaces of the conductors where the dielectric material is epoxy glass with a relative permittivity of about 4. Velocity of propagation decreases as the relative permittivity increases.

A different set of experiments which monitor the aerial-mode coupling between two adjacent conductors identifies the fact that quarter-wave resonance of aerial-mode current occurs at a higher frequency than the resonance of the differential-mode current (www.designemc.info section 7.5) Since resonance occurs at a higher frequency, aerial-mode current must be travelling at a higher velocity.

The scope traces reproduced in Ivor's article identify another significant feature. Pulse amplitude decays rapidly as it propagates down the line. This is because transient energy is departing from the conductors in the form of electromagnetic radiation. Since the separation between the leading edges is constantly increasing, more and more transient energy is radiating away from the line; and less and less is being captured.

This has practical implications. Switching transients occur on power lines when any device is switched on or off. Electronic equipment is protected from the worst effects by the filters at the mains input connector. If the input impedance is capacitive, the transient current doubles and power is reflected back into the supply cable. If the input impedance is inductive, the voltage doubles. In both cases, the only place for transient energy to go is into the environment. So a high level of transient radiation is polluting the vicinity of every item of equipment for a brief period at random times. We can live with this; but for how long?

The only way of absorbing unwanted energy is to direct it into a resistance, preferably at source. So it is gratifying to learn that at least one manufacturer is including resistive components in the transient suppression circuitry.

**Ian Darney**

# USB and RS232 in Data Acquisition SYSTEM DESIGN

IN THIS SERIES, **MAURIZIO DI PAOLO EMILIO**, TELECOMMUNICATIONS ENGINEER, SOFTWARE DEVELOPER AND DESIGNER OF ELECTRONIC SYSTEMS, PRESENTS A TUTORIAL ON DATA ACQUISITION SYSTEM DESIGN

It is difficult to define a typical data acquisition system as the requirements and, hence, implementations vary so considerably. Although simple solutions may utilise a data logger, these data loggers may not be suitable for data acquisition systems requiring data from a large variety of different sensors to be collected and analysed.
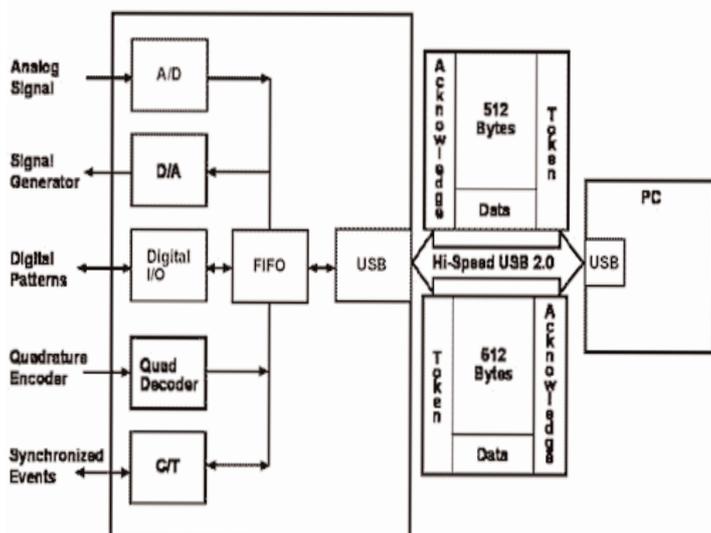
Often the ideal solution for a data acquisition system is to use a central computer to control the system and to collect the data, store and process it. In some instances the system may include a data acquisition card. More comprehensive systems may include a greater number of test instruments, in either discrete or standalone format, with a more likely scenario being the use of VXI or PXI technologies. VXI or PXI chassis will be used with the relevant instruments containg cards within a VXI or PXI rack. Technologies such as PXI are widely used for data acquisition as they are able to house and control test instruments within an electrical environment where fast data transfers can be made and a suitable level of control provided.

While PXI and VXI may be the most obvious candidates for linking an instrument to a data acquisition system, there are other methods too. The General Purpose Interface Bus (GPIB) is still widely used and may be applicable in some instances. However for many, possibly smaller data acquisition systems, it is worth considering using the Universal Serial Bus (USB).

