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THE ESSENTIAL ELECTRONIC ENGINEERING MAGAZINE

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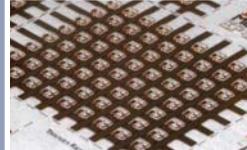
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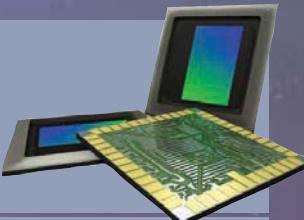
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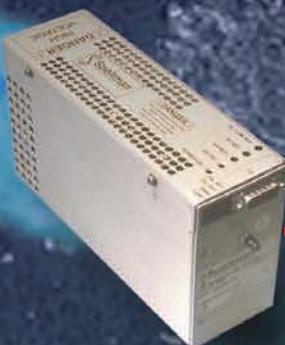
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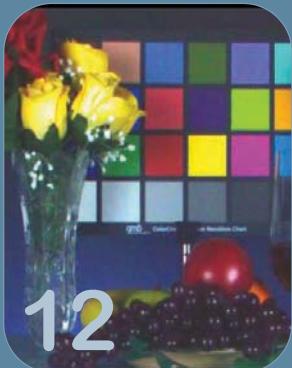
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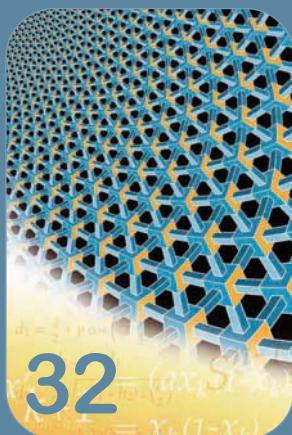
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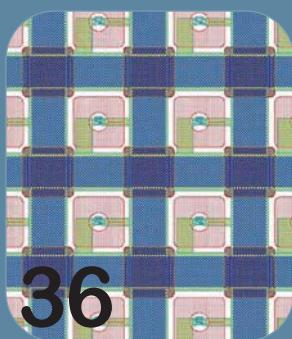
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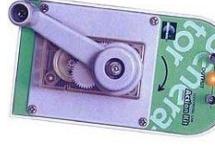
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What's novel about innovation

Innovation is now recognised as the single most important ingredient in any modern economy. It is a necessity in these fast-paced times.

The Asian countries have cottoned on to this rather quickly and, today, their patent applications are growing four times faster than that of the Western world.

You'll find many of us chasing that rather elusive major innovation and listen carefully to any advise that might link us to a guaranteed innovation success. To achieve this, some have even included all aspects of the value chain in the process to access the experience from the different players. Others are involving multi-disciplinary teams, even across different geographies. Nowadays, as we have all become highly specialised in one subject matter only, a truly innovative project can come from sharing ideas between different specialists from different fields.

To quickly get to innovation some firms are even resorting to merger and acquisitions (M&A) as a shortcut. There's a modern saying: "M&A is the new R&D".

Bell Lab's executive director in Ireland, Dr Lawrence Cowsar, recently said: "We are continuously talking about what to do with the research: lop it all off, spin it out, or make it just a shell – a thin layer of research that might lead to that one key discovery. The reality is different: we want to have our cake and eat it." So now, Bell Labs has adopted a strategy where start-ups are created internally.

Bell Labs employs nearly 600 PhD researchers and works with 300 universities worldwide and yet, it never stops to innovate when finding new ways of working on innovation. One method is to align its strategy to different governments' imperatives. For example, in the US the government's current imperative is to focus on research linked to home security. In Asia, the local governments' focus is on applications and end uses, and in Ireland the government's goal is to change the economy from being manufacturing led to innovation led. By analysing these governments' necessities, Bell Labs has come up with a brilliant way of not only funding its own research through local government grants but also by having access to local universities' research to boost its own innovation. After all, industry is a lot quicker to recognise and commercialise a good idea than a university ever can.

But whichever way you look at it, innovation is a complex process. It is almost multi-dimensional: it's about the product, about the process and about the strategy that will bring it to market. It is less about whether a project is on time, within budget and has enough resources. It is more recognised that, nowadays, innovation is less about 'blue sky' projects and more about the process around it which will make it work in the market and bring benefits to the company medium to long term. Innovation alone is not enough, even if it's of the so-called 'disruptive' type – a technology that has the potential to overturn dominant technologies, bring new markets and new customers.

So, successful innovators advise: look at your projects, assess which one is going to bring major benefits and think of a step-by-step way of how to bring it to market and keep it going for many years. One other advice: don't be scared to kill the ones that are unlikely to bring big benefits back.

Svetlana Josifovska
Editor

Electronics World would like to wish you all a very happy Christmas!

Telairity offers complete HDTV encoder to encoder makers

Chip start-up Telairity has launched an HDTV encoder based on its high-performance VLIW chips and software, taking the encoding element away from the system design and allowing encoder makers to concentrate on the system and control elements.

The BE8000 is a slim 1RU rack unit that uses eight of its T1P2000 chips, each with five VLIW digital signal processing cores, to encode one H.264 stream in real time with the AVClarity encoder software developed by Telairity itself. The encoder takes a 1920 x 1080 HD resolution stream and achieves a bit rate of 8-10Mbit/s, which is competitive with other real-time broadcast encoders that use 24 FPGAs and DSPs.

The system is also available as the TM8000 motherboard for equipment makers to put together their own system with their own mezzanine cards or an audio mezzanine card from Telairity.

"This is still an OEM solution," said Shubha Tuljapurkar, vice president of marketing at Telairity. "We went to all our customers and they said they needed a complete solution where they add the system value."

One of the key points of using a standard processor chip was to reduce the cost. "I think this gives our customers a significant price advantage," she said.

The other advantage is to simplify the hardware design and allow new products to be developed through software. "You can expect us to deliver a new chip every two years and new products fairly rapidly," said Howard Sachs, CEO and founder of Telairity. "By offering the TM8000 motherboard as a stand-alone product,



HDTV encoder board from Telairity

Telairity is enabling OEMs to create encoders that are tailored to provide specific, differentiated features for their individual applications. We are providing the fundamental video encoder hardware and software design, so each OEM can focus on its particular value-add while getting to market much more quickly."

Video reclocker lowers power

National Semiconductor has developed a multi-rate video reclocker that can handle both SD and HD data rates.

The 48-pin LMH0056 has the lowest power in the industry at 350mW and is the final element for a complete chipset for video routers, switches, distribution amplifiers and editing and



National Semiconductor reclocker

conversion equipment, alongside National's adaptive cable equaliser and cable driver.

The reclocker is used to automatically recover the clock from up to four incoming SDI video streams, removing the jitter even when up to 60% of the eye pattern is closed, with output jitter of 0.02 unit intervals (UI) at 270Mbit/s for standard definition streams and 0.05UI for HD streams at 1.485Gbit/s.

These are significantly better than the jitter performance that is possible with FPGAs which are looking to recondition signals, says the company. National Semiconductor is working with both leading FPGA makers, Xilinx and Altera, on a reference design with the reclocker coupled to an FPGA.

In addition, the company launched a low jitter HD/SD sync separator device that uses purely analogue processing rather than digital control to detect and synchronise the video stream with out extra processing or filtering.

The LMH1981 performs all the synchronisation for NTSC, PAL and SECAM SD and HD formats up to 1080p, and automatically detects the format of the stream. This analogue design has been patented and removes the need for a microcontroller to work out what the stream is.

The future's bright for LED lighting

LED light sources will replace the common bulb as the dominant source of lighting in the near future. So says Steve Landau, marcom manager at Philips Lumileds, manufacturer of solid state lighting. "LEDs will be a major – if not the dominant – light source in the future and they will displace conventional technology."

LEDs offer much better efficiency, efficacy and life-time characteristics than incandescent lighting. They are also more environmentally friendly as they don't contain mercury or cadmium. Some 19% of electricity today is used up on lighting. With LEDs this figure is going to be dramatically lower.

"We will not see a total eradication of conventional technology, but LEDs will become the dominant source for lighting. The infrastructure [for lighting] will see a similar change. We are used to 60W bulbs and near-white light, but that will change – however, this will happen over a long time. For home lighting, LEDs will be used by 2010, 2011; they are already being used in retail lighting and the market is already worth several billion US dollars."

All major countries' governments, including that of the UK, US and Japan are installing energy programmes in place that encompass the future use of LEDs. All of them are also encouraging local businesses and academia to make the most of the solid state lighting opportunity.

Among the major LED manufacturers are Philips Lumileds and Avago Technologies. Recently, Avago announced its strengthened solid state lighting portfolio. Philips Lumileds, on the other hand, according to Landau, has several clear objectives for the near future: to increase the lumens per Watt (efficacy), lumens per package and lower the cost of lumens per US dollar in its product range.



Luxeon Star
White LED from
Philips Lumileds



Europe changes engineering courses, as industry shuns old graduates

Universities across Europe are starting to abandon their long-term engineering courses in favour of the much shorter UK model.

In Germany or France for example, an electrical or electronic engineering course can last years, whilst in the UK, the courses are only three to four years long. In Europe, if undergraduates fail exams, they can keep retaking them until they pass, a process that can last a very long time. By the time they graduate, a freshman will not be so 'fresh' for the industry at the ripe age of 30 and above.

"The industry does not want them [graduates] that old," said Dr Alec Reader, sales director at the UK R&D facility Innos. "The industry likes PhD graduates, but when they are 24, not a lot older than that."

The Netherlands has already shortened its courses, whilst Italy is in the process of doing so now. Other countries are likely to follow. "Changes are afoot," confirmed Dr Reader.

The question, however, is whether the remuneration package of electronic engineers in the UK will match those in Europe. "The deference in salaries is a lot less now," said Dr Reader. "Salaries are improving in the UK. Shortages [of engineers] help, too; for example there's a severe shortage of engineers in Dublin and this has affected salaries."

IMEC is the role model for Innos

Innos, the semiconductor spin-off from the University of Southampton, has set its sights on becoming the UK's answer to IMEC in Belgium; a facilitator between industry and academia.

"We want to act as a translator between industry and academia," said Dr Alec Reader, sales director at Innos. "IMEC is known for this role in Europe, but there's no other company doing the same in the UK."

The company is already known for its R&D, small-scale wafer fabrication and rapid prototyping service. A combination of all three will allow the company to move into the role which will see Innos create bridges between university research and its

market realisation.

"There's a big gap between industry and universities. There are plenty of ideas at the universities, but they can't [successfully] bring that to the industry. They [universities] need prototypes – and we [at Innos] even do small scale production. This will allow the industry to see whether they'll like a product or not [first]."

At present, Innos is seeing venture capitalists about funding, which will help the company implement its idea. Although Innos has already handled several smaller projects along the same lines, it is currently in negotiations over a much larger project, which will also need this funding.

The European Commission has replaced the BS EN 50419:2005 standard with BS EN 50419:2006, which affects the Waste Electrical and Electronic Equipment (WEEE) Directive.

BS EN 50419:2006 Marking of electrical and electronic equipment in accordance with Article 11(2) of Directive 2002/96/EC (WEEE) contains the marking requirements needed to meet the requirements of the WEEE Directive.

The revised standard contains additional information relating to the marking requirements, including positioning, visibility, dimensions, location and referenced documents. The marking serves to clearly identify the producer of the equipment and that the equipment has been placed on the market after 13 August 2005.

* * *

The University of Sheffield has invested £10m to create a new Nanoscience and Technology Centre which incorporates the UK's largest cleanroom laboratory for research into semiconductors, nanomagnetics and other devices. Supported by the Science Research Investment Fund (SRIF) and the European Regional Development Fund (ERDF), the centre will provide state-of-the-art facilities and support for high-tech businesses in the region.

Based on the University's North Campus, the Centre includes a suite of business incubator offices and laboratories, as well as leading research and expertise in areas such as optical communication devices, magnetic storage media and solar cells.

* * *

Electronics is the most widely favoured industry sector among investors in unquoted companies, according to annual research from the nationwide business angel network – Beer & Partners.

The survey took into account the preferences of more than 1000 high net worth individuals who have registered their interests as potential business angels. These are people with upwards of £100,000 available to invest in smaller, often start-up companies in return for a portion of the equity. Moving up from sixth place in last year's rankings, electronics has leapfrogged IT and the Internet to take the lead with 63% of investors choosing it as one of their favourites.

Bandlets transform SDTV

A Paris-based university spin-off, Let It Wave, has developed a new scaling technology that can turn standard definition digital TV (SDTV) broadcasts into a signal that is acceptable on today's high quality HDTV screens. Its 'bandlet transform' or 'geometrical wavelet transform' technology (see box below) improves the quality of upscaled pictures, either from the 1080i format to higher quality 720p, or even 1080p formats.

"The big difference with bandlets is that they can be scaled and elongated and can be adapted to the different types of content on the screen," said Dr Christophe Bernard, chief technology officer of Let It Wave.

In principle, the technology improves Fourier and wavelet filtering tech-

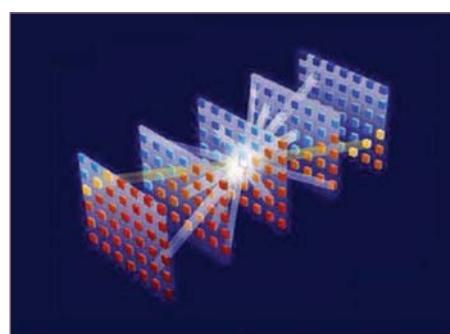
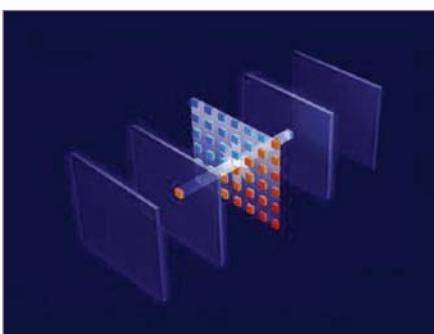
ques. The algorithm is implemented in two million gates in a Cyclone FPGA from Altera, and the first customer is Brick House Video in the UK. It is being used in a new system for post production studios called Syntax that allows SD content to be inserted into HD streams at professional quality.

"Syntax was developed specifically with Let It Wave's FPGA bandlet technology, and we have performed extensive trials with prominent end-users and it does a fantastic job – a genuine case of 'seeing is believing,'" said Paul Hiorns, managing director of Brick House Video.

Let It Wave is now looking to get the technology integrated into consumer flatscreen TVs.

Left: Motion adaptive upscaling algorithms compute missing pixels with spacial or time interpolation from the previous and next pixels at the same location

Right: Bandlets optimise over the whole region in both space and time with directional interpolation to improve the image quality



Bandlet bases decompose images into multiscale geometric bandlet elements. For quality enhancement, bandlet coefficients are processed to restore fine details and remove distortions. A Fourier filtering processes the image information over fixed neighbourhoods. Wavelets provide a first improvement by adapting the computational neighbourhood to the scale of local image details. Bandlets further improve this process by following geometrical image structures to better discriminate noise and distortions from image information.

For video processing, space-time bandlets are adapted to the time geometry corresponding to movements. Bandlets take advantage of time redundancy of video sequences by following time displacements. In super-resolution applications, missing pixels are calculated to improve image resolution by combining this bandlet technology with a total variation control. It guarantees that no oscillatory artifacts are introduced by the geometric processing that restores fine image details.

You can take HD videos on your mobile phones

A French chip start-up is looking to put HDTV video encoding into mobile phones with multi-processor hardware and software. MnD Semiconductor has developed an array of up to 20 SPARC processors on a chip with the software codecs that can be used for low power, high performance transcoding of video in mobile phones.

"You take your video with your mobile and you want to see it on your HDTV screen at home," said Ian Walsh, CEO of MnD in Paris. "If you connect to an HDTV and try to show QVGA video, it's very poor."

MnD has also developed the encoding and decoding algorithms to go with the array through a development system for both hardware and software, and is

focusing on low power applications, tuning the number of processors to the power requirements. By using an array of processors, the power consumption can be matched to the application by switching off parts of the array for encoding with the full array or decoding with part of it.

The multi-processor technology is proven, says Walsh, having been used in telecoms chipsets for DSL lines which are very price-sensitive.

The company has licensed an ARM processor core to include alongside the array so that it can be a standalone chip rather than a co-processor. The prototype is running in an FPGA for demonstrations at the end of this year, with samples expected in 2007.

Programmable RFID platform protects perishables

A new start-up from Italy, Montalbano Technology (MT), has come up with a multi-tag RFID concept, which will help many industries protect their perishable products and, hence, investments.

Its so-called multiTag family is based on a modular and programmable platform which can be configured to suit different applications and requirements. The platform consists of a single-chip IC which includes a microcontroller (MCU), non-volatile memory, sensors, an RFID interface and other interfaces to connect to optional components, such as a crystal oscillator for example.

"Our solution is unique for three reasons: it has extra sensors, extra memory and extra accuracy [than any other]. It's a modular product that can change its features by adding or removing components. It's programmable and it's configurable," said Daniel Grosso, general manager at MT.

The device can monitor the exposure of perishable goods to heat, light,

humidity and pressure among others. "The food industry loses some \$32bn per year on perishable goods. Our products can get close to the product [rather than just be attached to the crate] to check for the quality of the perishable goods and their history of temperature and humidity changes. The accuracy is $\pm 1\%$, lifetime is 6-18 months and temperature ranges between -20°C and $+50^{\circ}\text{C}$."

The chip operations are triggered and coordinated by the embedded MCU, which executes pre-loaded software. It periodically acquires data from the sensors and associates a time stamp to each acquisition so that events can be placed in time accurately. The stored data can be transferred via an RF link at any time during the device's life-cycle.

In addition to monitoring food, these devices can be also used to monitor cut flowers and pot plants, pharmaceutical and medical supplies, blood derivatives and others.

NXP Semiconductors, STMicroelectronics, Nokia, INRIA, IBM Haifa Research Lab and Universitat Politècnica de Catalunya have kicked off the so-called ACOTES (Advanced Compiler Technologies for Embedded Streaming) Project to address software complexity to drive down power consumption in consumer devices.

The participants will jointly research and implement the advantages of massive parallel processing. The project will use efficient compilation techniques to enable a dramatic increase in productivity for application programmers to leverage the benefits of parallel computing. As a result, consumers will be able to run applications demanding high compute power and enjoy increased battery life on their mobile devices.

The project will last three years, until mid-2009.

* * *

A new radio standard called WiBree has hit the research labs. It aims to open up a new market for ultra low power wireless connections to button battery cell powered devices, which according to some industry observers has not been served effectively by other radio technologies.

WiBree will target wireless control and information applications and, as such, it is seen as complementary to Bluetooth with many of its strengths.

Bluetooth supplier CSR is a supporter of WiBree.

* * *

IBM and Xing Incorporated, a subsidiary of the Brother Industries, have jointly engineered, designed and developed two wireless karaoke portable controllers – the Kyoku-NAVI II and Kyoku-NAVI (see below). The acoustic systems will be available in Japan from Xing at the year end. The main points to note are: each controller offers four language options and replaces the conventional thick karaoke song catalogue, searching and entering songs is easily managed with a touch screen panel and enhanced search engine. It also allows each customer to register favorite songs respectively.



RFID and Wi-Fi are a good match, say companies

Communications companies have started to combine RFID with the Wi-Fi infrastructure. One such company is AeroScout from the US.

"Wi-Fi networks have become common so we can benefit from that infrastructure [to run RFID]," said Andris Berzins, managing director of AeroScout EMEA. "AeroScout invented the idea of Wi-Fi RFID tags."

AeroScout's solution uses a Wi-Fi chip with a low power consumption battery. There's a location "engine", which calculates the distance to the tag from the Wi-Fi access point using the triangulation method. According to Berzins, the lifetime of an RFID tag battery is four years. The resolution is 5-10m indoors and outdoors.

"With this technology we can address a whole set of new needs: tracking work-in-progress in a manufacturing facility, real-time location, presence of an RFID tag within the vicinity and others," said Berzins.

Among the industries already using the combination of RFID and Wi-Fi are the semiconductor industry for work-in-progress applications, the mining industry for tracking people, the aerospace industry for tracking parts in and around the plane assembly site and automotive dealerships who can track cars on large forecourts.

Currently, AeroScout's tags work only with Cisco's 802.11 WLAN infrastructure.

USE CASE MODELLING

Use Case modelling was originally developed by Ivar Jacobson for modelling telephony systems. Incorporated into the Unified Modelling Language (UML), it has been used in IT projects for many years, but is now becoming more popular in the real-time and embedded market place. However, programmers are not necessarily accustomed to 'thinking in Use Cases'. Here are some tips to help you on your way:



1 **i Start with a context diagram** – this should describe the boundaries of your system to help define what is inside and outside the system. (You will be surprised that not all people have the same views on this.) Anything outside is an Actor and has the potential to link to or require a Use Case.

2 **i Don't just look at the operational and obvious Actors** – there is an area of Use Case modelling called Mis-Use Cases, which looks at undesirable Actors and usage scenarios. Be sure your system can cope with them.

3 **i Start with the major Use Cases before going on to Includes and Extends relationships** – otherwise, your Use Case diagram will look suspiciously like a data-flow diagram.

4 **i Write the complete Use Case descriptions before moving on to the other aspects of the design** – if you don't really understand what the system is supposed to do and how to use it, you can't build it.

5 **i A Use Case description should describe a sequence.** – if it doesn't, it is not a Use Case.

6 **i Agree on a Use Case template BEFORE the project starts** – there are a variety of attributes a Use Case can have. The ones you need will depend on the level of safety, security and process of the project.

7 **i If appropriate, review the Use Case model with the stakeholder/ customer** – it is certainly cheaper and easier than waiting until the system is built to clarify misunderstandings.

8 **i Validate the Use Cases and your system architecture with interaction diagrams such as activity and object sequence diagrams** – update the Use Case descriptions based on this.

9 **i Name your Use Cases from a consistent point of view** – do they describe goals that Actors have in relation to the system, or system functionality that the Actors make use of?

10 **i Base your test scripts on your Use Cases** – Use Cases describe how the system should be used and the test scripts should show how to prove this.

This month's Top Ten Tips were supplied by Matthew Hause, Principal Consultant at ARTISAN Software Tools. For more information, or download any white papers on Use Cases and other topics go to www.artisanaw.com. If you want to send us your top five or ten tips on any engineering and design subject, please write to the Editor at EWeditor@nexusmedia.com.

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SALES + SERVICE + CALIBRATION

Too Many Variables... one outcome wanted

The UK medical devices market is among four of the biggest EU markets and is growing at a phenomenal rate – around 7%, with a 2005 market estimated to be worth £2.49bn. As such, there is a very good case for businesses to enter this market in search of high margins and high growth.