> *The USB-based DAQ module sets itself up upon installation; addressing and other potential resource utilization conflicts resolve automatically*

Several USB data acquisition modules are already available on the market. USB provides a very cost-effective form of transferring data to a computer and such modules can form a very cost-effective and compact solution for many applications. Where more than one USB data acquisition module is required, it is possible to use a USB expander to provide more connections.

The USB provides an ideal method of connectivity between a computer and remote sensors for data acquisition. As a result USB data acquisition modules and devices are now widespread. The use of USB has grown in all sectors as a result of its convenience.

Not only has USB proved itself an ideal platform for many mainstream computer applications, it also offers many advantages for data acquisition. These include:
● Allowing much faster speeds than RS232.
● The power for the sensor or data acquisition module can be obtained from the computer, simplifying the system setup.
● Enabling portability for the data acquisition systems.

**Figure 1: USB data acquisition system**

- USB data acquisition modules can be connected and disconnected without the need to power down the computer.
- USB ports are standard on most PCs, making it an almost universally available method of connection.
- It is possible to use USB as well as other data acquisition communication standards together.
- It is possible to expand the connectivity using a USB hub so that several USB data acquisition devices can be connected.

There is a considerable number of different USB data acquisition products (see Figure 1) that are available. Although dedicated measurement modules may be available, other items may be capable of taking in a variety of analogue and digital inputs. These are particularly useful in applications where a number of points and sensors need to be monitored. Also, having a multiple input USB data acquisition module means that only one module may be required. These modules may also come with their own data acquisition software.

A further advantage of this form of data acquisition is that only one module may be required. If several modules are needed, then ultimately the power supply on the computer may become overloaded.

Serial communication data acquisition systems are a good choice when the measurement needs to be made at a location away from the computer. There are several different communication standards, with RS232 being the most common but which only supports transmission distances of up to 50 feet. RS485 is superior to RS485 and supports transmission distances of up to 5,000 feet.

Utilizing the USB as a data portal provides many advantages for data acquisition (DAQ). For one, the external connector and "plug-and-play" software installation of USB peripherals means that users do not have to open their PC, set up and configure the hardware in order to begin acquiring data. The USB-based DAQ module sets itself up upon installation. Addressing and other potential resource utilization conflicts resolve automatically.

The USB also has electronic advantages. The bus can power the peripheral (within limits) so that the DAQ system does not need its own power source. This further eases system installation and use and has the added benefit of removing the sensitive A/D converters and amplifiers from the electrically noisy environment inside the PC's housing. Unlike PCI plug-in cards, a USB-based DAQ module is easily shielded for achieving high bit-level resolution. ●

# SIMULATION IMPROVES TIME-TO-MARKET

## BY BRUCE KLIMPKE, TECHNICAL DIRECTOR AT INTEGRATED ENGINEERING SOFTWARE

The majority of electronics engineering designers today use modelling software to speed up the design process before moving on to prototype and manufacture. The ultimate aim of such a tool is to improve designs by minimising cost, maximising reliability and optimising parameters.

In the past designs were tested by building a physical prototype and trying to measure its performance. This is costly with little design insight gained. Simulation tools allow the engineer to 'see' the invisible, and no amount of prototyping can replicate this. The data accrued from the software can then be utilised to maximise performance alongside reducing materials and associated costs.

Changing parameters, such as dimensions and materials, enable designers to gauge the effect on performance and using software with built-in parametric features means models can be changed without complicated scripting language. As some simulations require hundreds of solutions for the optimal design this can then be achieved with a very short learning curve, and designers do not have to relearn the process every time a new problem needs solving.

When designing products requiring power (which is practically everything today), calculating the heat density volume is essential. Once established, the aim is to minimise the heat produced as the result of electrical current passing through a conductor, and then manage that heat to minimise any cooling energy requirements.

Electrical energy is not conserved. A proportion is converted into heat through eddy currents and the creation of heat through ohmic and/or dielectric losses can determine the performance of a design. Using simulation software for special modelling techniques such as Boundary Element Method (BEM) for electrical field calculation and Finite Element Method (FEM) for thermal analysis makes finding the solution for energy conservation more simple and time-efficient.

When using simulation software select the best field solver for the problem. Using both FEM and BEM solvers gives an independent verification of results.

For an electromagnetic problem, Maxwell's equations can be solved in either integral or differential form. The integral solution is mainly associated with the Boundary Element Method (BEM) and the differential with Finite Element Method (FEM). Both solve the same physical problem, so results should be the same but the two solution methods are completely different, one ideal for one problem but totally wrong for another.

In general, BEM suits the problem which is linear with a large open region to handle but can lose lustre when solving highly non-linear material properties. Some classes of transient analysis are not easily handled in BEM, so FEM is the best solution for that problem. Whilst a hybrid approach could be ideal, this can greatly increase the solution times for some problems. So, the question is not which is better but which best suits the specific application.

The first move in simulation is to input the physics of the problem – often the most difficult part is entering the geometry. This can be achieved using the geometric modelling tools within the software or by using CAD tools. Normally this geometry is not precise enough for problem solving but Integrated Engineering Software includes 'healing' tools to prepare the geometry for either a FEM or BEM mesh.

The big question is whether to use two or three dimensions. Whilst the real world is 3D, most designers work in 2D because data input is easier and solution times are faster. Modelling thousands of solutions is only practical in 2D as full equivalent 3D models may take hundreds of times longer to solve.

As desktop computing improves it becomes more practical to include the time dimension, meaning that with the three spatial dimensions some practical solutions can be obtained for the full 4D world. Providing even more realistic simulation of true world conditions, the 4D problem solution will move into mainstream computations as memory and processing power increase.

Simulation software therefore reduces costs and minimises risks associated with physical prototyping. It also allows companies to reduce design time and costs, spend less money on expensive prototypes, improve product performance, shorten time-to-market and, ultimately, increase profitability. ●

## Protection Solution with 'RK-Safe Box'

The new Safe Box from Conta-Clip offers a quick and easy protection solution for din rail mounted terminal blocks and components.

The Safe Box effectively prevents unauthorised access to terminals and is ideal for applications on the metering side of a power distribution system where potential damage could be caused by incorrect configurations.

The side panels are directly mounted to the din rail and they completely enclose the terminals or components. There are three sealing location points enabling the use of security wires or tabs to keep the lid in place.

When the transparent lid is removed, the sliding mechanism of the two halves can extend to a further 16mm. This makes maintenance work or the changing of the terminals or components much easier.

The main features include: 3 sealing locations, transparent lid, locks to TS35 din rail, it suits RK & SRK terminals, quick and easy installation and dimensions of 91 x 101 68.5mm (L x W x D).

**www.oem.co.uk**

## FLEXIBLE CODING SYSTEM FOR D-SUB MINIATURE CONNECTORS

Harting has developed a highly flexible coding system for the D-Sub miniature connector series. This coding system prevents cable connections from being connected to the wrong port in an I/O front panel incorporating several identical D-Sub miniature connectors.

The Harting coding system offers 36 different variants which can be adapted to all D-Sub miniature series with housing type E. The system can either be installed by customers using an adapted Harting service tool or delivered fully assembled. The new system is compatible with the standard D-Sub 9-pole, D-Sub high-density 15-pole and D-Sub mixed 2W2–2W2C–5W1 configuration.

The Harting D-Sub coding system can be attached to existing front panels using two female connector screws without any special modifications. On the cable side, the coding frame and the standard cable connector are compatible with the Harting Inducom metal hood series.

**www.harting.com**

## MULTI-OUTPUT VOLTAGE REGULATOR IC FOR AUTOMOTIVE INFOTAINMENT APPLICATIONS

The new A8601 from Allegro MicroSystems Europe is a fixed-frequency, multiple-output voltage regulator IC designed to provide the LCD display bias in automotive infotainment applications.

The A8601, which is Automotive Grade AEC Q-100 qualified, produces five regulated outputs from one low-voltage supply. It offers a robust solution in automotive applications and uses fewer components than existing solutions, while providing higher efficiency power conversion.

The switching frequency of the A8601 can be either programmed or synchronised with an external clock signal between 350kHz and 2.25MHz to minimise interference with AM and FM radio bands.

The five output voltages are provided from three linear regulators and two charge-pump regulators. Each output voltage can be adjusted independently. During power-up and shutdown, the outputs are turned on and off in preprogrammed sequences to meet sequencing requirements of LCD panels while simplifying design.

The device is extremely robust under fault conditions.