There is, however, a flipside. Products must be fit for some of the toughest regulatory approval processes there are. Add to this the NHS which is constantly looking to save money and you get a conflict with the norm that medical device R&D projects are extremely lengthy and costly, involving many parties. The result is an

“ Ten to twenty years may be completely realistic in the conservative medical world for the life of a product. However, if you choose cutting edge components for your product, will they still be available then? ”

interesting design challenge for the team charged with developing a new medical device and it can be a very daunting task when one looks at the design infrastructure that is required to enter this market.

In the case of medical electronics, software



Mike Lloyd, Managing Director of ML Electronics based in the UK, goes over the basic requirements that any electronics designer would face when developing new medical devices

can be an interesting minefield for the developer. With risk assessment being one of the major goals for a medical product and a simple ride through the approval process being very useful, the approach (and what functions are carried out by each) to hardware design and software can have probably the biggest impact on the simplicity of the design. The category of risk for a device can generally be increased or decreased by a wise choice of hardware interlock, measurements, alarm detection etc. Interwoven into all of this is the need to meet the regulatory approval, mostly ISO 60601 and, also, the needs of UL and FDA for the US markets.

As manufacturing is becoming too expensive to carry out in the UK, developers are looking to other locations to cater for their production and assembly requirements. Decisions like these carry design implications, in terms of where the device will be made and what manufacturing techniques will be used.

Obsolescence is a major challenge for medical devices. Ten to 20 years may be completely realistic in the conservative medical world for the life of a product. However, if you choose cutting edge components for your product, will they still be available then? Probably not.

In the medical world, there are many issues with placement of components, restraining wiring and isolation, to ensure patient safety. These are however the specifics, the detail of the challenge for the developer of an electronic medical device.

In reality, it is not these that will cause the headache for a designer, its catering for the multitude of product features the suitability for regulatory approvals and the simplicity of user interface.

With space at a premium in the operating theatre and A&E, medical customers are demanding smaller devices, which are either portable or small and easily stored. These mechanical specifications have a knock on effect on the electronics required to make them function.

There is also the calling from end users for more simple interfaces. For example, in the operating theatre most surgeons don't even want an on/off switch on the equipment, just in case it is pressed by mistake at a crucial moment. If you contrast this with the engineer, who by nature is generally a perfectionist and wants to extract every last ounce of performance out of the equipment, you end up with the very traditionally styled equipment complete with knobs and dials. The result is a nightmare waiting to happen. In the increasingly litigious world we inhabit, this is a concern for the company developing the medical equipment and the medical professional using it.

Unfortunately, this outcome can quite easily occur when you take into consideration all the

different parties that are involved in the development of a new medical device. Marketing has its role to play in increasing the challenge. Developers are tasked with creating designs that cater for marketing expectations, including every feature possible as the enthusiastic marketing department identifies every possible upgrade path and competitors feature that needs to be incorporated into the end product.

As medical device companies place greater demand on their development teams, devices will not become any less complex. This is partly because of the number of people involved in developing a medical product and partly because of the increased medical possibilities that technology can provide. It is unlikely that the numbers of parties involved with the development of medical devices will decrease. This is being demonstrated with the increasing trend for collaboration within the medical industry. Whilst this can prove a management challenge, it can also be a positive, bringing with it the opportunity to learn from partners, to cross-pollinate ideas and give rise to the option for deploying the right people to undertake the tasks they possess the expert skills in, when they are needed. The key is open and clear communication and working with a partner that you can trust.

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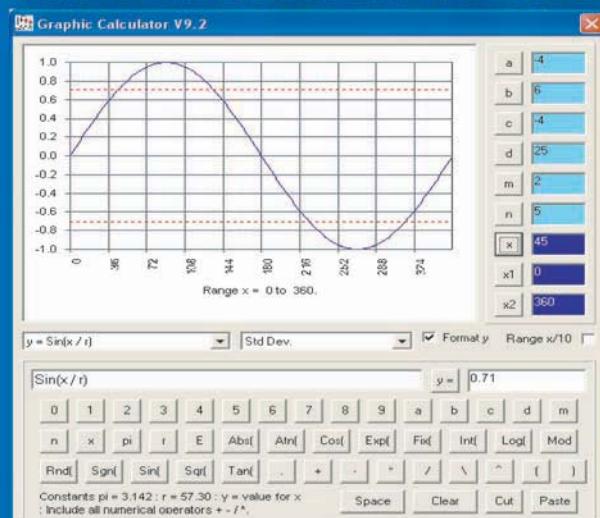
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Seeing through CMOS

By John Walko

CMOS image sensors (CIS) are currently one of the biggest growth markets in the electronic components sector, driven by huge demand from makers of increasingly feature-rich mobile handsets. Research firm Gartner Dataquest recently estimated the global CIS market would increase from \$3.2bn in 2005 and surge to \$5.6bn by 2008.

Almost on a monthly basis, suppliers of CISs are racing to bring to market new products said to boost picture quality in both entry-level handsets and more specialised models. The market is, thus, seeing a major shift as the devices move from the relatively dark ages of VGA quality into the megapixel era.

Yet despite these advances, we do have a different kind of "image" problem. Camera phones, while undeniably handy, are not considered even by the most casual photographer as a real alternative to the stand-alone digital still camera (DSC) for capturing that really important

moment. There is a long list of 'to do' for both the image sensor makers and the phone designers before this is likely to change.

The main issue is a high resolution image sensor does not of itself guarantee a better picture from a mobile device. A well thought-through system level design is needed to ensure usability and picture quality, and to compensate for lens systems that can be mediocre.

The problem for handset designers is simple enough. The extreme space, power and cost constraints of the handset environment have kept the image quality of handset image sensors well

Robert Gove, VP at Micron Technology, holding a mobile phone with good imaging band on CMOS



below that of their DSC counterparts. Those same constraints have limited the code space and processing power that a handset designer can devote to post-capture image processing, the stage where most of the perceived image quality is created.

Yet, the problem is not simply a matter of resolution. Resolution of handset sensors has already passed the 1-Megapixel level and is rapidly headed towards the 3-Megapixel capability. There are also design issues in areas that are more difficult to resolve: light sensitivity, systematic and random noise, and colour correction. Small size

and low energy consumption exacerbate those problems. Incorporating automatic flash illumination into the handset can help, but that has implications for computing power, battery drain and enclosure design.

Luckily, we have some of the most innovative semiconductor companies involved in developing and making image sensors, all vying to solve the image quality problem. The problem for the handset makers, perhaps, is that there are too many. A recent survey suggested there are about 30 CMOS image sensor suppliers, which clearly makes for an overcrowded market. Consolidation is already rife and the shakeout is expected to accelerate despite the exploding growth, according to analysts. Players include the likes of Avago (the relatively recent semiconductor spinout from Agilent), Micron Technology, Sony, Toshiba, OmniVision, Kodak, Canon, Cypress, MagnaChip, Samsung, Sony, STMicroelectronics, Toshiba and a few start-ups in the wings claiming technology advances.

For example, though details are limited, Israeli start-up Advasense, which counts Blue Run Ventures (formerly Nokia Venture Partners) as one of its investors, is readying a CMOS image sensor it suggests will have ten times better image quality than currently available devices. Given the stiff competition in the marketplace, coupled by falling average selling prices (ASPs) for CIS products, not all vendors will succeed – or survive – wrote in a recent note Doug Freedman, an analyst with American Technology Research. “Ultimately, when the market settles, I think that there will be three major players and about six niche players,” he added.

Robert Gove, vice president of the Imaging Group at Micron Technology agreed. “There is a lot more consolidation to come. Increasingly, you need deep pockets in the business,” he told *Electronics World*.

And while Micron has a healthy share of the CIS business, put by some analysts at nearly 28% of the global market, “we intend to play a part in the ongoing consolidation,” Gove added.

He stressed the traditional charge couple devices (CCDs) are running out of steam against CMOS, and all recent statistics bear out this assertion. CMOS image sensors, which have always had to battle CCDs at the high-end, in terms of resolution and image quality, have a distinct advantage in these applications. The imagers can be run off on existing CMOS production lines at low cost, and they can integrate a wide variety of image processing, compression and other logic circuits to streamline designs for small size.

Gove adds that, while mobile phones are now the fastest growing market, there are many other applications for CISs, for instance security

cameras, PC cameras, and automotive and medical applications. “We’re just at the beginning stages of the CIS market,” he said. “I can see them everywhere.”

Traditionally a memory maker, and still a big player in that sector (notably with flash devices), Micron has already played its part in the fall-out, entering the area in 2002 through the acquisition of Photobit, a developer of CMOS imaging chips for professional cameras. Meanwhile, National Semiconductor last year sold its imaging chip business to Eastman Kodak, while at the same time South Korea’s MagnaChip Semiconductor bought IC Media, a developer of CMOS image sensors. In addition, one of the fastest growing suppliers, OmniVision, is being helped by its acquisition last year of CDM Optics, which brought with it patented optical encoding technology, dubbed Wavefront coding, targeted at adding instant focus capabilities. The technology is said to use specialised optics and algorithms to transform the essential task of focusing a lens from an optomechanical process to one of optical encoding and signal processing. It eliminates motors and

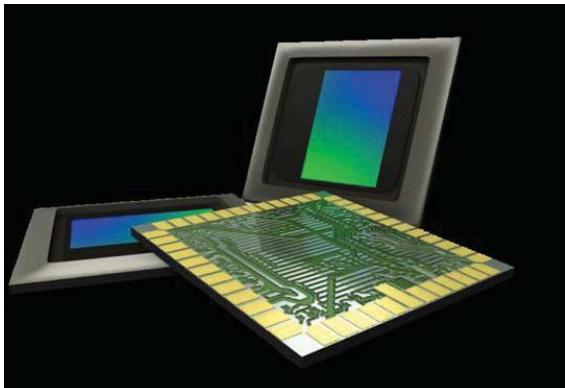
“There is a lot more consolidation to come. When the market settles, there will be three major players and about six niche players.

Robert Gove, VP, Micron Technology ,”

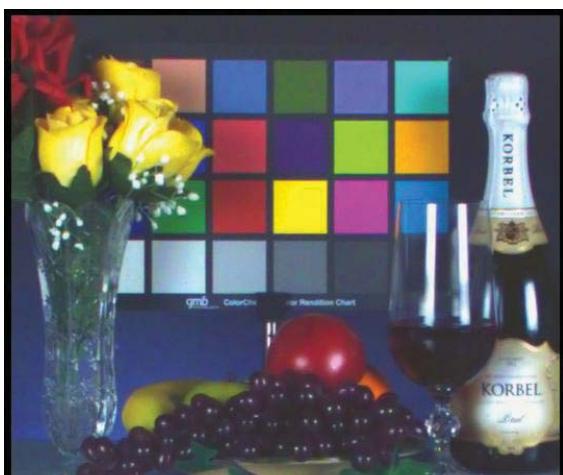
actuators that are used in “instant focusing” features in today’s high-end and expensive mobile camera phones. It also reduces the size and complexity in a camera module, according to the company. OmniVision is readying a 3-Megapixel CMOS image sensor that will incorporate the “instant focus” capabilities for camera phones in full resolution at 15 frames per second.

Samsung Electronics and Japan’s Sony Corporation are relative newcomers in the market but, given their respective and dominant positions in consumer electronics, both could have an inherent advantage in the CIS arena; they already have internal customer bases for the devices. And judging by some recent papers given at international conferences, they are pushing the envelope in terms of functionality. For instance, at this year’s International Solid-State Circuits Conference (ISSCC) in San Francisco, Samsung and Sony pushed the limits of the technology by separately describing CMOS image sensors with resolutions of 7.2 and 6.4 Megapixels, respectively.

Of course, resolution is not the only parameter involved to achieve the kind of functionalities needed in mobile phones. Pixel design continues to



Die of CMOS image sensors



Tan image output from Micron Technology's first 1.4-micron pixel sensor

be tweaked to improve sensitivity. Cypress Semiconductor has recently rolled a three-transistor-per-pixel architecture that provides low-light sensitivity without increasing the pixel transistor count or sacrificing image quality. And Kodak's Pixelux technology combines pinned photodiodes, four-transistor pixels and a shared-pixel architecture to achieve high sensitivity under low-light conditions.

Another "size" issue for image sensor producers is the number of pixels that can be packed onto the chip. The trend is clearly towards more megapixels. But since size and cost constraints prevent the die size from growing along with the number of pixels, the solution is to shrink the pixel. The generation of image sensors currently in production contains aggressively scaled pixel sizes.

With size as the only variable, smaller pixels are less sensitive for low-light conditions and are also noisier. The result is that even the best-designed and best-manufactured image sensor will produce poor quality images, unless the image processing can compensate.

To allow for pixel size scaling, today's CMOS processing for image sensors is becoming more specialised. One way to specialise is to create the micro lens that focuses more light onto the smaller photodiodes. At the front end of the manufacturing process, vendors can also create more sensitive photodiodes with lower inherent noise. The channel surface of a MOSFET is noisy and a poor choice for converting light into electrical charge. Therefore, most modern image sensor vendors implant dopants into the surface of the silicon. This "pinning layer" pushes the light absorption region deeper into the silicon and away from the noisy surface. This type of "pinned photodiode" works extremely well, but adds extra processing costs.

Last year Micron demonstrated the industry's first 1.7-micron pixel image sensor. The company believes shrinking pixel size enables camera phones to offer DSC-like photo quality, camcorder functions and high-definition capabilities. And Micron is planning to improve the sensitivity in next generation sensors by moving to 1.4-micron pixel sizes, said Gove.

The basic features needed for camera phones include quality images, demosaicing (translating the Bayer colour filter bit-stream into a real image), noise compensation, auto white balance, auto exposure, small file size and low power.

The standard for reducing file size and memory requirements is JPEG compression. This algorithm appears on some image sensor ICs but is most often handled by a companion chip known as the image signal processor (ISP). Before the advent of the CIS, all of the image processing took place on a devoted processing IC.

While that approach is still true today for both CCD and CIS, things are beginning to change. The shift means solid-state imaging has been dropped into the system-on-chip vs system-in-package battleground.

Developers that want to put digital processing on to the image processor focus on the most obvious issue: overall camera footprint. Avago, a leader in the integration of digital processing in the sensor die, is perhaps the only supplier with a CIS device that includes on-chip JPEG encoding and autofocus control. Naturally, it advocates the use of a single system-on-chip device in the camera module.

But there is no consensus within the industry over the partitioning of the image sensor and the ISP block. Some advocate the separation of the two so that the baseband processors provide that functionality. Others argue tight coupling between the two leads to faster time-to-market for handset makers.

GET THE BEST OUT OF THE



by Myk Dormer

“ Some transmitters output over half a watt of RF energy. Treat them wrong and range falls, link reliability degrades and there are unexpected spurii ”

ISM band radio module

So your product needs a radio link? You've waded through the data sheets, decoded bewildering specifications, got quotes and, finally, unwrapped the first samples in their gleaming, tiny glory.

Job done? Not quite!

Commercially available radio modules are designed to be easy to use, isolating the customer from the difficulties of designing complex RF circuitry. However, there is still a certain amount of care to be taken if the full performance and reliability of what can be a very expensive "component" is to be realised.

Receivers handle sub-microvolt signal levels. Some transmitters output over half a Watt of RF energy. Treat them wrong and range falls, link reliability degrades and the transmitter can emit unexpected spurii (breaking statutory regulations).

So what needs to be kept in mind?

1. Mount your module with good RF practice in mind.

Use a groundplane. Mount the module directly on it. If possible, solder the screen can to it, for a good, low impedance, earth. Do not use tall sockets. The added inductance can degrade performance.

Keep PCB tracking to the module short and direct, and provide filtering where possible (series chokes or 'stopper' resistors at least) to minimise pick-up. Take special care of the aerial tracking – as short as possible and as good an approximation to a 50Ω stripline as you can achieve (2.5mm thick tracking on 1.6mm epoxy board is a good start). Seriously consider using a coaxial cable.

2. Beware of interference, coupling and pick-up. Keep the module – and its aerial – away from interference generating circuitry (high-speed logic, switch mode power supplies or other radio sub-systems). External interference can degrade the selectivity of a receiver (its ability to reject unwanted signals) even if the apparent sensitivity is unaffected. This shows up as good 'under test' performance on the lab bench, but unexplained poor performance in the field. Physical separation is often the best form of 'screening'.

Provide a clean power supply. DC-DC converter ripple is a particular problem, while battery voltage 'droop' under load can cause unpredictable behaviour.

Wideband noise from older low drop-out regulators (especially the LP2931 series) has caused problems. It is unwise to share a common power rail with noisy digital circuitry.

3. Design your system to minimise its interference 'footprint'. Choices made early in a product's lifetime can make it much more 'radio friendly'. Noisy techniques can be avoided and sufficient suppression of unavoidable EMI designed in from the start. (This will also help at your product's EMC/CE approval stage).

Lay out all your circuit boards as if they are radios: keep fast data and clock tracks short, decouple for high and low frequencies and always use a ground-plane. Choose the lowest clock rates that your system design can tolerate. Make sure that none of the clock frequencies (or harmonics) fall on or near your radio's operating frequency.

Minimise the bit rate of external communication signals and, where possible, use balanced, low voltage standards like LVDS in preference to 'raw' logic waveforms. Use linear regulators if you can. If a switch mode must be used, a constant frequency type is best (compared to constant on-time, variable frequency designs). If more than one switch-mode is present, synchronise them all to run at the same frequency. Keep the external fields of power inductors and transformers to a minimum. Choose toroidal core units or screened parts.

Avoid inherently noisy components. Stepper or brushless motors are better than commutator types; LED or incandescent lamps are better than fluorescents; and semiconductor power switches are less noisy than mechanical contact relays.

4. Read the small print. All modules are designed to be easy to use, but they all have interface details that can trap the unwary user.

'Raw data' radios connect your data-

stream directly to the radio channel, which is prone to interference and noise, and which is rarely DC coupled. This requires your datastream to be coded in a way which balances the overall mark space ratio and allows a decoder to identify a valid data burst. Typically, the user's data must be formatted into packets, including address and framing (identifier) sequences, and the whole stream then biphasic (or similar) coded.

In addition, the radio will impose timing restrictions. The transmitter requires a specific amount of time to switch on (or off), while the receiver also requires time to settle. These timings can vary from less than 1ms to over 50ms, depending on the design. A 'preamble' sequence will need to be added to the packet.

'Data links' or 'radio modems' take care of the coding and framing functions, and frequently offer some data error handling too. In these cases the module is simply connected to a UART and treated like a serial cable, but the user must be alert to any control or set-up commands needed by the modem and by possible handshaking restrictions (often 'buffers full' or 'link busy' signals require a pause in the datastream, while simple radio modems never offer true duplex working). Additionally, some modules will require further interface signals to be handled, ranging from simple channel select inputs to quite complex SPI bus operations. Read the maker's data sheet very carefully.

5. Remember to consider the non-electrical environment.

Radio systems rarely operate properly outside their specified temperature range. Thermal extremes upset their accurate frequency references.

Some radios (synthesised multi-channel units) suffer from microphony and are not suitable for use in high-vibration environments.

RF circuitry is not tolerant of contamination. Condensation will often disable a module and, if potted during assembly, the encapsulating compound must be excluded from the module housing.

6. Pay attention to your aerial. A radio system depends on the aerial to function, yet too little care is often taken in its specification or design.

Some modules have built-in aerials. These are easy to use, but

are typically quite short-ranged. They also require the module to be mounted away from conducting objects (and not inside a metal housing).

Most manufacturers give simple aerial designs in their data sheets, but with the exception of the quarter wavelength whip (a straight piece of wire of specific length: about 16cm for the 433MHz band) they require specialist knowledge and test equipment to optimise them.

The final option is a commercially manufactured aerial. There are a very wide range of these available and your module manufacturer will be able to recommend suitable parts. This is the most expensive option, but it offers some advantages: it is electrically predictable and requires no adjustment; it is robust and can be mounted externally to the product casing and aerials can be obtained with connector mounting (SMA, BNC, N and similar), allowing easier testing or replacement.

Link performance is maximised if the aerial is:

- a) Mounted free from interfering objects;
- b) Located as high up as possible (to get the best radio 'horizon' distance);
- c) Connected to the module by the shortest length of the best cable that the application will allow. (In some cases, the module is best mounted with the aerial at some distance from the rest of the system with interface and power wires instead of an RF cable).

7. And lastly: TEST EVERYTHING.

Do not assume that "everything will be OK". The only real proof of design is to use it successfully in its final intended environment. Conduct range trials; use the prototypes in the field; ensure the radio link reliability is good. Time spent here buys product reliability and customer respect later.

If the performance of the radio in your completed system isn't what you were anticipating, do not give up. Contact your module supplier's technical support department and get them involved. The support engineers have probably seen 'your' problem before.

Good Luck!

*Myk Dormer is Senior RF Design Engineer at Radiometrix Ltd
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“ Minimise the bit rate of external communication signals and, where possible, use balanced, low voltage standards like LVDS in preference to ‘raw’ logic waveforms ”

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A New Approach to **DEMODULATION**

Archie Pettigrew and colleagues here show that current understanding of multi-path reception conditions is wrong, proving it through thousands of hours of extensive testing. Something can be done, however, to improve multi-path radio reception

Some ten years ago or so, I published an article in this magazine describing the advent of the Amplitude Locked Loop (ALL) and its use in the improvement of demodulation of both AM and FM transmission.

Much development work has taken place in the intervening years both from a circuit development viewpoint but, more importantly, from a better understanding of the nature of radio transmission, with special attention to the science of multi-path reception.

The current understanding of multi-path reception conditions is wrong and has been shown to be wrong during thousands of hours and over extensive road-testing.

The standard analysis of multi-path conditions assumes that a large number of radio waves arrive at the antenna with different delay times due to path length variations. Their amplitudes are also quite different, with the signal becoming weaker as the path length increases. This situation was first analysed by Lord Rayleigh in the 19th century to describe a large group of violinists all playing slightly out of tune. This work resulted in the type of statistical distribution now referred to as the Rayleigh distribution that is well documented already.

The fundamental flaw in the Rayleigh distribution is that it does not consider that the individual carriers making up the ensemble of echoes are themselves an ensemble of carriers and sidebands. Further, it is in the sideband pairs that the desired information is located when the carrier is being demodulated.

Back To Basics

To avoid the normal academic path of stating the mathematics in the most general of forms, we will look at the simplest specific case first and will build out from there to obtain the overall picture without mathematical overload.

We analyse a single FM modulated incident carrier added to a reflected carrier delayed by a time τ seconds.