**www.allegromicro.com**

## HARWIN ADDS EXTRA-SMALL BORE DATAMATE CONNECTOR RANGE

Harwin has added an extra-small bore crimp contact to its Datamate family of high reliability 2mm pitch connectors, designed for use in challenging applications. Adding to Datamate's existing wire sizes of 22 AWG (large bore) and 24-28 AWG (American Wire Gauge) small bore, the new additions to the range feature an extra-small bore, female crimp contact, suitable for use with 28, 30 and 32 AWG wire.

This new contact enables designers to use wire which is less bulky and lighter in weight, allowing designers to achieve a closer packing density of components or reduce equipment size. For aerospace and portable applications the reduction in weight is very significant. The new contact is gold plated to ensure good conductivity and has a current rating of 3.3A in isolation and 3A on all contacts simultaneously. Contact resistance 25mΩ (max), durability is 500 operations. And operating temperature range is -55 to +125 deg C.

**www.harwin.co.uk**

## MLC WIDE-TEMPERATURE SSD WITH CF AND SD INTERFACES

Despite the increase in adopting SSDs in the industrial computer sector, price remains a major concern. Apacer seeks to address this issue with a quality SSD product and has therefore introduced a large capacity MLC wide-temp SSD with CF and SD interfaces, designed for industrial computer systems and automatic applications.

Favourably priced, the product employs vendor-guaranteed flash chip, which means it can run reliably under industry-level extended-temperature (-40°C ~ 85°C) environments. It stays reliable even at very high or very low temperatures, which makes the SSD a great storage solution suitable for the military, aviation, automobile, oil-well drilling and other industries.

Apacer's next-gen MLC wide-temp SSD includes a CF card compliant form-factor with CFA 4.1 specifications and an SD card supporting the SDHC Class 10 standard. The CF card adopts the standard 50-pin connector; the data transfer mode is up to PIO-6, Multi-Word DMA-4 and Ultra DMA-5, available in capacities from 8GB to 32GB.

**www.apacer.com**

## New SPECTRALUX Light Engines Enable Effective LED Lighting Design

OMC has introduced a range of 'light engines' designed to simplify LED lighting design. SPECTRALUX light engines enable luminaire manufacturers and other lighting users to produce a vast range of products that deliver excellent illumination and have an extremely long life time at particularly high luminous efficiencies, which in many cases exceed 100lm/W.

OMC's SPECTRALUX light engines are arrays of highly efficient, tightly-matched LED die material bonded to an aluminium or copper substrate with a precision phosphor coating. In these designs the total chip area has been increased substantially and distributed optimally across the substrate surface to reduce current density and enhance optical efficacy, thereby achieving more light output for the same drive current, optimising heat-dissipation and increasing life-expectancy to as long as 40 years for some parts.

They are very simple to use, requiring only a constant-current supply to drive them.

**www.omc-uk.com**

## LINUX-BASED APPLICATION/DEVICE SERVER FOR REMOTE AND MOBILE M2M APPLICATIONS

New from Alpha Micro is the PremierWave XC, a high performance, multi-port secure device server developed by Lantronix that offers Ethernet or GSM/GPRS connectivity for remote access and easy management of machines and equipment over a network and across the Internet.

It is ideal for applications in a variety of markets including telemetry, utilities, industrial automation, healthcare and energy, PremierWave XC systems combine ease of use, robust device server functionality and GPRS connectivity. By utilizing the GSM/GPRS network, this new product provides a solution for applications in areas without Ethernet or Wi-Fi infrastructure or for installations that have Ethernet connectivity and rely on GSM/GPRS for failover backup ensuring redundancy.

PremierWave XC provides extended security by offering a variety of robust data encryption and authentication options. Featuring the industry-proven Lantronix device server application suite with AES, SSH and SSL, it provides enterprise-level security allowing safe and secure remote access and management from practically anywhere.

**www.alphamicro.net**

## IP66-Sealed HMI Device Achieves Reliable Operation By Eliminating Moving Parts

ITAC Systems has announced Hand-Trak – a patented high-reliability gestural input device where the user simply moves a hand or finger over the device's optical lens to communicate the desired direction, speed and distance of cursor movement, providing more precise control than either a sealed touchpad or joystick. It's designed primarily for use in public access kiosks, manufacturing and marine electronic systems, medical equipment and food processing machinery, and aeronautical and automotive electronic systems.