Using the standard nomenclature let the incident voltage at the antenna be:

$$v_{inc}(t) = \cos(\omega_c t + \beta \sin \omega_m t)$$

and the reflected voltage striking the antenna be:

$$v_{ref}(t) = m \cos(\omega_c(t - \tau) + \beta \sin \omega_m(t - \tau))$$

These two voltages are added together to obtain the composite:

$$v_{inc}(t) + v_{ref}(t) = \\ \cos(\omega_c t + \beta \sin \omega_m t) + m \cos(\omega_c(t - \tau) + \beta \sin \omega_m(t - \tau))$$

To maintain simplicity, we set the delay to be the time equivalent to π radians of the carrier frequency and the value of m to be unity, the loss-free reflection case. After some basic trigonometry, the value of the composite waveform can then be shown as:

$$v_{inc}(t) + v_{ref}(t) = -\pi \beta \frac{\omega_m}{\omega_c} \cos \omega_m t \cos(\omega_c t + \beta \sin \omega_m t)$$

So, we come to the startling – if not astonishing – observation that the received signal in the antenna is the original FM waveform severely attenuated by the scalar $\frac{\pi}{\omega_c}$ and, even more importantly, multiplied by the pure differentiation of the modulating function:

$$\omega_m \beta \cos \omega_m t$$

By inspection, this function may be described simply

as double sideband Suppressed Carrier Amplitude Modulation on Frequency Modulation (SCAM-FM). The carrier at the centre of the modulation has been completely filtered out by an 'infinite notch' circuit in free space. The envelope of the carrier is now equivalent to a full wave rectified version of the modulation and the phase of the carrier reverses every time the modulation changes from positive to negative and vice versa.

This has a devastating effect on any demodulator, whether it is of the PLL type or the quadrature detector type. This is the true source of the harsh grating distortion that is heard at specific points in space when travelling in a moving vehicle. It is not due to the receiver going into threshold operation as has been supposed in the past.

The signal can only be recovered by applying a new level of technological understanding.

There are a number of further implications. This is the solution for a delay time of π radians only. There are continued repetitions of this distortion process at every $(2n-1)\pi$ radians interval up to, say, 500 wavelengths when the distortion starts to become an independent beat frequency. The distortion event is not a point in space since there is a transition into the SCAM zone and a transition out of the SCAM zone. The SCAM zone is shortest when the delay is shortest and increases with delay distance. The attenuation is also most severe at the shortest delay distance (π radians) but decreases as the delay distance increases. At a certain delay value equal to $\omega_c/\omega_m \pm \pi$ radians, the composite waveform actually doubles up then attenuates again in a comb filter trend at $2\omega_c/\omega_m \pm \pi$ radians; that is 999π or 1001π if the carrier frequency is 500 times greater than the

Figure 1: The top waveform shows the IF carrier at 10.7MHz during a SCAM event. The envelope is smooth in reality; the noise is caused by sampling in the scope. The lower waveform shows the raw PLL output with a sharp pulse at every zero crossing of the modulation. The signal is 1kHz and the bandwidth is 2MHz

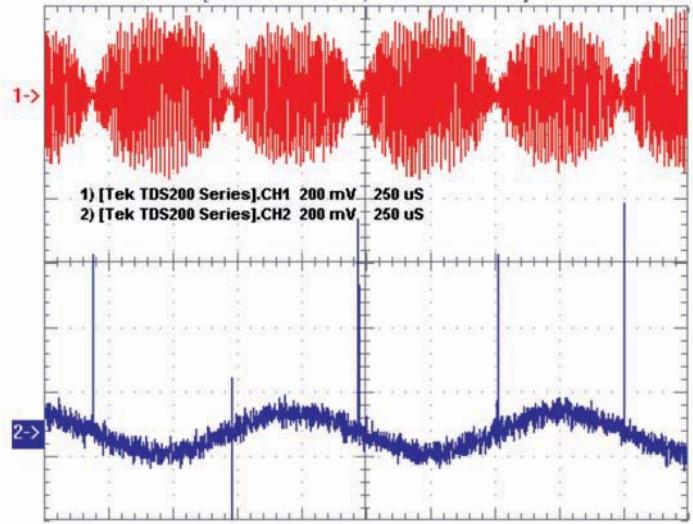


Figure 2: The top waveform is the PLL output again and the lower trace is the Corrective Time Function (CTF). The CTF is the mathematical reciprocal of the PLL spike. When the two are multiplied the result is unity

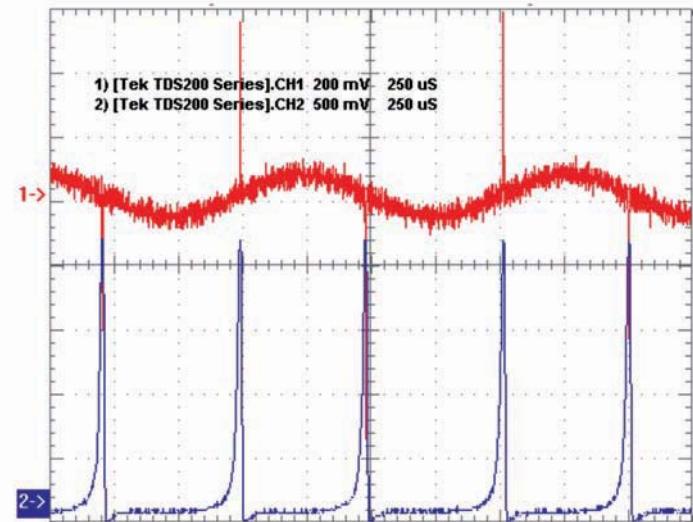
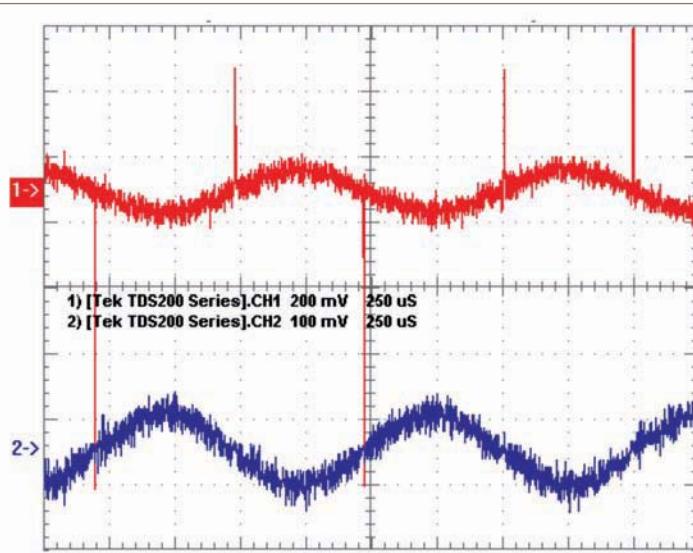


Figure 3: The top waveform is the PLL output and the lower trace is the product of the PLL signal and the CTF signal. The distortion has been removed



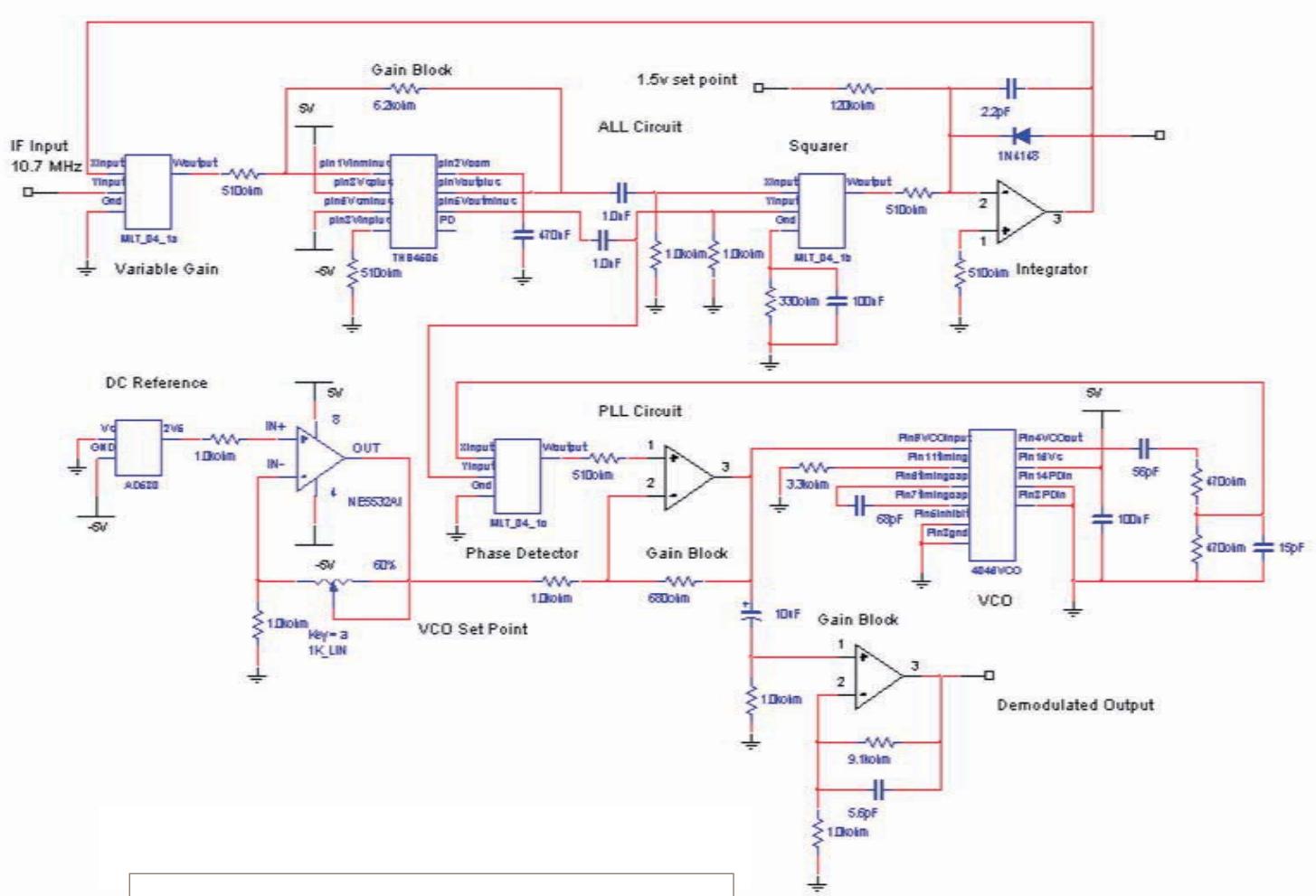


Figure 4: System block diagram. The top two blocks are shown in detail in Figure 5. The lower five blocks comprise the circuitry required to generate the reciprocal of the PLL pulse. This is called the Corrective Time Function (CTF)

modulation frequency. This phenomenon repeats indefinitely for increasing delay.

When the SCAM waveform is presented to the demodulator, independent of its type, there will be a spike generated at every zero crossing of the modulating signal, if you are in the centre of the SCAM zone. This spike is the differentiation of the 180° phase shift and is very large compared with the modulation signal. This has a severe distorting effect on the signal quality and cannot be tolerated for any significant period of time (see **Figure 2**).

When the SCAM zone is offset, the spikes move towards each other until they coalesce at the positive or negative peak of the modulating signal. They finally disappear and the demodulation returns to a distortion-free satisfactory signal. The length of this SCAM zone can vary from 3mm at 100MHz carrier with π radians delay to 1.5m at the worst-case longest delay.

SCAM Zones With A Number Of Echoes

If there is one strong line of sight signal, then there is low to no probability that a second reflection will meet the criteria of exactly 180° phase shift and be loss-free. So, there will be perfect reception. If steel framed building has blocked the line of sight, then the reception will rely on a reflection. The strength of the signal will be much weaker but reception will be adequate so long

as the receiver does not go into threshold operation. However, what happens in practice is that there can easily be a second reflection created by the same process as the first one and these can be nearly identical in size. If the delay is near $(2n-1) \pi$ radians, then a SCAM event will occur and the demodulated signal will become heavily distorted. The two echoes almost annihilate each other and leave only the sideband pairs available for demodulation.

The interesting condition now arises that should there be a third reflection, it will not be attenuated and will therefore capture the receiver and adequate reception will be restored. To avoid SCAM reception with three echoes the sum of the three carriers must equate to unity, the size of the line-of site carrier, and they must be $(2n-1) \pi$ radian in phase with each other. This probability rapidly becomes vanishingly small when even more reflections are considered.

We arrive at the astonishing conclusion that the more reflections you experience, the lower the probability that you will enter a SCAM zone and the better will be your overall reception. You want the third reflection to save the day!

Since the SCAM zones can be as long as the carrier wavelength under certain delay distances, the argument used in DAB radio that not all the carriers would vanish at once and that digital correction can recover the signal now looks very unlikely. All the carriers will vanish simultaneously and DAB will fail miserably. This is the cause of the well-established unreliability of DAB receivers when positioned in certain places. You are not trying to deal with white noise effects and very short

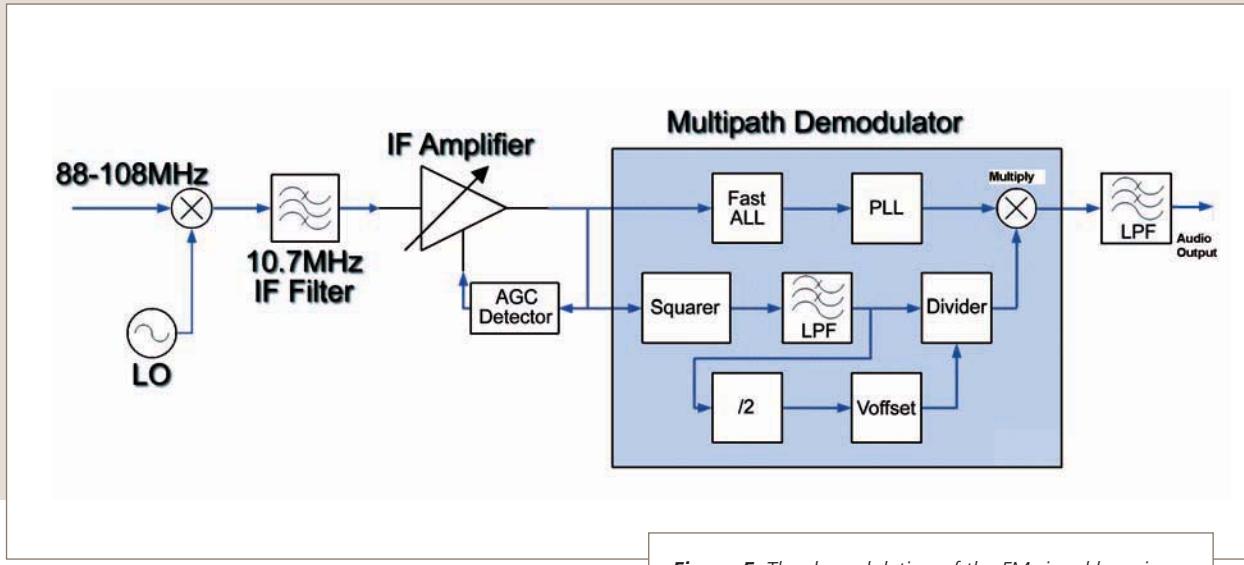


Figure 5: The demodulation of the FM signal by using an ALL and PLL combined to eliminate the noise effects of a hard limiter

failure duration. You are dealing with complete carrier failure over substantial SCAM distances. This may well lead to the abandonment of DAB as a technology. It has already been abandoned in Finland and Sweden.

Amplitude Modulation

Using k to denote the depth of modulation instead of m , since we are using m as the reflection coefficient, amplitude modulation is defined as:

$$v_{inc}(t) = (1 + k \cos \omega_m t) \cos \omega_c t$$

$$v_{ref}(t) = m(1 + k \cos \omega_m(t - \tau)) \cos \omega_c(t - \tau)$$

Applying the same argument used earlier, we equate m to unity (loss-free reflection) and the delay τ to be π radians at the carrier frequency:

$$v_{inc}(t) + v_{ref}(t) =$$

$$(1 + k \sin \omega_m t) \cos \omega_c t + (1 + k \sin \omega_m(t - \tau)) \cos \omega_c(t - \tau)$$

$$v_{inc}(t) + v_{ref}(t) = k\pi \frac{\omega_m}{\omega_c} \cos \omega_m t \cos \omega_c t$$

For 100% modulation or k equals unity gives:

$$v_{inc}(t) + v_{ref}(t) = \pi \frac{\omega_m}{\omega_c} \cos \omega_m t \cos \omega_c t$$

Once again, the 'great notch filter in the sky' has removed the carrier and we are left with suppressed carrier amplitude modulation or SCAM-AM with the same attenuation factor as in FM. If we are using a standard diode circuit for the demodulation process, then severe distortion will result since the envelope becomes the full wave rectified version of the original modulation.

To demodulate AM carriers in the presence of SCAM multi-path, you need to use a DSSC AM demodulator without requiring a pilot tone. When I published the technique for doing just this, ten years ago, I was told that there was no requirement for it since no one ever uses DSSC AM transmission.

Digital Modulation

The simplest and most basic form of digital

modulation is Quadrature Phase Shift Keying (QPSK), which is amplitude modulation with two orthogonal carriers. Without proving the case mathematically, it can be shown that when the conditions for SCAM are met, the carriers will be filtered out leaving only the sidebands and will suffer severe attenuation. There will be no energy present at the carrier to keep the locking circuits on track and the system will fail due to loss of lock.

The Demodulation Challenge

Returning once again to multi-path distortion in FM, which is now known to be caused mainly by two echoes only, the challenge is to demodulate the signal with minimum distortion during a SCAM event. The current approach to this problem is to use diversity reception. This uses two or more antennas to try to avoid the SCAM zones by switching over to another antenna once a SCAM zone has been detected. Apart from the substantial cost of the antennas, there is the cost of extra tuners and the switch over circuitry. The way they work is to try to jump to another antenna in the hope that it will not be in a SCAM zone also. Unfortunately, a SCAM zone can be as long as one half wavelength and where it is, diversity fails and you are no better off. A more elegant solution is to design a circuit that will continue to operate during the entry, through the SCAM zone and out of the exit. Also, the carrier can be quite strong during a SCAM event and is, therefore, an unreliable measurement for controlling the switchover point.

Demodulation Of FM During SCAM Events

At the core of all FM demodulation is the limiter, first implemented by Edwin Armstrong in his original demodulator to remove amplitude variations from the incoming carrier and present only frequency variations for signal extraction. This was a perfectly reasonable approach, since the quality of FM demodulation was much worse without a limiter. There was the unfortunate side-effect that the signal-to-noise deteriorated rapidly when the carrier

A New Approach to **DEMODULATION**

became weak, but this had to be accepted.

No alternative to the limiter could be suggested until the invention of the ALL in the early 1990s by the author. The ALL may be described simply as a high bandwidth servo loop using a linear multiplier with a pure integrator in the feedback path as the gain-varying element.

The ALL has a number of interesting properties that are not obvious at first inspection. They can be summarised as follows:

1. When the carrier vanishes, the loop falls out of lock and ALL output also drops to zero. The white noise is not highly amplified as happens with the limiter.
2. The circuit acts as an extremely high Q filter for the sideband pairs of an AM carrier. The pure carrier can be recovered without any resonant filter components.
3. When combined with a linear PLL phase detector, the jitter on the PLL spikes can be eliminated, since there is no arc sin law caused by the limiter.

When these three properties are combined in an appropriate manner, the spikes that appear in a typical demodulator output can be correlated with the envelope values of the carrier and information therein can be used to assist in improving the demodulated signal. This approach has never been feasible before.

The circuit diagram shown in **Figure 5** is of an ALL operating in concert with a PLL to demodulate an FM signal, without the use of a hard limiter. There is no extra excessive phase jitter in the PLL output and the correlation with the carrier envelope is unity under most conditions. This means that all the valuable information contained in the envelope can be used to assist the demodulation of the final product. The bandwidths of the ALL and the PLL are made as high as possible, being 10MHz and 2MHz, respectively. This generates the narrowest value of spikes.

In the demodulation of an FM carrier during a SCAM event, a very large spike occurs at every zero crossing of the modulating signal, especially when the delay distance is small. This is the delay distance shorter than 1km (at 100MHz), where the difference frequency is still zero. The carrier has been transmitted through a delay line and the echo added to the original. This is shown in **Figure 1**. The PLL output is shown in the lower figure, with a spike at every zero crossing.

To eliminate this spike, it is necessary to multiply the spike by its 'reciprocal' value. If the demodu-

lator spike has values between, for example one half and twenty units, the reciprocal spike must have values between two units and one-twentieth unit of amplitude. The product then becomes unity times the wanted signal.

If there is no jitter between the phase of the demodulator spike and the Corrective Time Function (CTF), then the two waveforms can be multiplied together to obtain distortion-free demodulation. The two component waveforms are shown in Figure 2. In **Figure 3**, the corrective time function multiplies into the PLL output and the spike is quenched or eliminated. **Figure 4** shows a system block diagram of the new demodulator. A detailed circuit diagram of ALL and the PLL working in concert with each other is shown in Figure 5.

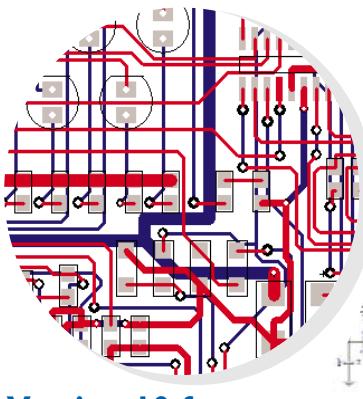
Using the technology just described, multi-path distortion has been eliminated or greatly reduced in test sites, ranging from built-up city environments (short distance SCAM) to long distance mountainous terrain SCAM, during thousands of hours of testing and the recording of results. Plans are now in the process of converting the new demodulation to an ASIC that will become available under appropriate licence agreements. The technology can be applied to all communication links that are prone to multi-path distortion conditions, such as car radios, radio microphones, RFID and all mobile FM communications, including mobile phones (see Figure 4 and 5).

The Right Solution

It has been discovered that the Rayleigh distribution is not valid for describing multiple echoes in FM (or AM) demodulation. Using some fairly elementary mathematics, starting from the basic delay equation addition of two carriers, there is a phenomenon whereby the carrier is removed from the composite addition and the signal cannot be demodulated. This is called the SCAM-FM zone and has a length from 3mm to 1.5m at, say, 100MHz carrier frequency.

Attempts to solve the problem using diversity receivers can only ever be partially successful, since there is a very common condition where the carrier can be quite strong and yet be still in a SCAM zone. The better solution is to understand the problem and build appropriate high-speed analogue circuitry that reacts instantaneously to the presence of multi-path conditions. Since there is no processing delay, the listener is unaware that SCAM multi-path is happening and reception is perfectly satisfactory.

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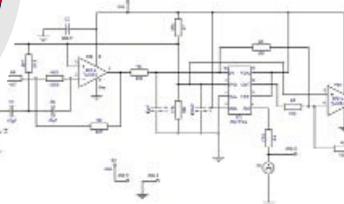


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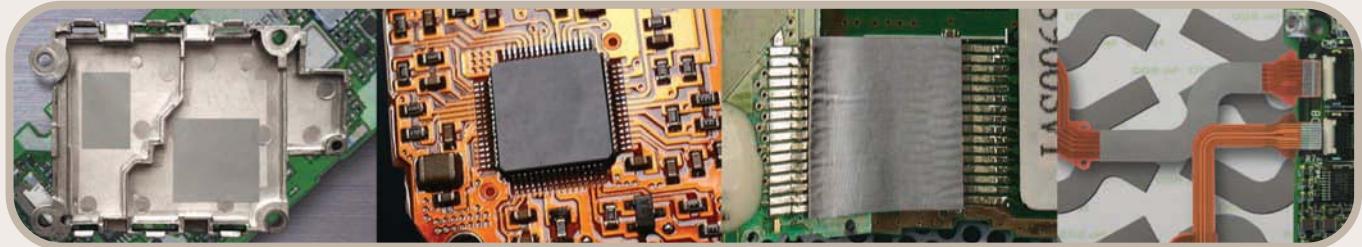
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RF SIMPLIFIES IN-CAR WI



In-car wireless communications is one of the most exciting and rapidly evolving fields in automotive. It does, however, demand getting to grips with certain complexities of high frequency RF design. As Dr Andreas Riemann of TDK Electronics's European RF design centre in Dublin explains

Anything that successfully differentiates one manufacturer's car model or after-market product from another can significantly help sales in the fiercely competitive automotive industry. This is why automotive is one of the earliest and most passionate adopters of new technology.

One area that is transforming the modern driving experience is in-car wireless data communications. Prime applications include MP3, gaming and DVD video streaming, in-car digital TV, 'infotainment' systems, high-speed web browsing and e-mailing, Digital Audio Broadcasting (DAB), traffic reports and automatic mobile phone access via Bluetooth. It is also expected that in the not too distant future some form of computer will be mounted in the car, sharing information with the passenger space, probably via a high speed wireless 802.11a/b/g connection. This would enable the user to seamlessly port MP3 media from home to car to office, at leisure.

Delivering such pervasive wireless in-car data communications, however, means getting to grips with a level of high-frequency RF design complexity never before seen within a car, and that only continues to grow. Many companies, including semiconductor firms, have worked hard to shift as much RF complexity as possible away from the design engineer and into their extended product portfolios. This has allowed numerous automotive RF module and component suppliers to produce "off-the-shelf"

Figure 1: EM absorption using cut-to-shape Flexield from TDK, where Flexield is a flexible, thin ferrite based electromagnetic (EM) wave absorber material that can be cut to shape and attached to the interfering component or the shield can via its double sided adhesive

ferrite and ceramic RF products that, in some instances, demand little or no RF design expertise to incorporate. That said, the basics of RF design cannot be completely ignored. This article will look at the broad use of black and white ceramic in four key areas of automotive design: power supplies for RF, RF circuit layout, RF boards and antennas.

Power Supplies For RF

Successful in-car wireless communications begin with a clean, stable power supply. From an RF perspective, a car's power supply should be considered both poor and noisy, contaminated with a mixture of short and long spikes radiating through the vehicle via bus wires and power lines (typically some mixture of traditional 12V plus some 24V and 48V systems) running in parallel.

Common voltage requirements for RF circuits are +5, +7.5 and +12V with a low current negative supply. These have to be protected against both power black-and grey-outs.

The active semiconductor devices in in-car RF communications systems will amplify any noise in the power supply or signal chain and overlay it onto the desired signal. A received GPS signal at, say -150dBm, can be subjected to impulsive noise that can easily reach -30dBm. This will lead to problems ranging from high bit-error rates in any data transfer process, reception difficulties relating to problems locking on to signals and intermittent to total communications failure.

This issue is best addressed by removing noise as early as possible in the circuitry. This includes employing (automotive certified) noise suppression chokes, ferrite beads, feedthrough capacitors and varistors into power supply lines, as well as signal lines leading into the circuit under development.

Circuits detecting high frequencies often have special requirements, as even noise from wanted signals, such as that radiated from bus lines, can impair functionality. Careful

WIRELESS COMMUNICATIONS

circuit layout can significantly reduce such interference. If problems persist, however, wave absorption may be a more attractive option than wave reflection via the shield can.

RF Circuits

While it is relatively easy to create a basic LC circuit filter using discrete components, designing an RF filter that is optimised, stable and tuned to a specific frequency range and stable in automotive use (e.g. over a wide operating temperature range) is not a trivial task. There are, however, a wide range of high quality off-the-shelf filters available that are cost-effective, ready to use and automotive certified.

The three main types of RF filter relevant to in-car wireless communications are: low pass, high pass and band pass. For band-pass filters there are several ways of implementing these with block and multilayer ceramic being a first choice for emerging technologies.

Each filter type has its advantages and tradeoffs in cost, insertion loss, bandwidth, ripple and temperature stability. Block ceramic filters, for instance, can be designed into narrowband antenna amplifiers or used as IF filters. Their insertion loss is generally higher than that of multilayer filters, however, they are usually designed to have a narrower bandwidth and steeper frequency roll-offs. Multilayer ceramic filters, on the other hand, have a low insertion loss and are less selective: their design being similar to high- and low-pass filters. Typical values (TDK products) are 0.5dB insertion loss (IL) for low-pass filters and 1-3dB for block ceramic band-pass filters.

Depending on whether a differential or single-ended amplifier is used, a single-ended antenna signal can be divided using either a discretely implemented balun or off-the-shelf baluns available in all standard impedance configurations.

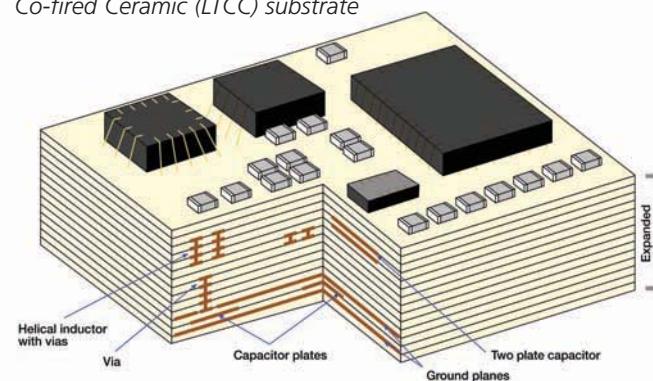
As multiband systems (e.g. IEEE 802.11a/b) move into the car, so does the need to separate received frequency bands. At frequencies above 1GHz, a discrete implementation is possible that carries the risk of performance fluctuations due to variations in assembly, additional mounting and testing costs, where a range of single component, low-cost diplexers, triplexers and couplers are readily available.

These components then have to be arranged on a RF-suitable circuit board, that has been specifically designed to avoid EMI problems by careful circuit layout.

RF Boards

Track lengths greatly influence noise propagation and coupling. With increasing frequency, the wave length decreases and a designer can quickly yet quite involuntarily create a track that has a quarter of the wave length, i.e. a good receiving antenna.

Figure 2: Example of an Low Temperature Co-fired Ceramic (LTCC) substrate



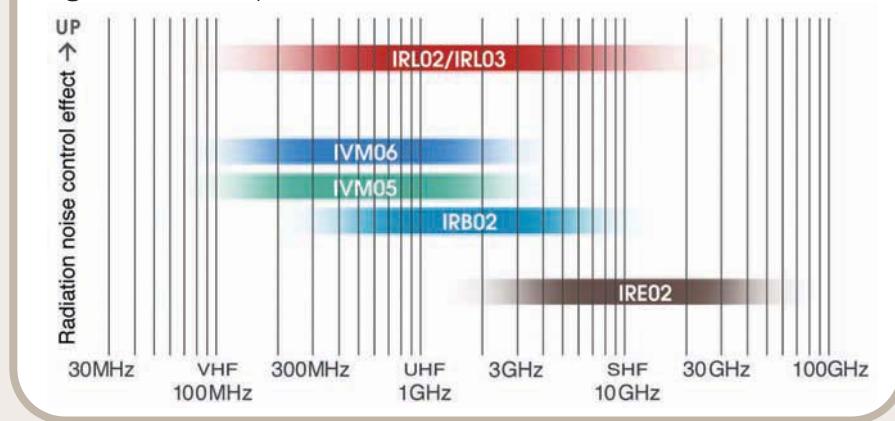
One way to cut down track lengths is to integrate components into the circuit board using Low Temperature Co-fired Ceramic (LTCC). Besides eliminating surface mounted components, which are more prone to failure in the automotive environment, cross coupling, size and weight are all reduced. This means that often the size of the integrated circuit (IC) is the determining factor for board size, which will change as the IC manufacturers move forward to providing bare-chip circuits. Size reductions of 40%-plus are common for LTCC implementations, and up to 80% has been achieved compared to all-discrete implementations.

To date, LTCC has generally been perceived as slow and costly. However, recent advances in design and manufacturing techniques are changing this attitude, especially if local design support is made available on a global basis.

RF Antennas

Automotive antenna location – currently seven different types with roadmaps of up to 30 having been presented – and associated communications electronics will have to be embraced. An 802.11a and 802.11b-compatible in-car wireless communications system (i.e. two bands) with quad-band GSM, GPS plus Bluetooth, will need to be able to operate at eight separate frequencies: 802.11a is 4.9-5.9GHz, 802.11b is 2.4-2.48GHz, GPS 1575MHz (receive only), conventional mobile bands run from 880 to 960MHz and 1710 to 1880MHz; and when 3G is fully rolled out, its frequency range is 1900 to 2200MHz and achieving that at present requires separate (i.e. its own) feeding circuits.

Furthermore, the majority of RF chipsets and antennas for each wireless communications standard will be sourced from different vendors who naturally design their products in isolation. This approach may cause compatibility problems when integrating into a unified product for automotive use.

Figure 3: EM absorption of selected Flexield materials

Although, to date, many automotive antennas are combined in a single roof-mounted external housing, this will no longer be possible for low-power in-vehicle information distribution. There also is a general aesthetic trend towards embedding selected antennas in the body of the car itself (some manufacturers prefer a clear line of sight to the transmitter to reduce attenuation).

At resonance, the antenna transmits EM radiation to a remote receiver. The directionality and sensitivity of the antenna can be adjusted by varying its gain, which is the power increase in a specific direction, compared to the power transmission achieved by a perfect isotropic antenna that spreads energy equally in all directions. Gain is usually expressed in isotropic decibels (dBi).

A wireless local area network (WLAN) antenna will have a relatively low gain of between -2 and +2dBi to ensure that it can communicate with equipment located anywhere within its small range of operation. By contrast, a car-mounted GPS antenna prefers higher gain e.g. +2dBi and higher directionality to communicate with distant satellites while reducing the impact of terrestrial transmitters in adjacent bands.

As a rule, the higher the power, the better the reception quality and the more tolerant the communications system is to less-than-optimum antenna design. The

general drive towards lower power transmissions, however, means that reception sensitivities will have to increase. In addition, signal-to-noise ratios, which are the minimum power difference between receive signals and ambient RF noise, must be well-defined with due considerations to design tolerances.

Know Your Basics

Successfully designing an in-car wireless communications solution isn't easy. But the task can be made significantly more straightforward if the designer selects suitable components and off-the-shelf modules that have passed stringent automotive certification and have been designed to be integrated together.



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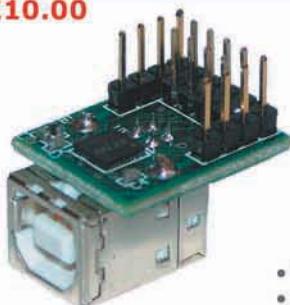
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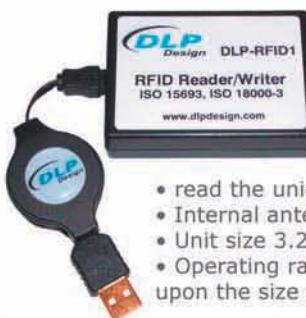
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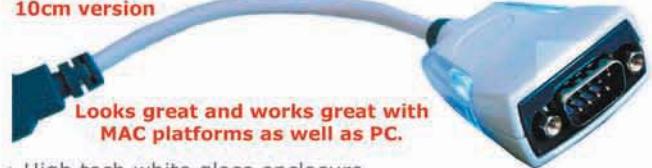
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Integration of BALUN FUNCTIONS in RF

Gerard Bouisse of Freescale Semiconductor based in Toulouse, France, here deals with the LDMOS IC substrate specifics, the balun design challenges, and presents two successful designs and their measurement data

Baluns (balanced to unbalanced) are used in push-pull amplifiers to provide signal splitting and/or combining and 180° phase shifting. Although their usage and design is well known, mainly for broadband amplification, with the recent arrival of high power LDMOS MMICs in the cellular basestation arena, and the subsequent reduction in component count, no attempt has been done to integrate this functionality on

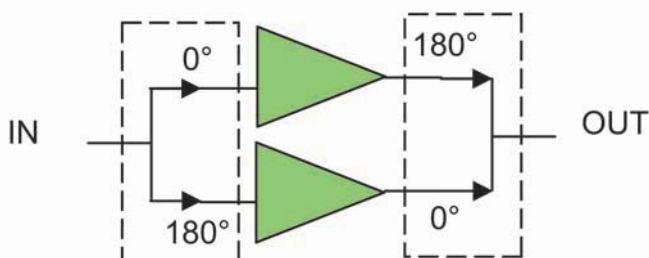


Figure 1: Push-pull power amplifier topology

the particular substrate used by LDMOS RFICs.

The simplified topology of a push-pull amplifier is presented in **Figure 1**.

The two rectangles in dotted lines represent the input and output balun functions. The input balun splits the RF signal in two, creates a 180° phase shift between the two signals, and can create, if desired, a broadband matching structure, therefore, decreasing the transformation ratio between the generator (50Ω) and the transistor terminal.

The output balun has an opposite role. It combines the two signals while outphasing them, and can also provide a broadband matching structure. The two transistors amplify in phase opposition. Among the different advantages of a push-pull configuration is the bandwidth performance, resulting from a lowered transformation

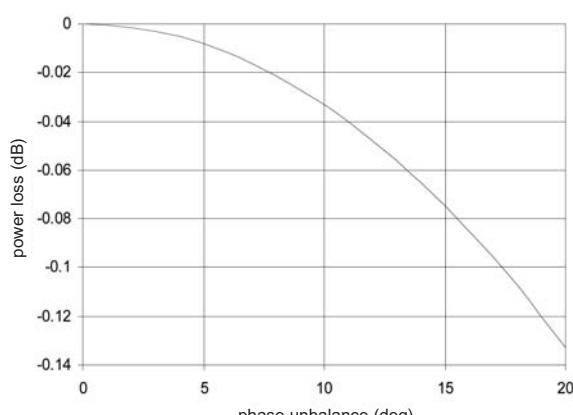


Figure 2: Power loss versus phase unbalance

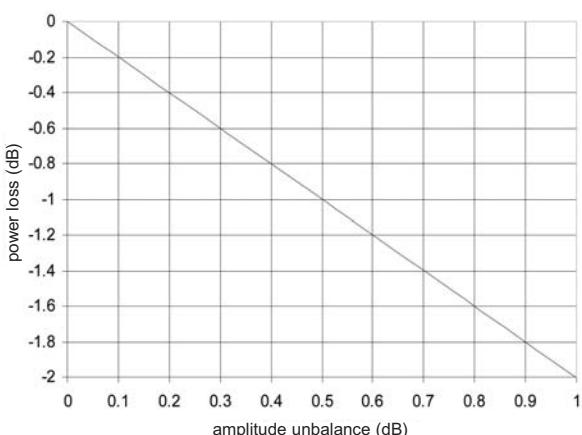
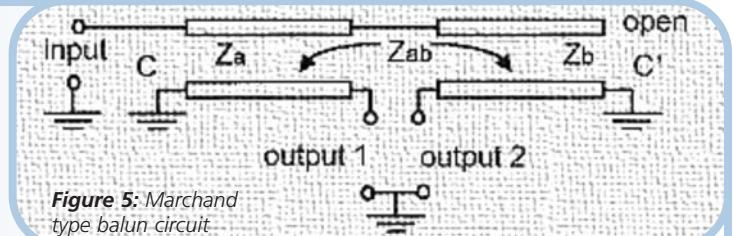
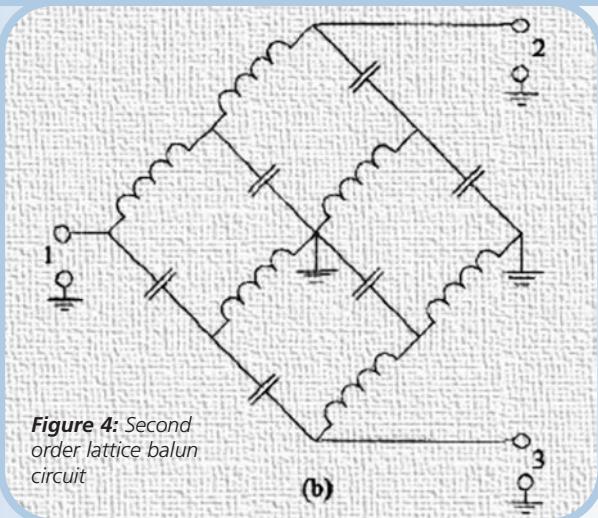


Figure 3: Power loss versus amplitude unbalance

ratio between transistor terminals and load, compared to a single-ended configuration.

LDMOS TECHNOLOGY



balun is 1.8GHz-2.7GHz with appropriate amplitude and phase unbalance, and insertion loss compatible with the achievement of a reasonable gain for a two stages LDMOS RFIC (25dB).

Let's consider the impact of amplitude and phase unbalance on the power loss of a push-pull power amplifier.

Let's assume that two signals $V_1(t)$ and $V_2(t)$ are applied on the balanced port of a balun and $V(t)$ the resulting signal at the output on the unbalanced port.

Recent Developments

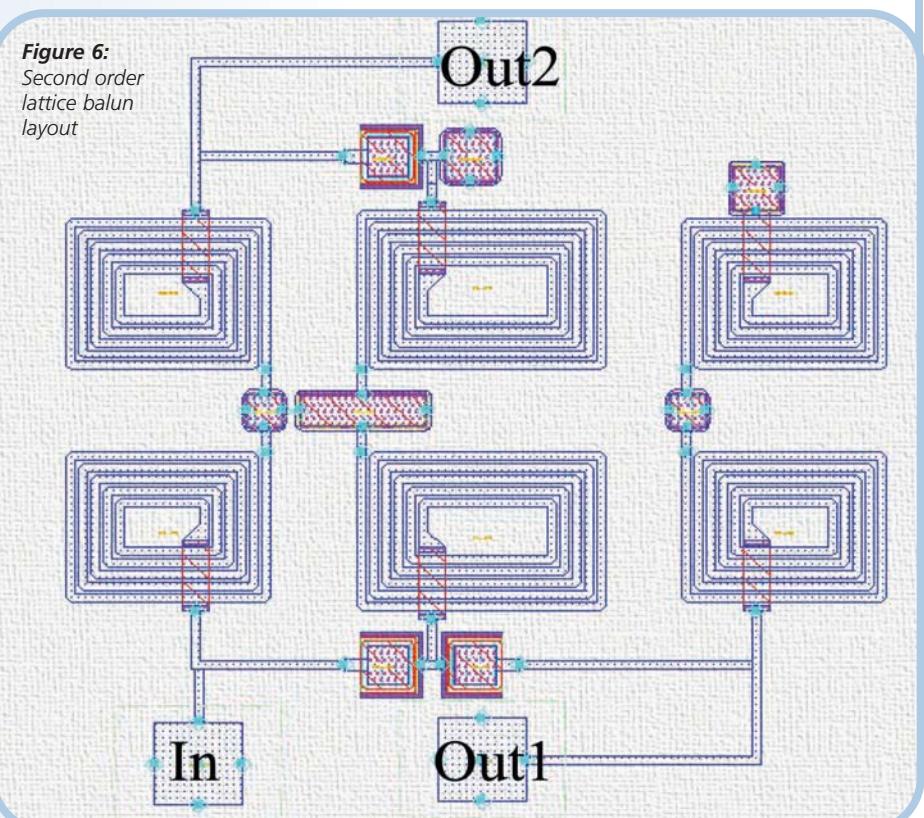
In recent years, in the RF power basestation world, many RF semiconductor manufacturers have introduced integrated power amplifiers using Laterally Diffused Metal Oxide Semiconductor. All these components are aiming at narrow band amplification and, therefore, feature a single-ended topology.

One of the specificity of the LDMOS technology is the usage of very low resistivity substrate, in the order of tens of $\text{m}\Omega/\text{cm}$. This feature, although highly desirable from the transistor standpoint for source grounding purposes, is a real nightmare in terms of passives, mainly inductors and transmission lines which suffer from very low quality factors.

The reported activity in this article relates, in general, to the design of broader band amplifiers than conventional 5% relative bandwidth single-ended power amplifiers, using push-pull structures with specific emphasis on the input balun circuits, in LDMOS technology.