With no moving parts, the IP66-sealed panel-mount or panel-top Hand-Trak unit is capable of withstanding heavy usage. It is vibration resistant and protected within glass-reinforced polycarbonate housing. Hand-Trak can be permanently or temporarily mounted, or just rested on a panel, and used at any angle. The device is suitable for use indoors or outdoors and its internal printed circuit board has a conformal coating to provide an additional barrier to liquids, moisture and dust.

**www.itacsystems.co.uk**

## NEW WAVEACE 40MHZ TO 300MHZ OSCILLOSCOPES FROM LECROY

LeCroy Corporation announced two new lines of the popular WaveAce oscilloscope series – the WaveAce 1000 and WaveAce 2000.

WaveAce 1000 oscilloscopes feature a sample rate of up to 1GS/s with 2Mpts of memory in two-channel models from 40MHz to 100MHz. WaveAce 2000 oscilloscopes deliver sample rates of up to 2GS/s and 24kpts of memory and are available in two- and four-channel models from 70MHz up to 300MHz. All new WaveAce oscilloscopes feature a large 7" widescreen display and powerful debug tools such as 32 automatic measurements, waveform math capabilities, pass/fail mask testing, large internal storage, remote control and waveform recorder.

Integration with LeCroy's logic analyzer and waveform generators provides expanded debug and testing capabilities. This powerful combination of features makes WaveAce the best oscilloscope for simplifying the debug process.

All WaveAce models provide a USB host port on the front panel for saving screen images, waveforms and setups to a memory stick.

**www.lecroy.com**

## CONDUCTIVE ELASTOMERS FOR RFI/EMI SHIELDING

Kemtron manufactures a range of conductive Elastomers as gaskets and gasket strips for EMI shielding of electronic devices. The base Elastomer is silicone for normal environments and Fluorosilicone for fuel and oil resistance. Both offer a wide temperature range of -40degC to +160degC and up to +200degC for some grades. The conductive fillers available are silver-plated aluminium, silver-plated copper, pure nickel and nickel-coated graphite. Other fillers such as silver-plated nickel are available to special order.

The manufacture of a conductive Elastomer is a balance of conductive particle loading and distribution throughout the silicone base; the distribution must be sufficient to ensure that the particles are in contact with each other to ensure a good conductive path through the Elastomer, but the loading must not be so great to cause the silicone to lose its elastomeric properties.

**www.kemtron.co.uk**

## Dual MOSFET Simplifies Synchronous Buck Converter Design

Advanced Power Electronics Corp (USA) has announced the new AP6922GMT-HF-3, a space-saving dual MOSFET for synchronous buck converter applications, with both the high-side (control) FET and low-side (synchronous) FET in one single 5 x 6mm PMPAK package.

AP6922GMT-HF-3 is a rugged device combining fast switching, low on-resistance and cost-effectiveness. The control MOSFET (CH-1) has a drain-source voltage rating of 30V, a maximum on-resistance of 8.5m$\Omega$ and a continuous drain current rating at 25degC of 15A. The synchronous MOSFET (CH-2) also has a drain-source voltage rating of 30V and a continuous drain current rating at 25degC of 25.7A, with a maximum on-resistance of 3.8m$\Omega$ to minimise conduction losses. The reduced parasitic inductances resulting from the short internal conduction paths also contribute to improved performance.

The AP6922GMT-HF-3 is the first in a family of parts at the company aimed at synchronous buck converter designs, improving the power density and simplifying the layout.

**www.a-powerusa.com**

## WASHABLE ILLUMINATED PUSHBUTTON SWITCH SERIES IS AVAILABLE IN FOUR LED COLOURS

One of Europe's leading switch manufacturers, knitter-switch, introduces a washable illuminated pushbutton switch available in a choice of four LED colours. Designed for a wide variety of applications, including office automation, games consoles, vending machines and measuring instruments, the TME 82 Series switches are designed for through-hole mount.

TME 82 pushbutton switches feature a choice of coloured LEDs – red, yellow, green or blue. These are SPST (OFF-MOM) switches with a minimum lifetime of 100,000 cycles.

TME 82 Series switches incorporate silver-plated contacts and terminals for added reliability. They are rated for 12VDC at 50mA.