Balun Designs

The targeted bandwidth for the



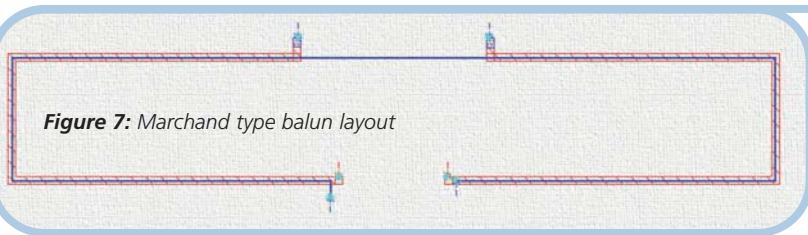


Figure 7: Marchand type balun layout

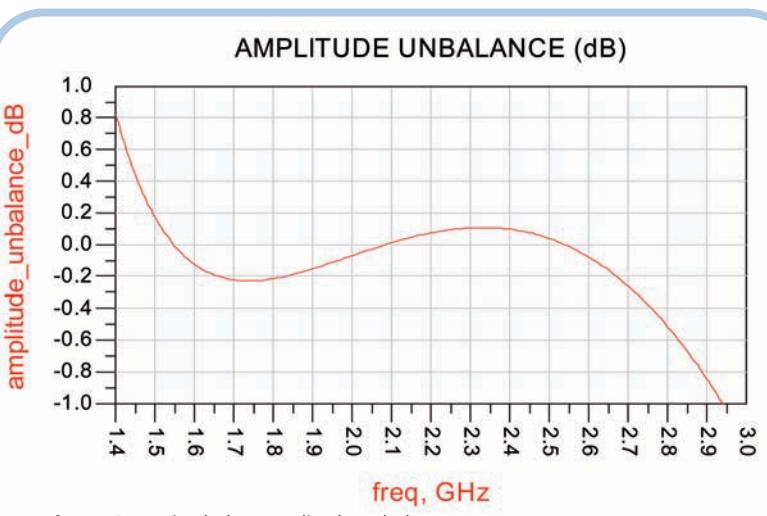


Figure 8: Lattice balun amplitude unbalance

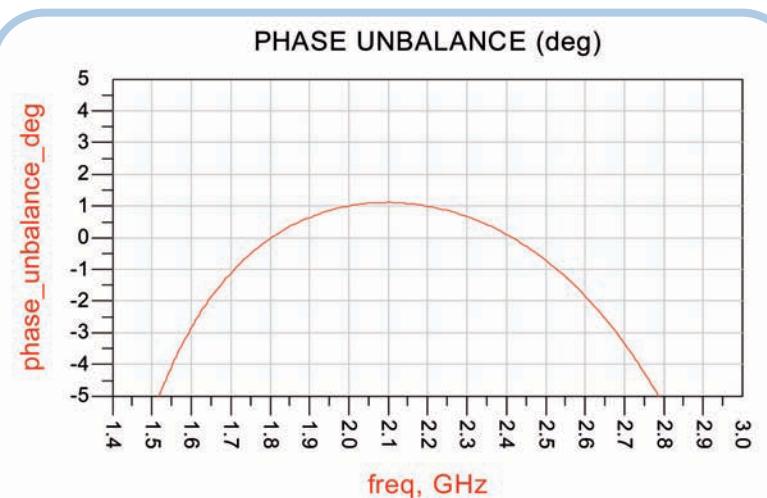


Figure 9: Lattice balun phase unbalance

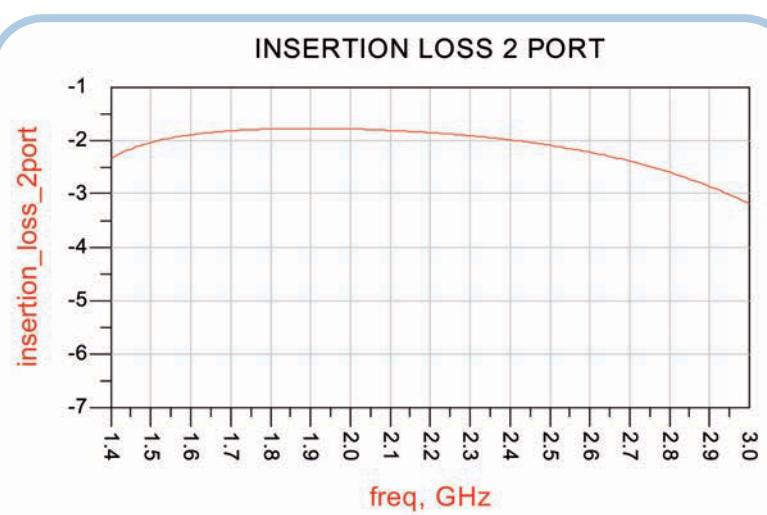


Figure 10: Lattice balun insertion loss

Phase unbalance:

$$V1(t) = V \cos(\omega_1 t)$$

$$V2(t) = V \cos(\omega_1 t + \Delta\Phi)$$

Therefore:

$$V(t) = 2V \cos(\Delta\Phi/2) \cos((2\omega_1 t + \Delta\Phi)/2)$$

and the power loss due to the phase unbalance becomes:

$$\text{Power_loss} = \cos^2(\Delta\Phi/2)$$

This is illustrated in **Figure 2**.

Amplitude unbalance:

$$V1(t) = V1 \cos(\omega_1 t)$$

$$V2(t) = V2 \cos(\omega_1 t)$$

Therefore:

$$V(t) = (1 + V1/V2) \cos(\omega_1 t)$$

And the power loss due to the amplitude unbalance becomes:

$$\text{Power_loss} = (V2/V1)^2$$

This is illustrated in **Figure 3**.

As demonstrated by these graphs, the amplitude unbalance has much more impact and is much more stringent than the phase unbalance.

Several active circuits have been considered, among them are the circuits using the "natural" outphasing between drain and source, and differential pairs. For the frequencies of interest, with today's available RF LDMOS transistors, the performance in terms of unbalance is not good enough, mainly because of excessive parasitic capacitances.

Among the passive structures several circuits have been simulated and some of them, such as "rat-race" or first order lattice balun, have been rejected because of insufficient bandwidth performance. Nonetheless, two of them have been considered, the second order lattice balun and the Marchand type balun.

The former is based on the principle of two paths having respectively + and -90° phase shift, achieved with low and high pass networks. This is illustrated in **Figure 4**.

The latter uses the vertical coupling between transmission lines and the opposite current flow on the balanced sides creates

the broadband 180° phase shift. The principle is described in **Figure 5**.

The lattice balun has been realised with conventional integrated inductors and capacitors, as shown in **Figure 6**, and the Marchand type balun is using the coupling between microstrip lines on different metal layers; the layout is shown in **Figure 7**.

The lattice balun has been simulated with a conventional circuit simulator, while the Marchand balun required 2.5D electromagnetic simulation.

Experimental Results

The two circuits listed here have been measured as stand alone three-port networks and also in cascade (as two ports), in order to measure the insertion loss. The results are presented in the **Figures 8 to 13**.

These measurements show that the second order lattice balun performs well in the 1.7GHz-2.7GHz with 0.2dB amplitude unbalance, 5° phase unbalance and about 2dB loss. The Marchand balun has an even wider bandwidth, approximately 1.7GHz to 4GHz with about 0.4/0.5dB amplitude unbalance, 6° phase unbalance and 4.5dB loss. Although these insertion loss numbers are much higher than their semi-insulating or dielectric counterparts, these performance level remains highly compatible with the design of 25dB and above two stages LDMOS MMICs (including the balun integration).

A Step Toward Power Amps

This paper describes the need for integrated baluns in LDMOS IC technology, the design challenges, linked mainly to the substrate limitations, and presents two functional circuits such as a second order lattice balun and a Marchand type balun. The measured performances confirm the possibility to integrate such functions and may constitute a step towards power amplifiers for software definable radio.

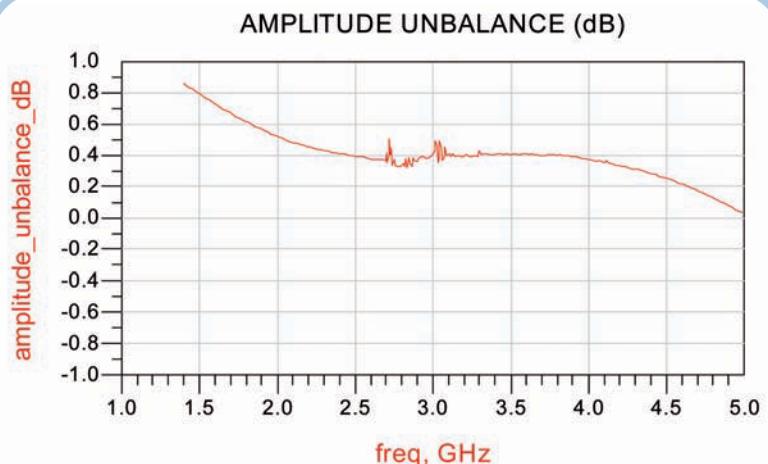


Figure 11: Marchand balun amplitude unbalance

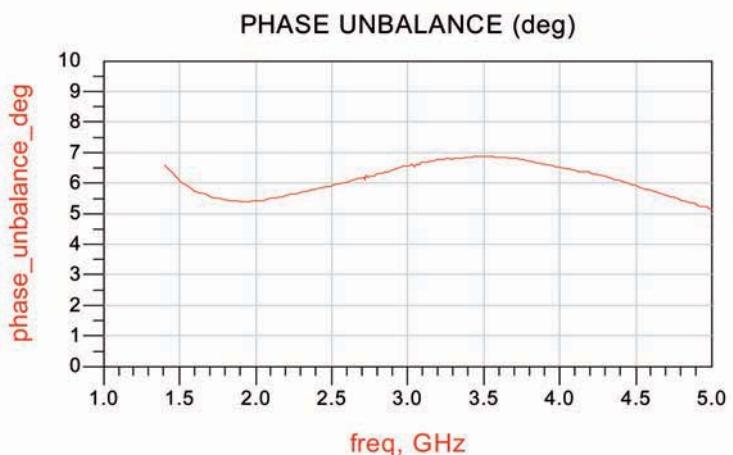
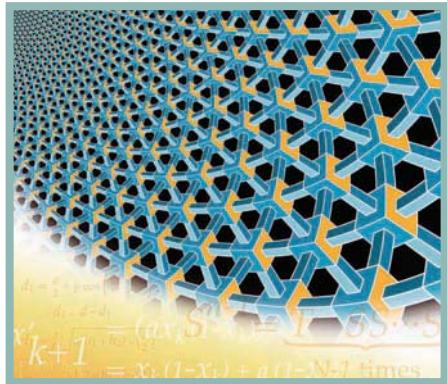


Figure 12: Marchand balun phase unbalance



Figure 13: Marchand balun insertion loss



ANTENNA TECHNOLOGY boosts the WIRELESS WORLD

Dr. Carles Puente, CTO and co-founder of Barcelona-based Fractus, describes a new geometry for antennas that will change the landscape for wireless devices

In the wireless era, the pace of change appears incessant and the demand for new applications and services is insatiable. From multimedia messaging to mobile TV, from location-based services to global roaming, the seemingly unstoppable market forces are pushing innovation beyond what has traditionally been considered to be the limits. As technology evolves and we witness the vast improvements in size, power consumption and processing speed that are taking place in electronics and RF design, the boundaries of what is possible are continuously being redrawn.

The evolution of the antenna exemplifies this process perfectly. The antenna is a key element in the value chain of a wireless system or device. Operators around the world stake their reputation on every precious bit of data that their customers entrust them with and every piece of this information is launched into the air through, at least, two antennas.

Despite the indispensability of the antenna within any wireless system, until recently the antenna had been considered a standard solution, with little innovation required. But the role the antenna is playing today on the design of any wireless device has led many device manufacturers to rethink its strategic importance. The antenna manufacturing industry has been galvanised by device manufacturers and, subsequently, end users, which place unprecedented importance on the size of a device, as well as its performance, form-factor and basic aesthetic.

The mobile phone business has undoubtedly engendered the most radical evolution in antenna conception and engineering. As the most successful consumer electronics product in history, the huge competition in the mobile phone market has led to increased demands for features that the conventional antenna had simply not been able to deliver.

What's In A First

Some first phones with a single-band internal antenna appeared in 1998. While today the advantages of a handset with an internal antenna appear obvious, just seven years ago it was unclear if anyone would pay for a phone that had no visible antenna. For a considerable amount of time, the myth prevailed that the internal antenna could never match the performance of the external antenna. In fact, this myth survives in some markets, despite numerous reports that conclude that this is not an issue when the handset is operated in real conditions, either next to the user's head or when held in the hand. Such myths were, in part, supported by a theoretical analysis of classical constraints in antenna science, as well as wireless engineering experiments carried out in the early days. However, most of these failed to address the all too pertinent environment and operating conditions of handheld devices.

As soon as the antenna was relocated inside the device, the operators and handset manufacturers realised that the huge growth in the demand of mobile telephony was about to saturate the allocated spectrum in the UHF band (mainly in the neighbourhood of 900MHz in Europe and Asia, and around 850MHz in the US and Japan) and that new bands were required

OVERVIEW OF HANDSET ANTENNA EVOLUTION

- 1983 – First 'portable' phones with large $1/4$, $1/2$ wavelength fixed antenna
- 1990 – First phones with retractable antennas
- 1993 – First phones with fixed, small, stubby antennas
- 1998 – First phone with internal, single-band antenna

(1800MHz for GSM in Europe, 1900MHz for PCS in the US). This would require that operators start upgrading their single-band networks to dual-band and that handset manufacturers begin to promote new phones with dual-band, seamless roaming capabilities.

The Antenna Dilemma

Since then, the number of handsets with increased bands and services has been constantly growing, with quad-band phones (GSM 850, 900, 1800, 1900) becoming widely available during 2005. In 2006, we've witnessed the rise of penta-band phones, featuring four GSM bands plus UMTS (3G).

The conventional approach of building multi-band functionality into any device had often been quite simple: use a single-band antenna for each frequency band or wireless communication service. The design of small multi-band antennas was viewed as a 'niche' field in antenna engineering since there were so few real needs for multiple band operation.

Nowadays, the notion of satisfying the penta-band market demand with a mobile phone housing five external antennas is unimaginable. Nevertheless, when packing five different wavelengths into a small, compact, embedded antenna, the device manufacturers are now forced to face the traditional antenna engineering dilemma.

A well known principle in antenna engineering holds that the performance of the antenna is primarily determined by the relationship between its geometrical features (shape, size, volume) and the operating wavelength. For instance, the size of an omni-directional antenna would typically be a quarter or half the required wavelength in order to transmit and receive electromagnetic signals efficiently. It soon becomes clear, therefore, that a problem arises as soon as a single antenna must accommodate multiple wavelengths (from about 35cm for GSM 850 down to about 12cm for the unlicensed ISM band hosting Bluetooth and Wi-Fi) in the limited and finite space available inside a handset.

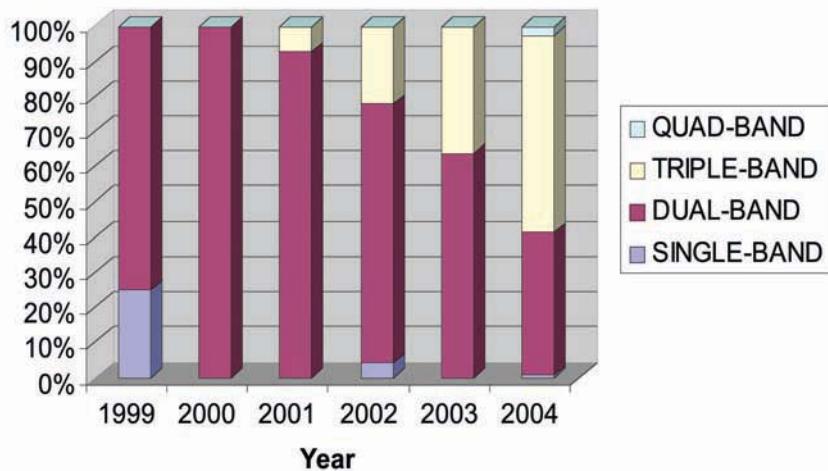
Clearly, a completely new approach to antenna design is required. A flexible approach that could meet the space constraints of modern handsets and wireless devices, where the antenna is competing for real estate with many other features of the handheld domain, such as cameras, MP3 players, connectors and folding and sliding mechanisms.

Fractal Antenna Technology

The invention of the first multiband fractal antennas in the early 1990s revolutionised the antenna industry and brought forward the current development of miniature multi-band antennas.

Since traditional Euclidean geometry with straight lines, squares, circles and parabolas was not meeting the requirements of the evolving wireless marketplace, a new technology based on a different geometry had to emerge. Fractal geometry, with its space-filling and multi-

Announcement of GSM mobile phones according to the number of bands (data from www.gsmarena.com)



scale geometries, quickly appeared as the most logical means of solving this problem.

The word fractal comes from the Latin word *fractus*, which literally means uneven or broken, and was coined by the mathematician Benoit Mandelbrot who provided a unified means of describing this new emerging geometry. A primary characteristic of fractals is their space filling properties as measured through the so-called fractal dimension that is their ability to fill the space in a quite different way. Surprising geometries such as infinite lines that fill up surfaces and infinite surfaces that fill up volumes are routinely created by means of fractal geometry. A second characteristic of fractals is their multi-scale nature, or their ability to host multiple sizes and resolutions within a single geometric structure.

Despite fractals originating from the conceptual, abstract world of mathematics, one of the most interesting facts about fractals is that the same characteristic properties are found everywhere in nature. Throughout millions of years of evolutionary optimisation, nature has found fractal geometries to be the most efficient way to transport energy through (fractal) vessels in animals and plants, as well as a way to organise the universe from the smallest scales (atoms) to the largest (galaxies).

Fractal antenna technology is rooted in the fact that the geometrical qualities of fractals provide highly efficient solutions to the needs of modern wireless devices. The space-filling properties of fractals are engineered to extract the maximum radiation from the available volume within a handheld device. The multi-scale property of fractals is used to pack multiple wavelengths into a single device, allowing the handheld device to efficiently support multiple communication systems and standards.

In the mid 1990s, fractal antenna technology was in the initial stage of development and working to prove itself to the scientific community. Now, in the first decade of the new millennium, we have seen the technology enter into the market. Today, there are millions of fractal antennas worldwide, bringing value to markets where a need for compact, multi-band antennas is at a premium. These markets range from telecom network infrastructure, mobile handsets and wireless devices, to wireless chipsets, cars and even warships.

Fractus Compact Dual-band Reach Xtend WLAN 802.11 antennas



Fractal Solutions Hit The Market

Telecom giant Telefonica was one of the first to deploy fractal technology in 2001, when 60% of its basestations for its new 3G network used fractal antenna technology. Those first basestation antennas, designed, developed and manufactured by Barcelona-based Fractus, were able to combine 2G and 3G services through the smallest form-factor on the market. More recently, fractal antennas have proved to be a hit in the automotive industry, when FIAT and the PSA Group (Citroen and Peugeot) adopted the technology for several new models, and Nippon Antennas licensed the technology for use in the Japanese automotive market. The technology was recently awarded the prestigious PACE award from the American car industry.

However, it is in the mobile phone and wireless device markets that the technology has found its most perfect environment to mature and develop. From compact, embedded antenna bar phones, to flip and slide phones, fractal technology is currently applied whenever there is a tiny space and/or a multiplicity of bands to be handled.

They antennas are to be found in some of the first multi-band slim phones on the market, for example Fractus provided the antennas for Sagem's ultra-slim My300X product line of handsets and for some of the new clamshell phones with internal antennas, such as the Samsung E340. In the wireless arena, the tiniest Bluetooth headset from Nextlink (www.nextlink.to) and one of the first MIMO reference designs for Wi-Fi from Atheros (www.atheros.com) are further examples of the successful application of this technology.

One of the key reasons for the success of fractal antennas is their versatility and flexibility. Since this is a geometry-based technology and the performance is obtained through the 'shape' rather than through a specialised new material, fractal technology is able to provide cost-effective solutions in a wide range of markets and applications.

Fractals provide a rich, infinite set of geometries that when properly engineered, provide effective solutions in multiple spaces. Due to the geometrical essence of the technology, fractal antennas can be

produced using virtually every manufacturing process for conventional antennas, ranging from the simplest metal strapping and printed circuit board process to more sophisticated MID, thick-film, Low Temperature Co-Fired Ceramic (LTCC) and thin-film processes. Although a complex

material is not needed to achieve the required performance, again, because of its flexibility, fractal technology can be supported by simple low-cost materials from plastic carriers and laminate substrates or more expensive materials like high dielectric ceramics and semiconductor materials.

In terms of the antenna topology, fractal solutions can take the form of simple monopoles, slots or loops, as well as more sophisticated multilayer and active-parasitic patch arrangements (such as micro-strip, PIFA and FICA).

In general, every market and every wireless product has its own technical, mechanical and marketing constraints, but there is always a proper antenna geometry that will extract the maximum performance from a device. In the same way that there is a wide variety of form-factors for handsets and portable wireless devices, there are also a wide range of fractal geometries that are ready to provide a solution for each of them. Despite the differences in shapes and form-factors, all those antenna geometries rely on some common basic geometrical rules.

Next Frontiers In The Wireless World

The success of free-space electromagnetic waves carrying billions of bits of information is also being translated into an increase in the scope of scales and ranges in the communication area. From the natural predominance of wireless technologies in huge range links such as a GPS satellite, to the several mile coverage of a cellular system, nowadays wireless solutions are starting to beat the traditional "wired" competition in the short distance as well. With a presence in hundreds of millions of Bluetooth and Wi-Fi devices, modern connectivity antennas are replacing the physical shackles of the traditional cables. The next wave of ZigBee, UWB and RFID products will join the ever increasing applications of Bluetooth and Wi-Fi. This trend toward wireless is only going to amplify the need for tiny, low-cost, easy to use antennas.

However, the increase in technical complexity and sophistication needs to be mirrored by a simpler, smaller, lower-cost and more user-friendly product. Such an apparent contradiction is, however,

addressed through the integration of electronics.

Nowadays, System-in-Package and System-on-Chip architectures are able to provide single-chip wireless solutions that integrate all the basic logic and memory functions, as well as the RF front-end. The antenna can no longer be an exception in this trend and, again, fractal technology has brought a cutting edge antenna solution for its integration into a wireless integrated circuit (IC) package.

Fractus has the FracWave antenna-in-package solution (AiP) for the wireless semiconductor market. This Fractus IP product enables chip makers to integrate the ultimate component of the wireless system and, therefore, deliver fully integrated, single-chip wireless solution. FracWave is available today for the unlicensed 2.4GHz band, so it is the ultimate tool to build a truly single-chip solution for Bluetooth, IEEE 802.11b/g and ZigBee. With a minimum footprint below 25mm², the FracWave antenna

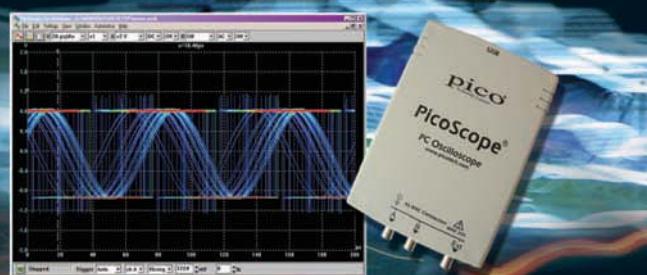
solution can be embedded into a standard, low-cost laminate substrate in a typical BGA, PGA, LGA or QFN package. The performance is equivalent to an external antenna yet the antenna-in-package solution wins with its size, cost or both aspects of conventional antenna solutions (www.fractus.com/aip.htm).

Despite being the key element of wireless connectivity – nothing is wireless without an antenna – for too long now the antenna has been forgotten about and left to languish in an outdated debate about internal vs external antennas and different materials of manufacture. However, the demand for multi-band communications across both cellular and short-range wireless has forced the antenna to undergo a fundamental redesign. Fractal geometry has opened up a new frontier in antenna design that in turn has helped unlock the promise of new applications, services and device form-factors.

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MEMS design steps into

Sensors can now be built into MEMS that take up a fraction of the space demanded by designs that do not take advantage of micro-machining. We are increasingly seeing that MEMS design demands a step into the third dimension. Paul Double, Managing Director of EDA Solutions, considers how some IC design tools can offer a low-cost entry into MEMS design

In contrast to conventional integrated circuit (IC) design, in which the design can be broken down into what can be thought of as 2D layers stacked on top of each other, successful MEMS design generally needs the perspective of the third dimension. Cantilevers need to move up and down, above the surface of a well to provide movement information in the case of an accelerometer. A MEMS filter for radio-frequency processing will vibrate using a number of modes, both vertical and horizontal. However, to make these design feasible using micro-machining techniques, what starts out as a 3D concept needs to be rendered into 2D layers that can be understood by wafer-processing tools and processes. **Figure 1** shows a wafer of 3D MEMS devices and **Figure 2** the corresponding 2D rendering in the design tool L-Edit.

Picking The Right Tools

It is possible for skilled designers to create effective MEMS designs that combine electronic circuitry with micro-mechanical components using 2D design techniques from scratch. With some layout tools it is easier than with others. Those layout tools that are aimed squarely at circuit design make the job more difficult than it needs to be. Most electronic circuit structures are rectilinear, which suits the lithographic environment. However, many MEMS designs demand the use of arbitrary shapes with curves and angles. Designers in this environment appreciate the addition of features to tools that allow them to create many different shapes.

Logical operations provide an example of what is

needed in a MEMS-friendly tool. These make it easy to construct complex shapes and define features such as release holes for a free-standing plate or a flow channel that needs a metal border of a certain width around it. Using a logical operation, it is possible to 'grow' a line to define a border to a specified width. This is much quicker than having to draw and align the border by hand. Further, any change to the flow channel can be accommodated in the border by maintaining the logical link. Logical operations also allow the easy creation of complex shapes in a 2D framework by adding simple shapes together.

However, many designs will be created using the third dimension. This is particularly true of designs where the packaging is critical, which is the case for many devices. The demands on the packaging used for MEMS devices are different from standard microelectronics because the packaging is often crucial to the correct operation of the micro-machined circuitry. MEMS packaging involves having multiple types of interfaces from the chip to the outside world. Not only are electrical connections needed, but there may need to be channels cut to allow fluids or gases to enter a chamber so that an integrated sensor can detect changes in conditions.

At the same time, effective seals are needed to prevent contamination of sensitive electronics around the micro-machined areas. This can require closer tolerances and better matching to the actual chip layout than with standard microelectronics devices that just need a surface passivation layer on top of which a uniform covering of epoxy resin is coated.

the **THIRD DIMENSION**

3D Packaging

For MEMS, package design is best handled using 3D models. This gives the engineering team the ability to better evaluate how the package will perform in different environments and gauge its manufacturability. The 3D treatment allows for detailed modelling of the conditions that the device will face in its target environment. By performing fluid dynamic simulations with a variety of candidate packages, the engineering team can work out how the package will affect the sensitivity of micro-machined fluid and gas sensors, for example.

Most of the initial design and simulation will be through 3D mechanical CAD tools such as Autocad. The question is: how do you convert from a full 3D representation into a set of 2D layers that a lithographic tool can understand? The answer is in the integration that tools such as Tanner's L-Edit for example, provide with mechanical CAD products such as Autocad.

Hymite is one company that starts off with a 3D model of a MEMS device that the engineers then convert into lithographic masks suitable for manufacture. The company, with facilities near Copenhagen and in Berlin, has built a design-

automation flow based around L-Edit.

For its MEMS devices, Hymite needs hermetically sealed packages matched at the wafer-level to the electronic components. Cavities are etched into the silicon to provide a home for an electroplated solder sealing ring and contact metallisation that provides for hermetic sealing.

Vertical micro-vias providing the connection between a metal layer deposited inside the cavity and the outer SMT bond pads. The micro-vias are hermetically sealed by electroplated gold metallisation as shown in **Figure 3**. To define this structure, Hymite defines several IC fabrication masks that will be used on either side of the silicon, as the company uses double-sided lithography and wafer processing.

At Hymite, once the design of the package has been completed in 3D models, the next step is to create a set of IC fabrication masks. The designers define features on 2D sketches that cut through the 3D model. These planes will ultimately become the layer masks that are processed using L-Edit.

One way to import each layer is to use a DXF import filter, although designers could choose to recreate each layer using the advanced drawing tools

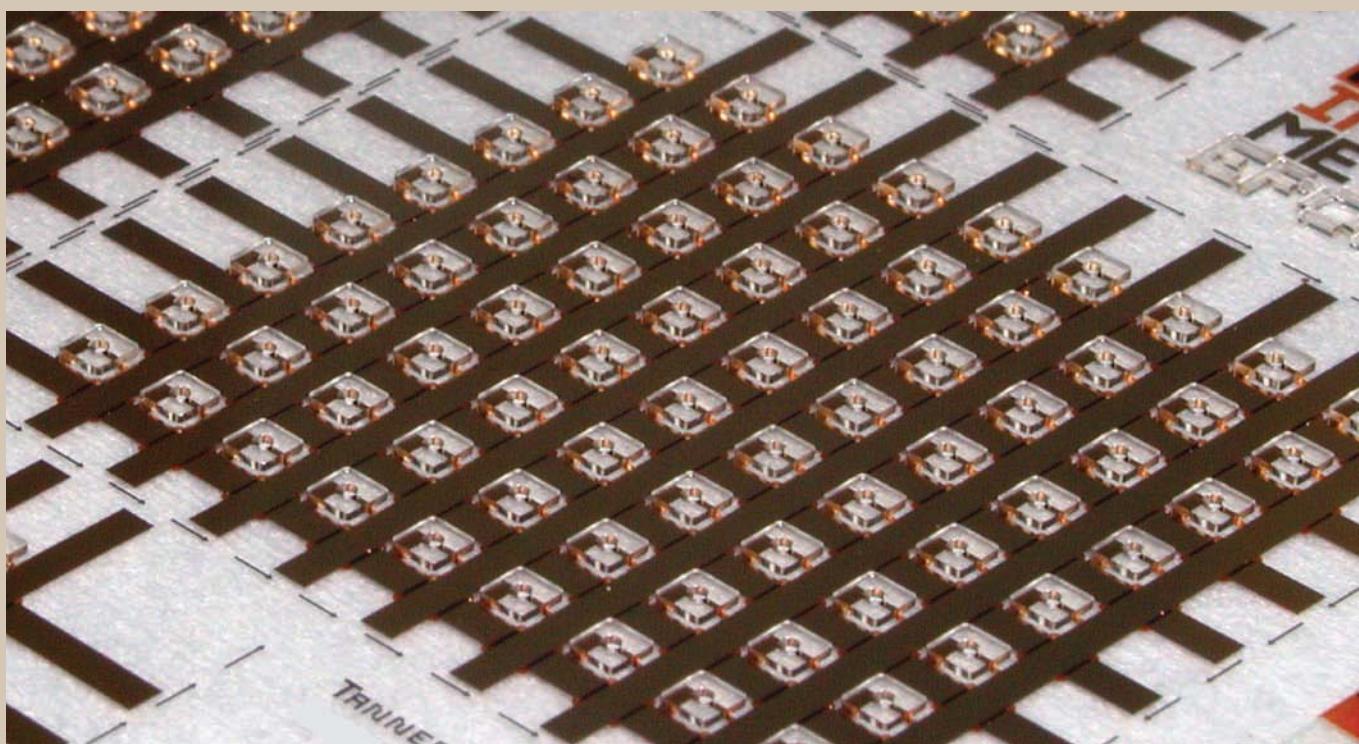


Figure 1: Wafer of 3D MEMS devices

Figure 2: 2D rendering of a wafer of 3D MEMS devices in the L-Edit tool

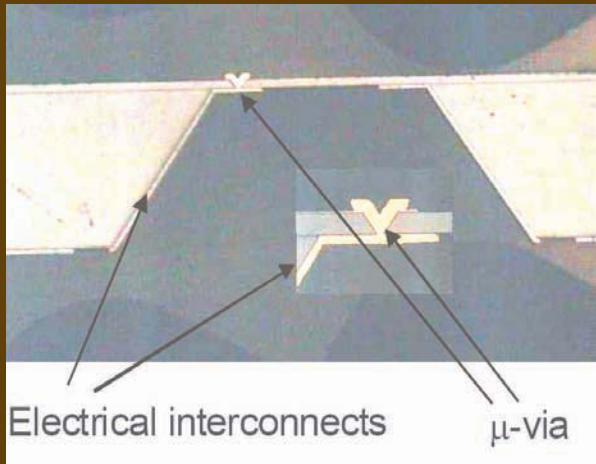
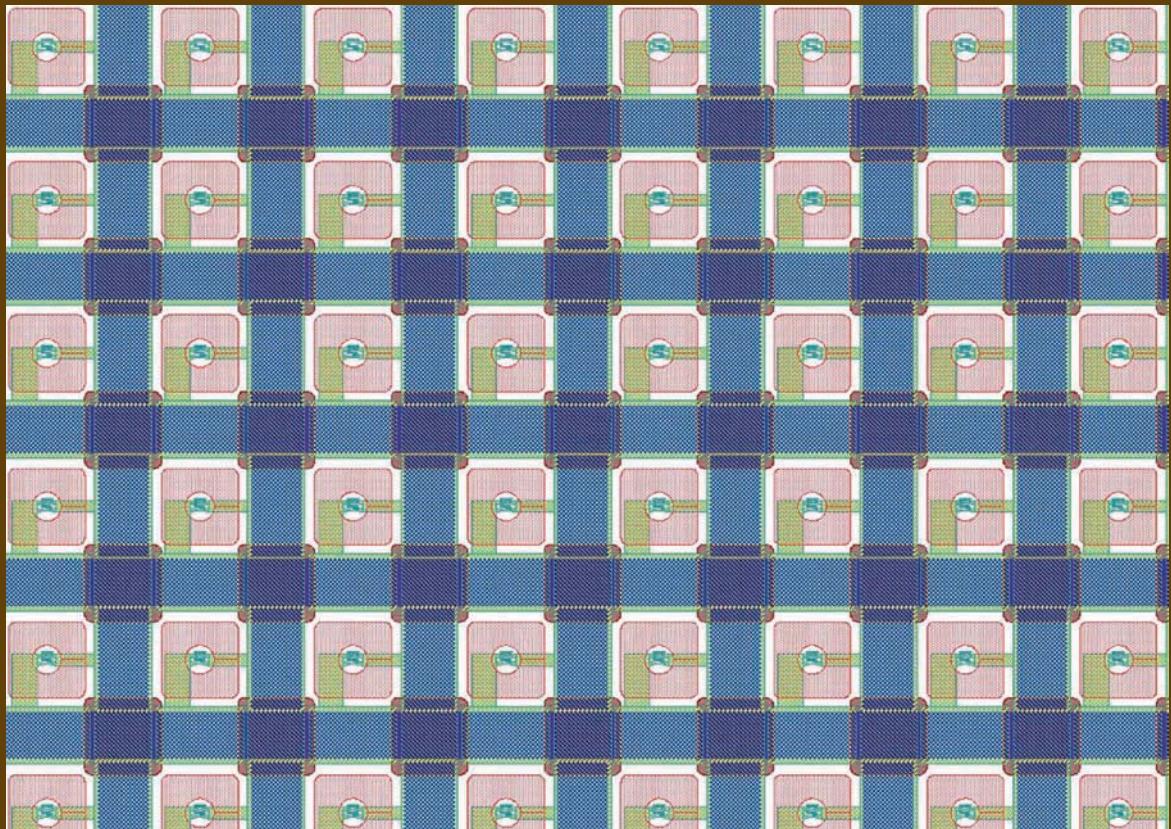


Figure 3: The micro-vias are hermetically sealed by electroplated gold metallisation

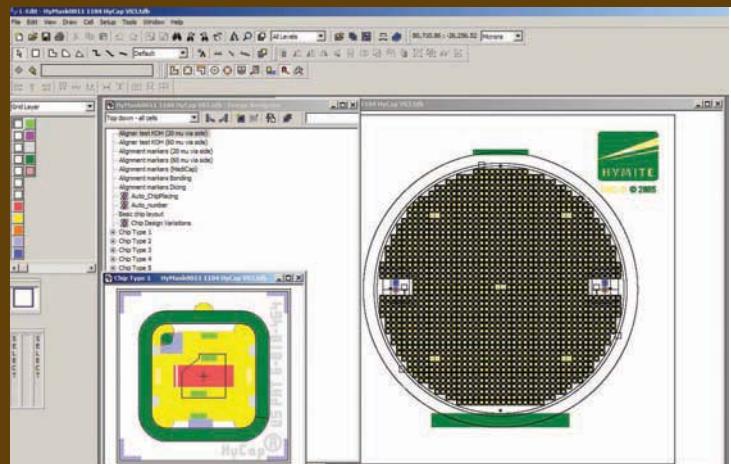


Figure 4: Hymite cap structure and the resulting wafer layout

in L-Edit, if they wanted more manual control over the translation process. With imports, a number of functions need to be in place to ease the process of taking information from mechanical design tools. This is something that not many CMOS-focused layout tools can achieve. 'Zero width' lines are often used in mechanical CAD files to define shapes but mask-writing tools do not recognise these lines. For successful mask-making, all features must be in the form of enclosed polygons. If the shape is a compound object, such as a square with a hole in the centre, it must be drawn in a specific manner – with only one enclosing boundary – so the mask manufacturer knows which areas are 'clear' or 'dark'. For MEMS designers, this rule can become cumbersome, for example, when designing a free-standing plate with thousands of release holes.

Conversion utilities that understand these issues can greatly simplify the import of mask-compatible shapes.

Down To a 'T'

At Hymite, for example, the engineers have written T-cells that take the features defined in the 3D model and then apply a number of modifications, such as widening or narrowing lines to meet the process requirements. By using automatic transformations from sketches that intersect the 3D model at different levels, it is easy for Hymite's designers to create the mirror-image masks needed for back-side wafer etching and metallisation. Other T-cells written by company apply per-package numbering to the 6000 individual caps that a 6-inch wafer can contain. Without the use of macros, the manual manipulations

needed would seriously stretch the resources of the design team and increase lead times. **Figure 4** shows the Hymite cap structure and the resulting wafer layout.

Easy import functions and the ability to construct complex shapes using logical functions plays into another aspect of MEMS design: an efficient workflow. In contrast to CMOS design, where the focus of design is on extensive simulation before sending a design to the mask house, the early stage of evolution of MEMS technology means that physical prototyping is much more commonly employed. Although finite-element simulation can be used to help guide MEMS design, many teams use simulation only for the first steps. Tuning of the design is often performed using manufacturing samples.

IC production techniques allow the fabrication of many different small IC designs using one reticle. MEMS engineers take advantage of this to produce variations of a design. These variations can be used to help debug a design or show which structures work best for a given process. Creating the variations is potentially a time-consuming process. However, the use of macros coupled with an easier import process or logical shape creation functions can do much to

streamline the job for the engineer. For example, if the purpose is to determine the best number of supports for a cantilever or the minimum effective bend radius for a fluid channel, macros can be created to generate the necessary basic shapes and their variations.

Integration with mechanical CAD is a two-way process. Export to DXF is an important feature for many MEMS designers as special packaging and encapsulation needs to be made specifically for each design. By exporting the design in DXF form, errors in alignment can be avoided and it is a much easier process to deal with late design changes.

Bridging The Gap

IC layout tool suppliers are bridging the gap between the needs of MEMS designers and the traditional needs of IC designers. The suppliers who have made the most progress have worked hard to understand the needs of the MEMS industry and have implemented features that greatly improve their workflow. Functions such as DXF input and output, with an understanding of the transformations needed have helped customers take advantage of 3D modelling and rapid prototyping to streamline the design of MEMS devices.

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Book Review

PIC in Practice - A Project-Based Approach

David W Smith
Newnes

There have been many publications on the PIC microcontroller but whereas others tend to follow the same format as those describing microprocessors, prefacing the subject with a general discussion on number systems and combination logic, 'PIC In Practice' wastes no time in attending to the subject in hand. Number conversions are instead placed in one of the appendices.

By adopting a graded project approach and at the same time introducing new concepts gradually through hands-on experience, the author manages to avoid placing nagging uncertainties in the mind of the reader due to essential data being placed elsewhere in the text. As with all such projects, there is a reasonable amount of programming to be done, often a time-intensive activity. This is greatly helped by the facility of being able to download such software from the publisher's website. Programming is achieved in assembler using MASM from the Microchip website. It is suggested that either Notepad or MPLAB are included, which are used as the editor for the software and specific instructions to use the Picstart Plus programmer.

As with the majority of texts on the subject, it is the 16F84 that has been selected as the main controller on which to base projects. Having said that, Smith is not afraid to spread his wings more widely and introduces several other types, including the enhanced and yet cheaper 16F818, the 8-pin 12C508/509, and the 28- and 40-pin 16F87X. He treats us to fascinating insights of the products in a conversational manner, such as Microchip's odd selection of 37kHz as one internal oscillator frequency instead of the more usual 32.768kHz in the case of the 16F627, making timing in whole seconds difficult. This is one of numerous examples indicating the excellent product knowledge of the author.

The book is arranged in 19 chapters with four appendices. After introducing the parts of a microcontroller, the component parts of the 16F84 are described. There follows introductory projects such as a traffic light controller. Details of keypad scanning, alpha numeric displays and A to D conversion are then covered. There is an interesting chapter on radio transmitters and

receivers, covering the measurement of pulse widths for encoding/decoding purposes. Details of other controllers are given together with more advanced projects such as electronic dice and a burglar alarm, including concise sections on how they work. The final chapter includes a full description of the instruction set for the 16F84.

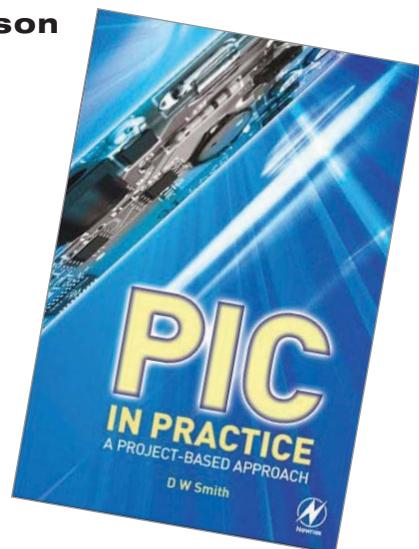
At this point, I would like to voice two minor criticisms; the index is very brief to say the least, confining itself to little more than references to individual instructions. I found myself using the contents pages, which had considerably more detail, as a substitute index. Also, I was looking forward to reading about motor control, an application to which the PIC is well suited according to the introduction but, alas, its usefulness in this

The 16F84 that has been selected as the main controller to base the projects on. Having said that, Smith is not afraid to spread his wings more widely and introduces several other types

area was not supported in the text.

However, these are minor qualms to set against what is otherwise a very complete and comprehensive introduction to the subject, composed in an easy to understand style. The early chapters progress from simple concepts and projects, which lead on to more advanced subjects. Flowcharts, full assembly listings and hardware diagrams are in abundance to aid understanding and project construction. If I were to have just one book on the subject of PIC controllers, then this would be the one.

John Mason



General Purpose, Cheap and Flexible Contact Debouncer

When a mechanical contact, such as push-button, user interface button, limit switch, relay or contactor contact, is opened or closed, the contact seldom demonstrates a clean transition from one state to another.

There are two types of contacts: normally open (NO) and normally closed (NC). When a contact is closed or opened, it will close and open (technically speaking make and break), many times before finally settling in a stable state. This behaviour of a contact is interpreted as multiple false input signals and a digital circuit will respond to each of these on-off or off-on transitions. This problem is known as 'contact bounce' and has always been a very important problem when interfacing switches, relays etc, to a digital control system.

In some industrial applications debouncing is required to eliminate both mechanical and electrical effects. Most switches seem to exhibit bounce duration under 10ms and, therefore, it is reasonable to pick a debounce period in the 20-50ms range. On the other hand, when dealing with relay contacts, the debounce period should be large enough, i.e. within 20-200ms range. Nevertheless, a reasonable switch will not bounce longer than 500ms. Both closing and opening contacts suffer from the bouncing problem and therefore, in general, both rising and falling edges of an input signal should be debounced.

There are several ways in which debouncing can be achieved. Well-known solutions include the SR debouncer and RC debouncer. The former requires two NAND gates, two resistors and one single-pole-double-

throw (spdt) switch for each input, while the latter requires one Schmitt-trigger, two resistors, one capacitor and one single-pole-single-throw (spst) switch for each input. The problem with these types of solutions is that printed circuit board (PCB) space and the system costs are increased due to additional circuitry, especially for multiple-input systems.

In order to reduce the component count, the power consumption, the PCB space and the cost, an alternative technique is to use switch debouncer ICs, examples of which include MAX6816/6817/6818 single/dual/octal switch debouncers, MC14490 hex contact bounce eliminator and EDE2008 push-button debouncer IC. **Table 1** gives a brief comparison of these three debouncer ICs. It can be seen that all ICs cost around \$6 per IC.

Although, MAX6818 requires no external components, EDE2008 requires one pull-down resistor for each input (eight in total). For the MC14490 it is necessary to use an external capacitor or an external clock source. While there are no restrictions for MAX6818, unused inputs of EDE2008 should be tied to GND. Immediately after power-up, the outputs of MC14490 are in indeterminate states. Both MAX6818 and EDE2008 have eight I/O, while MC14490 has six I/O. MAX6818 is mainly designed for data bus interfacing.

On the other hand, both EDE2008 and MC14490 offer independent I/Os. The typical debounce duration is fixed for MAX6818 and EDE2008, while it can be adjusted for MC14490 with an external capacitor or a clock source. In addition, all ICs offer debouncing for make and break type of contact, i.e. debouncing is applied to both rising and falling edges of an input signal.

Here, a general purpose, cheap and flexible contact debouncer is proposed, as briefly described in **Table 2**. The proposed debouncer, implemented by using a PIC16F628 microcontroller, can be used for both, contact debouncing and eliminating short transients on non-contact digital inputs. Therefore, it is a general purpose debouncer.