Standard switches are available from a number of distributors throughout Europe. Samples are usually available on next day delivery.

knitter-switch was founded in 1966. Its headquarters are located near Munich but it also has subsidiary companies in the UK, France and Asia and strategic alliances with a number of leading distributors.
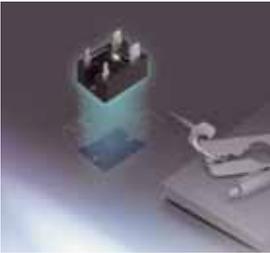
**www.knitter-switch.com**
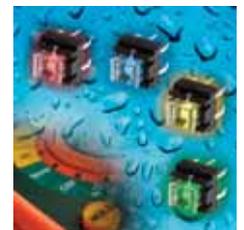
## New AQJ – SSR with Wide Range Input

With an amazing 40% reduction in the footprint area compared with the previous model, the new AQJ SSR relay is available in both 1a and 2 x 1a contact versions.

The choice of load current switching (25A max) allows a wide range of application specifications to be met with the added advantage of zero-cross switching on both turn-on and turn-off. Non-repetitive surge current capability of up to 250A offer reliable switching function in a host of industrial.

Incorrect connections are avoided by the reverse input protection circuit.

Typical applications include domestic appliances such as coffee percolators, microwave ovens, heated ovens, refrigerators and food appliances.

Industrial applications include packaging and wrapping machines, conveyer control, door movement control, forklift and reach truck controllers.

**www.panasonic-electric-works.co.uk**

## KEITHLEY PUBLISHES E-GUIDE ON MAKING ULTRA-FAST I-V MEASUREMENTS

Keithley Instruments has published an informative e-guide titled *"Ultra-Fast I-V Applications for the Model 4225-PMU Ultra-Fast I-V Module"*. Free copy is downloadable upon request from Keithley at: http://www.keithley.com/promo/pr/1107.

The 24-page e-guide provides an overview of ultra-fast I-V sourcing and measurement and why these have become increasingly important capabilities for many technologies, including compound semiconductors, non-volatile memory (NVM), MEMS devices, nanodevices, solar cells, and CMOS devices. Using pulsed I-V signals to characterize devices rather than DC signals makes it possible to study or reduce the effects of self-heating (joule heating) or to minimize current drift or degradation in measurements due to trapped charge. Transient I-V measurements allow scientists and engineers to capture ultra high speed current or voltage waveforms in the time domain or to study dynamic test circuits. Pulsed sourcing can be used to stress test a device using an AC signal during reliability cycling or in a multi-level waveform mode to program/erase memory devices.

**www.keithley.com**

## NEW RIGHT-ANGLE R24 CONNECTORS ACCOMMODATE LARGER CABLE SIZES

The popular Binder RD24 connector range has been extended with the introduction of new right-angled versions with larger cable outlets. Until now angled versions could only accommodate cables between 6-8mm but the new versions can accommodate cable sizes of 8-10mm (PG11) and 10-12mm (PG13.5) increasing the application range.

The new cable versions are available for both the standard 692 series and the UL approved 693 series of Binder RD24 connectors. Manufactured from durable PBT they achieve protection to IP67 when mated and locked making them ideal for a wide variety of applications including pressure and temperature transducers, welding equipment, CCTV and control systems.

Four and seven pole versions are available with options of screw, crimp and solder termination in male or female format.

Based in Hemel Hempstead, Binder UK is a subsidiary of Franz Binder GmbH, manufacturer of circular and other connector products that serves instrumentation, sensor, automation, medical devices and industrial equipment markets.

**www.binder-connector.co.uk**

## PUSH-PULL CONNECTORS THAT SAVE SPACE AND TIME

Intelliconnect (Europe) Ltd offers one of the most complete range of push-pull connectors available to design, system and test engineers.

Intelliconnect push-pull connectors have many advantages over screw and locking types. They offer panel designers space savings as there is no need for a coupling-tool or locking by hand, and fast and easy mating and un-mating for portable and test equipment as well as systems with frequently changing setups. Push-pull connectors also simplify assembly during production and offer the ability to replace or upgrade sub-assemblies on the factory floor.

Applications for Intelliconnect push-pull connectors include military and aerospace, industrial and medical nuclear systems, marine (including radar) SCADA and telematics, audio, safety and test equipment.

Intelliconnect offers four main types of push-pull connectors.