Debouncer IC	Price (\$) for one IC	External Components Required	Restrictions	Number of I/O	Typical Debounce Duration	Operating Voltage Range (V)	Min.	Max.
MAX6818	5.95	no	no	8 Dependent	40ms - fixed	2.7	5.5	
EDE2008	5.99	One pull-down resistor for each input (8 in total)	Unused inputs should be tied to GND	8 Independent	25ms - fixed	3	5.5	
MC14490	6.95	An external capacitor or an external clock source	Immediately after power-up, the outputs are in indeterminate states	6 Independent	Adjustable with an external capacitor or with an external clock source	3	18	

Table 1: Comparing some contact debouncer ICs currently available on the market

μC used	Price (\$) for one IC	External Components Required	Restrictions	Number of I/O	Debounce Duration	Operating Voltage Range (V) Min. Max.
PIC16F628	2.80	Only 2 pull-up resistors for 8 inputs	no	8 Independent	Adjustable (..., 20,... 50, ..., 100,... ms)	3 5.5

Table 2: Some characteristics of the proposed contact debouncer

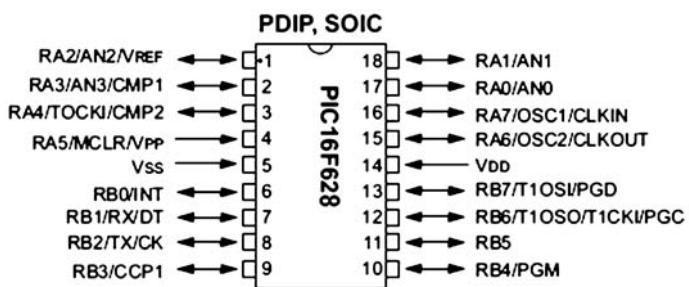


Figure 1: A PIC16F628 microcontroller

Input nr.	Pin nr.	Port name
I0	4	RA5
I1	3	RA4
I2	8	RB2
I3	9	RB3
I4	10	RB4
I5	11	RB5
I6	12	RB6
I7	13	RB7

Table 3: Inputs, outputs, pin numbers and port names of the proposed contact debouncer

Note that non-contact digital inputs are often routed through debounce filters as well. This technique can eliminate short transients at the input by ensuring a stable state before reporting the input on or off. The proposed debouncer costs around \$3, which is half the price of the above-explained, commercially available, debouncer ICs. It also requires only two pull-up resistors for eight inputs, with no restrictions.

Like EDE2008 and MC14490, it offers independent I/Os. The flexibility of the proposed contact debouncer is related to the adjustable debounce duration. It is possible to adjust the debounce duration of each input as desired depending on the application, separately from the other inputs. In addition, one can also choose different debounce durations for rising and falling edges of an input signal. This also gives even more flexibility to the proposed debouncer.

Debouncer Hardware

The proposed contact debouncer is implemented by using a PIC16F628 microcontroller, as can be seen from Figure 1. A PIC16F628 comes in three different packages: 18-LEAD PDIP, 18-LEAD SOIC (.300") and 20-LEAD SSOP. This means that the proposed debouncer

Output nr.	Pin nr.	Port name
Q0	17	RA0
Q1	18	RA1
Q2	1	RA2
Q3	2	RA3
Q4	6	RB0
Q5	7	RB1
Q6	15	RA6
Q7	16	RA7

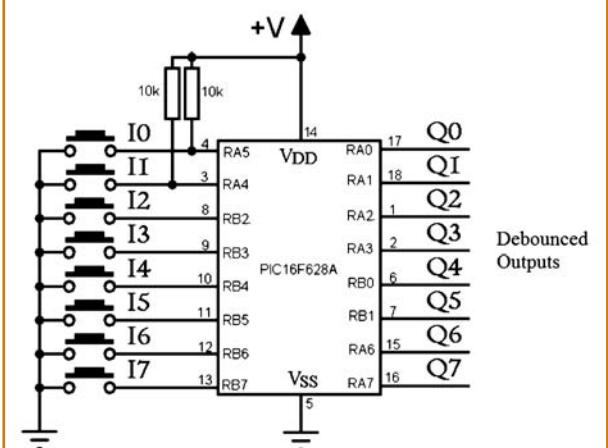


Figure 2: The proposed debouncer, used for debouncing 8-channel contacts

can be accommodated in one of these packages depending on the application. The features of the proposed debouncer can be summarised as follows:

- Up to eight independent debouncers per IC.
- Works with buttons, switches, relay or contactor contacts etc and, also, with non-contact digital inputs.
- Internal diode protection on all inputs.
- Only two external pull-up resistors required for two inputs (internal pull-up resistors used for the other six inputs).
- CMOS/TTL compatible data inputs/outputs.
- For each input a higher DC voltage input can also be accepted, by means of a transistor or an opto-coupler.
- Each input debounces both "make" and "break" contacts.
- Adjustable debounce period on both rising and falling edges of each input signal.
- Supply voltage range is 3.0V to 5.5V.
- Maximum current sourced by an output pin is 25mA.
- Maximum current sourced by all eight outputs is 200mA.

Inputs, outputs, pin numbers and port names of the proposed contact debouncer are shown in Table 3.

Figure 2 shows how the proposed debouncer can be used for debouncing eight-channel buttons, switches, relay or contactor contacts etc. The timing diagram for one channel is shown in Figure 3. It can be seen that the output changes its state only after the input becomes stable and waits in the stable state for the predefined "debouncing time". The debouncing is applied to both rising and falling edges of the input signal.

Initially, for each channel, it is assumed that the contact is open. When the contact is open due to the pull-up resistor a logic '1' signal is entered to the debouncer. In the debouncer, this signal is inverted in

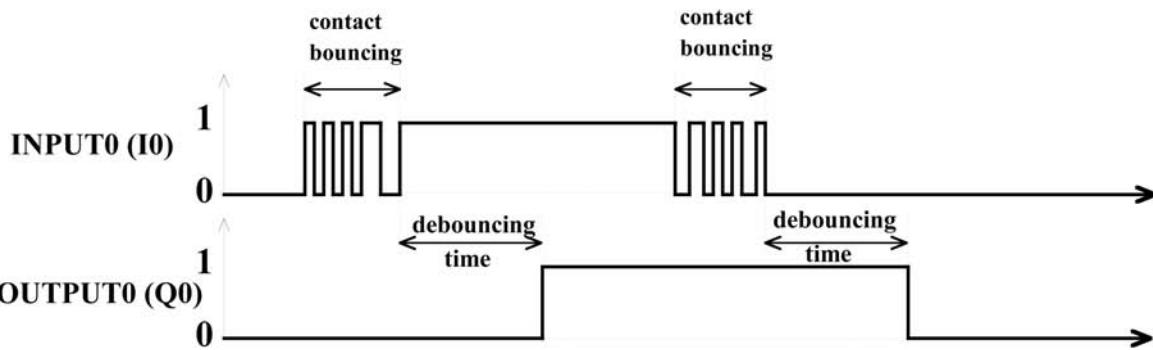


Figure 3: Timing diagram of one channel of the proposed debouncer

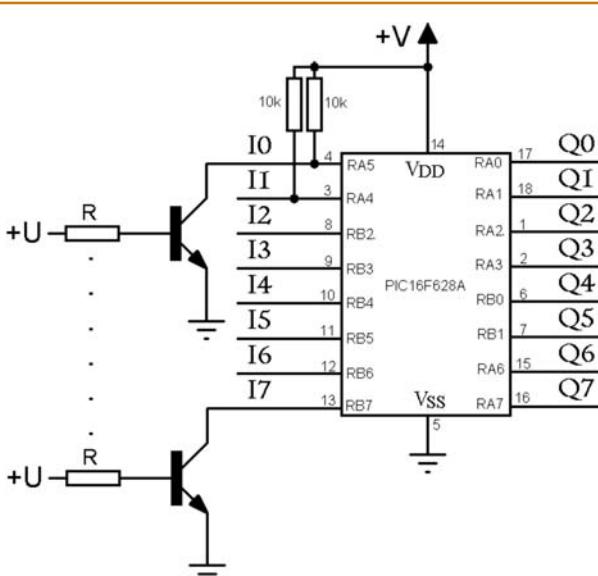


Figure 4: The proposed debouncer, used for debouncing non-contact digital inputs

order to obtain the true position of the contact. Therefore, if the contact is open, this is represented by a logic '0' signal. The "debouncing time" such as 20ms, 50ms, 100ms can be selected as required, depending on the application.

It is possible to pick up different debouncing times for each channel. It is also possible to choose different debouncing times for rising and falling edges of the same input signal if necessary. This gives a good deal of flexibility. It is simply done by changing the related number, defining the time delay for each channel and for both edges within the assembly program.

Note that if the state change of the contact is shorter than the predefined “debouncing time”, this will also be regarded as bouncing and it will not be taken into account. Therefore, no state-change will be issued in this case. Each of the eight input channels of the proposed debouncer may be used independently from other channels. The activity of one channel does not affect the other channels. Each channel can be used to debounce either a “make” or a “break” contact.

Figure 4 shows how the proposed debouncer can be used for debouncing 8-channel, non-contact, digital inputs. Here, NPN transistors are used as a switching tool. Resistor values should be determined according to the transistor and the external voltage source U .

In this circuit, both voltage sources V and U use the

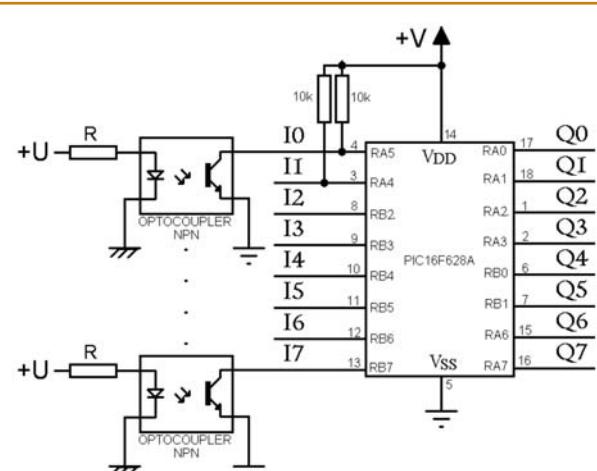


Figure 5: The proposed debouncer, used for debouncing optically-isolated, non-contact, digital inputs

same ground. This is acceptable for some circuits. If it is necessary to isolate electrically these two voltage sources one from the other, then one can use the circuit shown in **Figure 5**. Here, for isolating the two voltage sources opto-couplers are used. Again, resistor values should be determined according to the opto-couplers and the external voltage source U . Of course, each channel may be used in one of these three modes as required.

Debouncer Software

A good debouncing routine is actually real-time software acting as a simple low-pass digital filter.

The following illustrates the routine used for each channel of the proposed debouncer:

1. Initially, it is assumed that the input signal is LOW.
2. If the output of the debouncer is LOW and if the presence of a HIGH input signal is detected, then the debouncer starts a XX ms time-delay (XX stands for the predefined “debouncing time”).
3. Before the XX ms time-delay ends, if the input signal goes back to LOW level, then the time-delay is canceled and the output remains LOW.
4. After XX ms time-delay, if the input signal is still HIGH, then the output is set to HIGH.
5. If the output is HIGH and if the presence of a LOW input signal is detected, then the debouncer

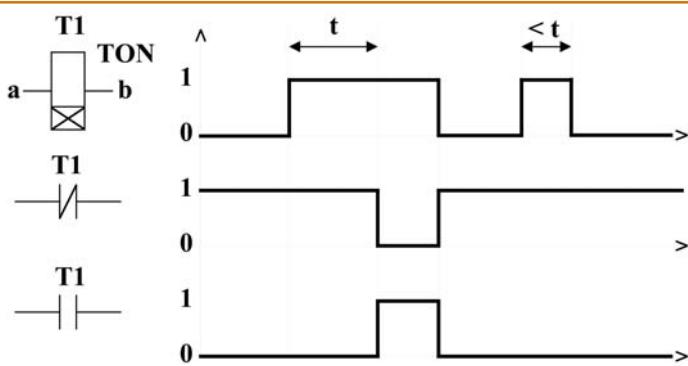


Figure 6: Operation of the on delay timer (TON)

starts a XX ms time-delay.

6. Before the XX ms delay ends, if the input signal goes back to HIGH, then the time delay is canceled and the output remains HIGH.

7. After XX ms time-delay, if the input signal is still LOW, then the output is set to LOW.

For obtaining the time delays, on delay timers are utilised. On delay timers (TON) are used widely in programmable logic controllers (PLC), in order to obtain a time delay function. Although there are different symbols to represent a TON, the one shown in **Figure 6** is a well known symbol, especially used in electro-mechanical control systems.

Once there is continuity in the logic flow for the coil of TON, the timer begins counting time-based intervals (ticks) and counts up until the accumulated time equals the preset time 't'. When these two values are equal, state of the timed contacts are changed, i.e. normally closed (resp. open) contacts are opened (resp. closed) (see Figure 6). The timed contacts can be used throughout the program either as a normally open (−|−) or as a normally closed (−|/|−) contact. When the timer times out, the timed contacts are maintained in the changed state, as long as the continuity in the logic flow for the coil is kept. If continuity in the logic flow for the coil is lost before the timer times out, the timer resets the accumulated register to zero, i.e. the time delay is cancelled.

In the debouncer software, for each channel (resp. for all eight independent channels), two (resp. sixteen) TONs are used. The debouncer software is

developed in PIC assembly language by using Microchip's MPLAB IDE. The proposed debouncer software, in which the predefined "debouncing time" is chosen to be 20ms, is as follows:

```
*****
; This program provides 8 independent debounced inputs
; all (16) time-delays are 20ms
*****
list p=16F628A
#include <p16F628A.inc>

CONFIG _CP_OFF & _DATA_CP_OFF & _LVP_OFF & _BOREN_OFF &
_MCLRE_OFF & _WDT_OFF & _PWRTE_ON & _INTOSC_OSC_NOCLKOUT

#define clk0 TMR0,0 ; Timer clock : 0.512ms
#define clk1 TMR0,1 ; Timer clock : 1.024ms
#define clk2 TMR0,2 ; Timer clock : 2.048ms
#define clk3 TMR0,3 ; Timer clock : 4.096ms
#define clk4 TMR0,4 ; Timer clock : 8.192ms
#define clk5 TMR0,5 ; Timer clock : 16.384ms
#define clk6 TMR0,6 ; Timer clock : 32.768ms
#define clk7 TMR0,7 ; Timer clock : 65.536ms

#define TONF0 TONflg1,0
#define TONF1 TONflg1,1
#define TONF2 TONflg1,2
#define TONF3 TONflg1,3
#define TONF4 TONflg1,4
#define TONF5 TONflg1,5
#define TONF6 TONflg1,6
#define TONF7 TONflg1,7

#define TONF8 TONflg3,0
#define TONF9 TONflg3,1
#define TONF10 TONflg3,2
#define TONF11 TONflg3,3
#define TONF12 TONflg3,4
#define TONF13 TONflg3,5
#define TONF14 TONflg3,6
#define TONF15 TONflg3,7

#define Q4 PORTB,0
#define Q5 PORTB,1
#define I2 PORTB,2
#define I3 PORTB,3
#define I4 PORTB,4
#define I5 PORTB,5
#define I6 PORTB,6
#define I7 PORTB,7

#define Q0 PORTA,0
#define Q1 PORTA,1
#define Q2 PORTA,2
```

```

#define Q3    PORTA,3
#define I1    PORTA,4
#define I0    PORTA,5
#define Q6    PORTA,6
#define Q7    PORTA,7

----- MACROS -----
ld  macro  reg,bit
  movlw  0
  btfsc  reg,bit
  movlw  1
  endm

ld_not macro reg,bit
  movlw  1
  btfsc  reg,bit
  movlw  0
  endm

and  macro reg,bit
  movwf  Temp
  movlw  0
  btfsc  reg,bit
  movlw  1
  andwf  Temp,w
  endm

and_not macro reg,bit
  movwf  Temp
  movlw  1
  btfsc  reg,bit
  movlw  0
  andwf  Temp,w
  endm

_set macro reg,value
  andlw  1
  btfss  STATUS,Z
  bsf    reg,value
  endm

_rst macro reg,value
  andlw  1
  btfss  STATUS,Z
  bcf    reg,value
  endm

BANK0  macro
  bcf STATUS,RP0
  bcf STATUS,RP1

```

```

endm

BANK1  macro
  bsf STATUS,RP0
  bcf STATUS,RP1
  endm

----- TON_0 'ON DELAY TIMER' -----
; This macro is introduced to obtain 8 independent on-delay-timers.
; num: 0, 1, 2, 3, 4, 5, 6, 7 is the number of the on-delay-timer.
; fval: is the final value (maximum 255) representing the count
; value of the input clock.
; rs_reg, rs_bit: is the reference clock signal to be counted
; for this macro to be active the value '1' must be stored
; in W register before running this macro
;
; For example if this macro is called as follows (while W=1)
; " TON_0 0,d'10',clk7 "
; the on delay timer will set its related flag (TONflg1,0)
; after 10 x 65.536ms) = 655.36ms.

TON_0  macro num, fval, st_reg, st_bit
  local L1,L2
  movwf Temp
  btfsc Temp,0
  goto L2
  movlw 00h
  movwf TON+num
  bcf TONflg1,num
  goto L1
  L2  btfsc TONflg1,num
  goto L1
  btfss st_reg,st_bit
  bsf TONflg2,num
  btfss st_reg,st_bit
  goto L1
  btfss TONflg2,num
  goto L1
  bcf TONflg2,num
  incf TON+num,f
  movf TON+num,w
  xorlw fval
  skpnz
  bsf TONflg1,num
  L1  endm

----- TON_1 'ON DELAY TIMER' -----
TON_1  macro num, fval, st_reg, st_bit
  local L1,L2
  movwf Temp

```

```

btsc  Temp,0
goto  L2
movlw 00h
movwf TON1+num
bcf   TONflg3,num
goto  L1
L2  btfsc TONflg3,num
goto  L1
btfs  st_reg,st_bit
bsf   TONflg4,num
btfs  st_reg,st_bit
goto  L1
btfs  TONflg4,num
goto  L1
bcf   TONflg4,num
incf  TON1+num,f
movf  TON1+num,w
xorlw fval
skpnz
bsf   TONflg3,num
L1  endm
;----- Variables -----
CBLOCK 0x20
TON
ENDC

CBLOCK 0x28
TON1
ENDC

CBLOCK 0x40
TONflg1, TONflg2, TONflg3, TONflg4, Temp
ENDC
;----- ;MAIN PROGRAM
org  0x00
start
    movlw b'00000111'      ; PORTA is
    movwf CMCON            ; a digital I/O port
    BANK1
    movlw b'00000111'      ; W <- b'00000111': Fosc/4 --> TMR0, PS=256
    movwf OPTION_REG        ; pull-up on PORTB, OPTION_REG <- W
    movlw b'00110000'      ; PORTA is both input and output port
    movwf TRISA             ; TRISA <- b'00110000'
    movlw b'11111100'      ; PORTB is both input and output port
    movwf TRISB             ; TRISB <- b'11111100'
    BANK0
    movlw 0                 ; Initialise all RAM bits to 'safe' values

    movwf TMR0              ; TMR0 <- 00h
    movwf TON               ; TON <- 00h
    movwf TON+1             ; TON+1 <- 00h
    movwf TON+2             ; TON+2 <- 00h
    movwf TON+3             ; TON+3 <- 00h
    movwf TON+4             ; TON+4 <- 00h
    movwf TON+5             ; TON+5 <- 00h
    movwf TON+6             ; TON+6 <- 00h
    movwf TON+7             ; TON+7 <- 00h
    movwf TON1+0            ; TON1+0 <- 00h
    movwf TON1+1            ; TON1+1 <- 00h
    movwf TON1+2            ; TON1+2 <- 00h
    movwf TON1+3            ; TON1+3 <- 00h
    movwf TON1+4            ; TON1+4 <- 00h
    movwf TON1+5            ; TON1+5 <- 00h
    movwf TON1+6            ; TON1+6 <- 00h
    movwf TON1+7            ; TON1+7 <- 00h
    movwf TONflg1            ; TONflg1 <- 00h
    movwf TONflg2            ; TONflg2 <- 00h
    movwf TONflg3            ; TONflg3 <- 00h
    movwf TONflg4            ; TONflg4 <- 00h
    movwf PORTA             ; PORTA <- 00h
    movwf PORTB             ; PORTB <- 00h

```

loop

----- I0 --> Q0 -----

ld_not I0 ; IF input I0 is HIGH (resp. low)
and_not Q0 ; and at the same time the output Q0 is reset
TON_0 0,40,clk0 ; THEN start (resp. stop) TON_0,0 for 20ms time delay
; (40 x 0.512ms = 20.48ms)

ld _set TONF0 ; IF timer flag TONF0 is set
Q0 ; THEN set output Q0

ld and I0 ; IF the output Q0 is set
TON_1 0,40,clk0 ; and at the same time the input I0 is LOW
; THEN start TON_1,0 for 20ms time delay

ld _rst TONF8 ; IF timer flag TONF8 is set
Q0 ; THEN reset output Q0

----- I1 --> Q1 -----

ld_not I1
and_not Q1
TON_0 1,40,clk0

ld _set TONF1
Q1

ld and I1
Q1

TON_1 1,40,clk0

ld _rst Q1

----- I2 --> Q2 -----

ld_not I2
and_not Q2
TON_0 2,40,clk0

ld _set TONF2
Q2

ld and I2
TON_1 2,40,clk0

ld _rst Q2

----- I3 --> Q3 -----

ld_not I3
and_not Q3
TON_0 3,40,clk0

ld _set TONF3
Q3

ld and I3
TON_1 3,40,clk0

ld _rst Q3

----- I4 --> Q4 -----

ld_not I4
and_not Q4
TON_0 4,40,clk0

ld _set TONF4
Q4

ld and I4
TON_1 4,40,clk0

ld _rst Q4

----- I5 --> Q5 -----

ld_not I5
and_not Q5
TON_0 5,40,clk0

```

ld      TONF5
_set   Q5
ld      Q5
and    I5
TON_1  5,40,clk0
ld      TONF13
_rst   Q5
;---- I6 --> Q6 ----
ld_not I6
and_not Q6
TON_0  6,40,clk0
ld      TONF6
_set   Q6
ld      Q6
and    I6
TON_1  6,40,clk0
ld      TONF14
_rst   Q6
;---- I7 --> Q7 ----
ld_not I7
and_not Q7
TON_0  7,40,clk0
ld      TONF7
_set   Q7
ld      Q7
and    I7
TON_1  7,40,clk0
ld      TONF15
_rst   Q7
;---- loop
goto  END

```

It can be seen that the implementation is carried out by using a PIC16F628 microcontroller. As described in the previous section, apart from the VDD and VSS pins, all other pins are used as I/O ports. The internal 4MHz oscillator of the

PIC16F628 is used for timing purposes. Both PORT A and PORT B are organised as digital I/O ports. Pull-up resistors on PORTB are enabled. Timer TMRO is declared as the divider of the $F_{osc}/4 = 4\text{MHz}/4 = 1\text{MHz}$ clock frequency, with the prescaler rate of 1:256.