A 7.0mm Nim Camac type high voltage miniature connector series is designed in accordance with the NIM-CAMAC CD/N549 standard. The ABMS series of rugged sub-miniature connectors may be used in FDA approved medical applications.

**www.intelliconnect.co.uk**

## NEW 4-CHANNEL, COMPACT, USB-POWERED OSCILLOSCOPES

The PicoScope 3000 Series of high-performance oscilloscopes has been expanded to include six new 4-channel models. The new oscilloscopes offer a maximum sampling rate of 1GS/s (up to 10GS/s effective for repetitive signals), a range of input bandwidths from 60MHz to 200MHz, and buffer memory depths from 4M to 128M samples.

The new FlexiPower system allows the scopes to run on either USB or AC power. With an option of either a built-in function generator or a built-in arbitrary waveform generator, and a new, slim case design, these scopes are perfect for engineers and technicians needing a complete, portable test bench in a single unit.
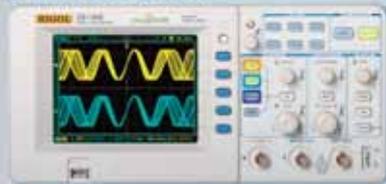
The PicoScope oscilloscope software includes as standard all oscilloscope and spectrum analyzer functions you would expect, as well as serial decoding, mask limit testing, segmented memory and advanced trigger.

PicoScope shows waveforms on a large, clear display and allows easy zooming and panning under keyboard or mouse control.

**www.picotech.com**

## Protect Circuit Boards with A Pioneering New UV Conformal Coating

Sil-Mid Ltd as part of its world-class customer service is always looking for new, high performance and fast production throughput engineered solutions for difficult and demanding applications on behalf of its customers. Consequently, it is adding the Novagard UV 800-260 silicone products to its 14,000+ product portfolio.

The Novagard UV 800-260 silicone product series combine the performance advantages of silicone with processing speeds of UV cure. As they are UV cured, there's no oven baking, no nitrogen blankets and no VOCs. Processing is extremely fast – parts remain at room temperature and can go straight to packages without racking.

Testing of Novagard UV 800-260 demonstrates cure with extremely fast processing speeds and also incorporates a secondary, moisture cure chemistry for shadow areas of the coating.

Novagard UV 800-260 is the only UV curable silicone conformal coating to receive UL 746E approval for conformal coatings of printed circuit and control boards for indoor and outdoor applications.

**www.silmid.com**

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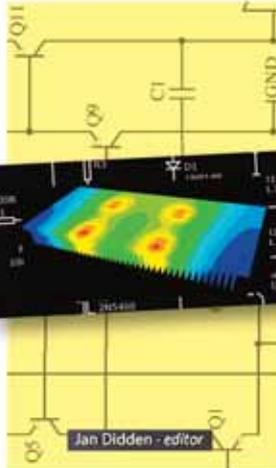email Johns@stjohnpatrick.com

**Electronics WORLD**

# RESEARCH PROGRAMME
# TARGETS
## NEXT-GENERATION
# ELECTRIC MOTORS
# FOR
## LUXURY AUTOMOBILES

Next-generation electric motors for low carbon emission vehicles are the target of a new collaborative research programme led by Cobham Technical Services. The project called 'Rapid Design and Development of a Switched Reluctance Traction Motor' will also involve partners Jaguar Land-Rover (JLR) and engineering consultancy Ricardo UK, and is co-funded by the Technology Strategy Board.

As part of its work in this 3-year project, Cobham will develop multi-physics software and capture the other partners' methodology in order to design, simulate and analyse the performance of high efficiency, lightweight electric traction motors that eliminate the use of expensive magnetic materials. Using these new software tools JLR and Ricardo will design and manufacture a prototype switched reluctance motor that addresses the requirements of luxury hybrid vehicles.

"It is important to understand the capability of switched reluctance motors in the context of the vehicle as a whole so that we can set component targets that will deliver the overall vehicle experience," said Tony Harper, Jaguar Land Rover Head of Research.

The project is one of 16 collaborative R&D programmes to have won funding from the UK government-backed Technology Strategy Board and the Department for Business, Innovation and Skills (BIS), which have agreed to invest £10m aimed at achieving significant cuts in CO2 emissions for vehicle-centric technologies. The total value of this particular motor project is £1.5m, with half the amount funded by the Technology Strategy Board/BIS, and the rest by the project partners.

**HAFIDH MECHERGUI**, **Associate Professor in Electrical Engineering and Instrumentation, University of Tunisia:** Climate warming and the reduction of oil resources question the use of fossil-fueled vehicles, which are in fact the symbol of pollution due to CO2 emissions. Substitute solutions are considered already, especially for the big cities, and electric vehicles are one of them.

Electric vehicles have many advantages: no CO2 emissions, no noise and very suitable for short trips. Unfortunately, these vehicles require suitable batteries, which so far are heavy and cumbersome, and their motors are made with rare-earth metals. As such this project aims to improve electric vehicle performances and is welcome.

Although the project is financed by the British government, it involves the co-operation of well-known and important car companies. The project will take three years at the end of which there will be a prototype of a luxury electric car.

The project will certainly utilize the latest technologies, but it will be interesting to see how certain issues will be dealt with, such as the size of the engine, the storing of energy and so on, which might prove challenging.

It is also interesting to note that the British government takes part in high-level projects that focus on developing science and technology and this can aid the economic prosperity of the country. It is an intelligent vision of the British officials today.

**HARRY JOSEPH**, **audio-visual consultant, New York City, US:** Speaking for the moment only of the US, as worthy as these research projects may be, they can be scuppered by the mere twitch of an eyebrow, if the twitch-er is what we call Big Oil, and the twitch-ee is nearly any Congressperson. Representatives, as opposed to Senators, face re-election every two years (Senators every six), so the need for campaign 'donations' is never-ending. In a parliamentary government the titles differ, but the principle remains: money talks.

The real solution is not just to reduce the CO2 emissions per car (who can argue with that?), but to wean the public away from cars altogether, a colossal undertaking. To me that means rail travel with its really low CO2 and other favorable numbers per passenger mile, and however much the British complain about the rail service, at least there's a service to complain about. In the US the struggle is not to improve the experience, but all too often to keep the tracks from being pulled up.
Count your blessings, cousins!

**PROFESSOR DR DOGAN IBRAHIM**, **Near East University in Nicosia, Cyprus:** It is very pleasing to hear that big manufacturing companies like Jaguar Land Rover will be carrying out research in environment friendly vehicle design with the aim of reducing CO2 emissions. The new vehicle will be based on Switched Reluctance Traction Motors, avoiding the use of rare-earth metals and permanent magnets. No doubt the expertise of Jaguar Land Rover will contribute to the design and development of the hardware and software tools required for the manufacturing of the next-generation environment friendly automobiles.

**MAURIZIO DI PAOLO EMILIO**, **Telecommunications Engineer, INFN – Laboratori Nazionali del Gran Sasso, Italy:** Energy conversion efficiency of electricity is superior to that of other types of secondary energy, such as gasoline or fuel gas, and its conversion involves lower emissions of carbon dioxide (CO2).

Electric motors have three major advantages: motor torque generation is quick and accurate, a motor can be attached to each wheel and motor torque can be estimated precisely. The motor controller is an important pillar of any electric vehicle (EV). The controller is basically the computer of the EV which governs the motor performance of the electric motor.

We can expect up to 90% or more electrical energy put into an electric motor out of it in the form of mechanical torque as compared to any combustion engine in the world.

**BARRY MCKEOWN**, **RF and Microwave Engineer in the Defence Industry, and Director of Datod Ltd, UK:** Developing Integrated Software Switch Reluctance Motor Modelling Packages for Real Time applications in Hybrid Vehicles with the goal of freeing up rare earth metals is one desirable aspiration where in this case the trade-off with rare earth metals in the electronics is quantifiable. However, the DSP issue here is with incorporating vibration measurement data using FFT Dynamic Spectrum Analysers (Agilent 35670/SR780) whereby Flat Top Windows are utilised in R&S instrumentation and possibly also in the embedded FPGAs required for real time control. Inherently we are dealing with non-sinusoidal excitation and both slow and rapid decaying resonant signals. Oh, Dear!

The real money to be made here is in a vibration analysis technique for the mass produced real time controller ASIC/FPGA which is three years away with this program.

**If you are interested in becoming a member of our panel and comment on new developments and technologies within the electronics sector please register your interest with the editor by writing to Svetlana.josifovska@stjohnpatrick.com**