As a result, we obtain eight different clock signals, namely $\text{clk}0$, $\text{clk}1$, ..., $\text{clk}7$. Macros `ld`, `ld_not`, `and`, `and_not`, `_set`, `_rst` are described

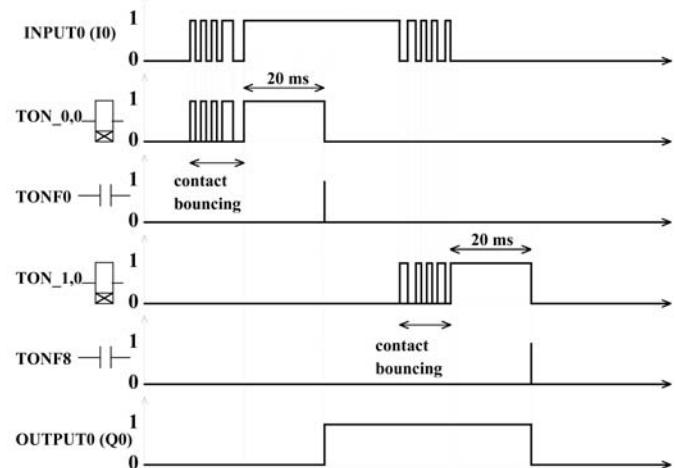


Figure 7: Detailed timing diagram of the first channel

for use in logical operations. Both macros `TON_0` and `TON_1` are used for declaring necessary 16 on-delay timers. Finally, in sections $\text{li} \rightarrow \text{Qi}$, $i = 0, 1, \dots, 7$, each channel is described complying with the above mentioned routine for the debouncer. The detailed timing diagram of the first channel is shown in Figure 7 for 20ms debouncing time.

It is possible to choose different debouncing times by changing the number associated with the on delay timers and/or by changing the `clk` signal. When we choose `clk0` as the reference signal to count, **Table 4** shows some numbers for which we can obtain different debouncing times. Note that it is possible to choose different debouncing times for rising and falling edges of an input signal for every single channel without depending on the other channels.

Table 5 shows three debouncer files ready to be programmed into a PIC16F628 microcontroller for using the contact debouncer provided with this article.

Up to now, the explained debouncer can be described as a “non-inverting debouncer”. This is because the debouncer is implemented in such a way that when the contact of an input is open, the output of this input is in off state and when the contact of an input is closed, the output of this input is in on state.

Clk	Multiplied by	obtained time-delay
clk0 (0.512ms)	×	40
clk0 (0.512ms)	×	98
clk0 (0.512ms)	×	196

Table 4: Changing the debouncing times for `clk0`

File	Debouncing time
8_bit_debouncer_v1.hex	20.48ms
8_bit_debouncer_v1_1.hex	50.176ms
8_bit_debouncer_v1_2.hex	100.352ms

Table 5: Three debouncer files ready to be programmed into a PIC16F628 IC

Related section of the non-inverting debouncer for the first channel	Modifications necessary to obtain an inverting debouncer for the first channel
<pre> ;----- I0 --> Q0 ----- ld_not I0 and_not Q0 TON_0 0,.40,clk0 . . . ld Q0 and I0 TON_1 0,.40,clk0 . . . ;</pre>	<pre> ;----- I0 --> Q0 ----- ld I0 and_not Q0 TON_0 0,.40,clk0 . . . ld Q0 and_not I0 TON_1 0,.40,clk0 . . .</pre>

Table 6: Three debouncer files ready to be programmed into a PIC16F628 IC

In some applications it may be necessary to use an “inverting debouncer” in which the debouncer must operate in the other way around. That is, when the contact of an input is open, the output of this input is in on state and when the contact of an input is closed, the output of this input is in off state. In order to satisfy such a request, we can modify our debouncer program. The following shows the related section of the non-inverting debouncer for the first channel, as well as the modifications necessary to obtain an inverting debouncer for the first channel. Naturally, it is necessary to modify all channels for obtaining an 8-bit inverting debouncer. It may also be possible to have non-inverting and inverting channels used together within the same debouncer, if it is necessary.

Conclusions

In this article, a standalone, general, easy to use, cheap and flexible contact debouncer has been proposed to solve the contact bounce problems. The debouncer is implemented by using a PIC16F628 microcontroller. The debouncer

assembly program provided within this article may be modified to satisfy any requirements regarding the debounce duration. In addition, it is possible to modify the debouncer assembly program to obtain an “inverting debouncer”.

Instead of a standalone debouncer, if someone needs debouncing in a PIC program for some inputs, then the proposed debouncer assembly program may be modified and used in most PIC microcontrollers. Moreover, the macro implementing on-delay timers may be modified and used in most PIC microcontrollers, whenever such a timing function is necessary.

Last but not least, the contact debouncer method proposed in this paper is based on PIC16F628 microcontroller, but it may be possible to apply the same approach to other microcontrollers successfully.

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PIC12F675-IP	0.51	PIC18F2520-ISP	2.82
PIC16F676-IP	0.63	PIC18F2525-ISP	2.82
PIC16C54C-04P	0.62	PIC18LF2525-ISP	3.18
PIC16C55A-04P	0.81	PIC18F2525-I/SO	2.78
PIC16C57C-04P	0.89	PIC18F2620-I/SO	2.88
PIC16F73-ISP	1.55	PIC18F4520-IP	2.72
PIC16F74-IP	1.84	PIC18F4525-IP	3.19
PIC16F77-IP	1.91	PIC18F4620-IP	3.34
PIC16F628A-IP	0.83	PIC18F6520-IPT	2.85
PIC16F84A-04P	1.59	PIC18F6520-IPT	3.99
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Letters

Whose room is it anyway?

Whilst I enjoyed reading about the digital projector technology on page 18 of the September issue of Electronics World magazine, I could not help but be struck by the unlikelihood of its application in the home as suggested in the article.

Just who has a spare room to use exclusively as a home cinema? Most of us have difficulty enough trying to lay out a conventional two-speaker stereo system without room acoustics and other furniture spoiling the result. So how would we implement a system that relied on wall reflections, when most of our walls are already obscured by sofas, bookcases, etc? I can see how this might work in a large auditorium, where a high ceiling and largely uncluttered walls might permit such a system to work; but in the home...?

Perhaps Alex Bienek could enlighten us on any research done in the home – a real home, that is.

Graham Field, UK

True home cinema?

I found the article by Alex Bienek of considerable interest, but it sadly suffers from two major problems. Much of his article comes across as a selling attempt for the product and the rest appears to show a lack of understanding of the applications at which he is targeting the product. Let me illustrate:

For my first point, I will just give one example from the article. Under the heading "Other Applications" he writes:

"...Two viewers only a few feet apart, can listen to different programmes simultaneously with minimal interference. A typical application may be for sport and a sitcom..."

The accompanying photograph (Figure 11) shows two chairs watching a split-screen TV with 'focused' sound beams. I estimate the subtended angle to the TV to be 30 degrees or less. In addition, he includes two polar responses (Figures 14 and 15) that are intended to show how 'good' the separation will be for the set-up in Figure 11. The data given in the accompanying text is "45 degrees off axis, 15dB at 2kHz and 20dB at 5kHz".

This looks good, but several things militate against his claim that the two chairs can each enjoy their own programme without interference!

Firstly, the responses shown are both for speech, as are the quoted programme examples. The spectral content of speech is

such that the 5kHz chart (the best one) is actually irrelevant – the 2kHz chart is almost relevant for the frequencies of interest, so we are left with only the 15dB figure.

Secondly, the chairs are listening with a separation of at most 30 degrees – probably less, so with room reflections added in the figure is probably nearer to 10dB at best.

Finally, take into account the dynamic range of the competing programmes and it is probable that the maxima of one will frequently coincide with the minima of the other; "with minimal interference"? – I think not!

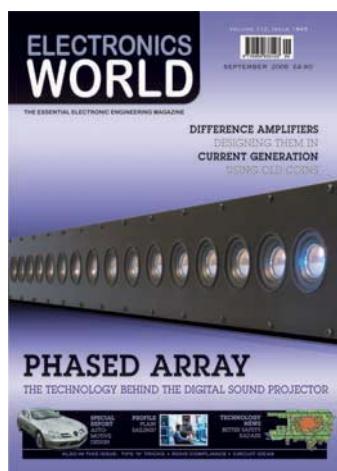
My second point is concerned with the writer's misunderstanding (in the context of the article) of the 'what' and the 'why' of surround sound. His "Brief History" is generally correct, but in my opinion, not enough emphasis is made of the point that surround sound is essentially a technique for the cinema. It has many problems when attempts are made to design systems that masquerade as personal cinemas (home theatre).

When Dolby and others introduced various sound systems to improve the multi-channel systems that were first tried out in the cinema, they accepted the research that clearly showed that the approach of simply sending different types of sound content via separate channels to loudspeakers around the auditorium is flawed. Thus, for example, a passing low-flying aeroplane could have the sound of its passage first fed to a speaker behind the screen and then to different speakers from front to back on one wall of the auditorium. This worked fairly well for very specific effects, but the proximity effect of a loudspeaker to a member of the audience sitting close by, greatly reduced the effectiveness. And so on for other types of effect, loudspeaker positioning, size of auditorium and other variables.

The Pro Logic system (and DTS etc) took a more reasoned approach and tailors the sound with matrix

coding and other techniques to deliver the sound in such a way that the proximity effect is minimised. By careful mixing of the dialogue, music and effects for each film, a much better simulation of sound apparently surrounding the audience, can be realised. But note that these systems are designed for auditoria far larger than someone's living room and for far better quantity, type and placing of loudspeakers than can ever be achieved for a home cinema. Not to mention the random placing of walls, furniture and audience at home!

All these problems are found for 1 Ltd's Digital Sound Projector, further aggravated by the necessity to 'beam' the sound via



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one or more wall and ceiling bounces, thus adding mirrors, pictures, light fittings and various surface treatments to the final mix.

I am not saying that some sort of impression of surround sound is not possible, just that the impression given by the article that their device is the 'be all' and 'end all' of loudspeaker design is false. At best, it would appear to be just another way of packing more into a smaller box with the usual loss of features that that thereby entails.

Tony Batchelor, Denmark

Alex Bieneck of 1 Ltd replies:

Mr Field questions the suitability of domestic rooms for use with the Digital Sound Projector (DSP). In fact, nearly all domestic sitting rooms work well. Sometimes more so than with conventional surround-loudspeakers, as the latter have to be sited either side of the TV/video screen and behind the listeners, where there usually is obscuring furniture. The DSP however, being mounted beneath, above or within the TV screen enclosure, is automatically in direct view of the listeners and necessarily free of clutter. Very few rooms have floor to ceiling wall coverage with soft furniture. Hard furnishings (such as book cases, tables, chests of drawers, pictures, windows, lamps) pose no problems as they themselves act as very suitable bounce points for the side and rear sound beams, although again such features would normally preclude the siting of a real loudspeaker in those same locations.

High ceilings are not necessary for DSP operation. In terms of research, we at 1 Ltd have investigated a very wide range of real domestic environments, and Yamaha in Japan has done so more extensively. That DSP works in real rooms is testified to by the excellent reviews in scores of audio magazines and by the many thousands of sales already made by Yamaha all over the world, sales which have grown steadily since the introduction of the first YSP-1 in November 2004 and then the subsequent models YSP-800 and YSP-1000.

Mr Batchelor raises some interesting and understandable points. Regarding the two simultaneous programmes with separate sound channels (referred to as Beam2Me), Mr Batchelor does not consider the psycho-acoustics of the situation. The human ear-brain system is small compared to a wavelength below, say, 1kHz and, therefore, is better at sound direction determination at higher rather than lower frequencies. As nearly all "real" sounds are rich in harmonics (i.e. very non-sinusoidal and often quite impulsive), the ear-brain can directionalise quite well on such complex sounds (including the lower harmonic

components) because the components are all well-correlated.

The DSP does quite a good job of separating the higher-frequency components of such real sounds and directing them correctly to the two listeners. The listeners' ear-brains then utilise their 'cocktail party effect' capabilities to separate out the related and unrelated lower frequency components; the correlation of the "wanted" sound components with the separate visual content of the two pictures is also used by the ear-eye-brain system to further reduce clutter, thus giving a significantly better perceived channel separation than the hard physics alone would suggest. Fortunately, humans are not plain vanilla wideband microphones!

Having said this, the DSP channel separation is not perfect, but adds sufficient extra physical channel separation to enable much more comfortable dual channel viewing. Remember that we are trying to produce a purely subjective end result.

We do not feel a responsibility to defend the virtues of home cinema per se, from "real" cinema. However, given that DVDs in particular are recorded in 5.1 channel sound and that a huge number of people do want to enjoy these in their own homes, then they are faced with the real difficulty of making the best of what they have: usually a smallish, cluttered room with lots of soft furnishings up to thigh-height at least, and not much spare space at all. As described above, siting beam bounce points off walls (or hard furnishings), above the soft furniture, is often far better than placing a small book shelf or smaller loudspeaker on the floor behind/beside a sofa (which is otherwise what usually happens).

Statistics from big manufacturers of low cost 5-speaker box conventional surround-sound systems indicate that as many as 60% of purchasers never connect the rear speakers, as they either cannot find a suitable mounting position (no space, or no fixing, or no line-of-site), or they cannot find a workable cable path from the TV/amplifier, or both.

Also in small (i.e. common) rooms, it's difficult to place the rear speakers so far from the listeners that the entire perceived sound field doesn't collapse into the closest point-source (rear) physical loudspeaker. The perceived distance of the DSP's rear (imaged) loudspeakers is greater than the distance of the listeners from the screen [because of the wall bounce(s)]; i.e. they are perceived to be much further away than the distance of the listeners from the wall, let alone a physical speaker mounted within the room. A Digital Sound Projector can usually overcome all of these difficulties and provide a very satisfactory home-theatre listening experience.

8-pin FLASH PICmicro Microcontrollers

TIP 1: LOW BATTERY DETECTION

When operating from a battery powered supply, it is important for a circuit to be able to determine when the battery charge is insufficient for normal operation of the circuit. Typically, this is a comparator-based circuit, similar to the Programmable Low Voltage Detect (PLVD) peripheral. If the PLVD peripheral is not available in the microcontroller, a similar circuit can be constructed using a comparator and a few external components (see **Figures 1** and **2**). The circuit in Figure 1 assumes that the

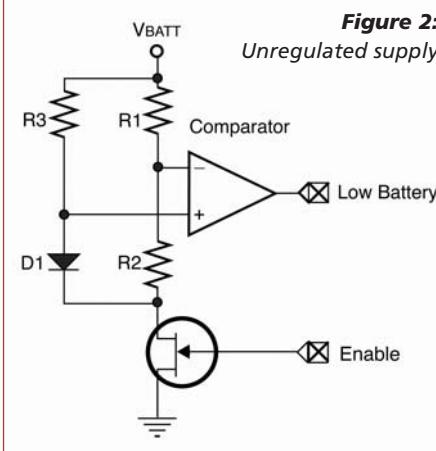
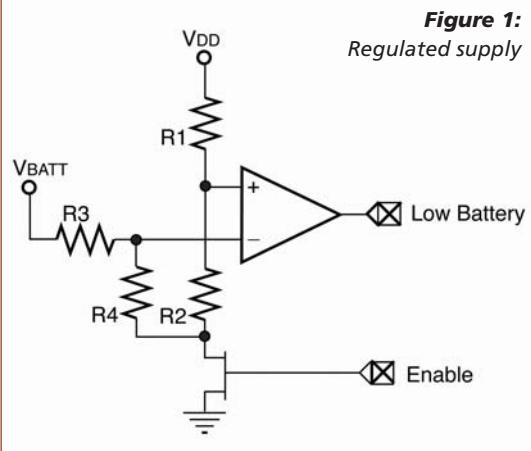
microcontroller is operating from a regulated supply voltage; the circuit in Figure 2 assumes that the microcontroller supply is unregulated.

The comparator will trip when the battery voltage: $VBATT = 5.7V$: $R1 = 33k$, $R2 = 10k$, $R3 = 39k$, $R4 = 10k$, $VDD = 5V$.

In Figure 1, resistors $R1$ and $R2$ are chosen to place the voltage at the non-inverting input at approximately 25% of VDD . $R3$ and $R4$ are chosen to set the inverting input voltage equal to the non-inverting input voltage, when the battery voltage is equal to the minimum operating voltage for the system.

Comparator will trip when $VBATT = 3V$: $R1 = 33k$, $R2 = 10k$ and $R3 = 470\Omega$.

In Figure 2, resistor $R3$ is chosen to bias diode $D1$ above its forward voltage, when $VBATT$ is equal to the minimum battery voltage for the system. Resistors $R1$ and $R2$ are chosen to set the inverting input voltage equal to the forward voltage of $D1$.



TIP 2: FASTER CODE FOR DETECTING CHANGE

When using a comparator to monitor a sensor, it is often just as important to know when a change occurs as it is to know what the change is. To detect a change in the output of a comparator, the traditional method has been to store a copy of the output and periodically compare the held value to the actual output to determine the change (see **Example 1**).

This routine requires five instructions for each test, nine instructions if a change occurs and one RAM location for storage of the old output state.

A faster method for microcontrollers with a single

comparator is to use the comparator interrupt flag to determine when a change has occurred.

The routine in **Example 2** requires two instructions for each test, three instructions if a change occurs and no RAM storage.

If the interrupt flag cannot be used, or if two comparators share an interrupt flag, an alternate method that uses the comparator output polarity bit can be applied.

The routine in **Example 3** requires two instructions for each test, five instructions if a change occurs and no GPR storage.

Examples:

```
Test
  MOVF hold,w ; get old Cout
  XORWF CMCON,w ; compare to new Cout
  ANDLW COUTMASK
  BTFSC STATUS,z
  RETLW 0 ; if = return "no change"
  MOVLW CMCON,w ; if not =, get new Cout
  ANDLW COUTMASK ; remove all other bits
  MOVWF hold ; store in holding var.
  IORLW CHNGBIT ; add change flag
  RETURN
```

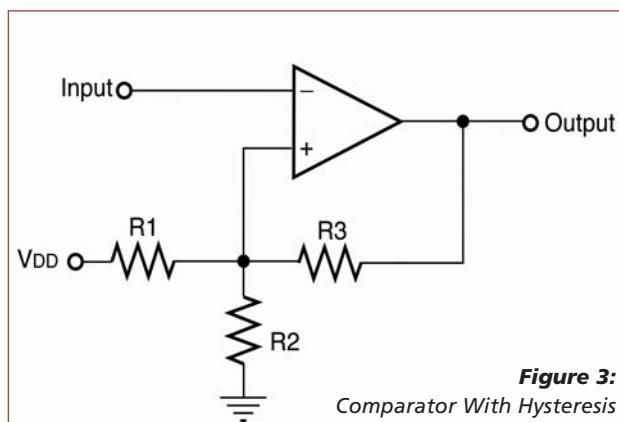
```
Test
  BTFSS PIR1,CMIF ;test comparator flag
  RETLW 0 ;if clear, return a 0
  BTFSS CMCON,COUT ;test Cout
  RETLW CHNGBIT ;if clear return
  ;CHNGLAG
  RETLW COUTMASK + CHNGBIT ;if set,
  ;return both
```

```
Test
  BTFSS CMCON,COUT ;test Cout
  RETLW 0 ;if clear, return 0
  MOVLW CINVBIT ;if set, invert Cout
  XORWF CMCON,f ;forces Cout to 0
  BTFSS CMCON,CINV ;test Cout polarity
  RETLW CHNGLAG ;if clear, return
  ;CHNGLAG
  RETLW COUTMASK + CHNGLAG;if set,
  ;return both
```



TIP 3: HYSTERESIS

When the voltages on a comparator's input are nearly equal, external noise and switching noise from inside the microcontroller can cause the comparator output to oscillate or "chatter". To prevent chatter, some of the comparator output voltage is fed back to the non-inverting input of the comparator to form hysteresis (see **Figure 3** below). Hysteresis moves the comparator



threshold up when the input is below it, and down when the input is above the threshold. The result is that the input must overshoot the threshold to cause a change in the comparator output. If the overshoot is greater than the noise present on the input, the comparator output will not chatter.

To calculate the resistor values required, first determine the high and low threshold values which will prevent chatter (V_{TH} and V_{TL}). Using V_{TH} and V_{TL} , the average threshold voltage can be calculated using **Equation 3**.

$$V_{AVG} = \frac{V_{DD} * V_{TL}}{V_{DD} - V_{TH} + V_{TL}} \quad (3)$$

TIP 4: PULSE WIDTH MEASUREMENT

To measure the high or low pulse width of an incoming analogue signal, the comparator can be combined with Timer1 and the Timer1 Gate input option (see **Figure 4**). Timer1 Gate acts as a count enable for Timer1. If the input is low, Timer1 will count. If the T1G input is high, Timer1 does not count. Combining T1G with the comparator allows the designer to measure the time between a high-to-low output change and a low-to-high output change.

To make a measurement between a low-to-high and a high-to-low transition, the only change required is to set the CINV bit in the comparator CMCON register, which inverts the comparator output.

Because the output of the comparator can change

Next, choose resistor values that satisfy **Equation 4** and calculate the equivalent resistance using **Equation 5**.

Note: A continuous current will flow through R1 and R2. To limit the power dissipation in R1 and R2, the total resistance of R1 and R2 should be at least 1k. The total resistance of R1 and R2 should also be kept below 10K to keep the size of R3 small. Large values for R3, 100k-10MΩ, can produce voltage offsets at the non-inverting input due to the comparator's input bias current.

$$V_{AVG} = \frac{V_{DD} * R2}{R1 + R2} \quad (4)$$

$$R_{EQ} = \frac{R1 * R2}{R1 + R2} \quad (5)$$

Then, determine the feedback divider ratio D_R , using Equation 4.

$$D_R = \frac{(V_{TH} - V_{TL})}{V_{DD}} \quad (6)$$

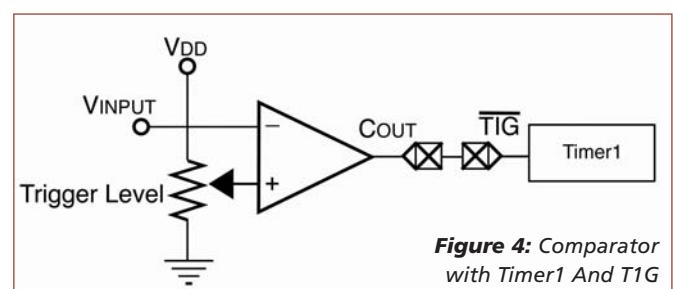
Finally, calculate the feedback resistor R3 using **Equation 4**.

$$R3 = R_{EQ} \left[\left(\frac{1}{D_R} \right) - 1 \right] \quad (7)$$

Example:

- A $V_{DD} = 5.0V$, $V_{H} = 3.0V$ and $V_{L} = 2.5V$
- $V_{AVG} = 2.77V$
- $R = 8.2k$ and $R2 = 10k$ gives a $V_{AVG} = 2.75V$
- $R_{EQ} = 4.5k$
- $D_R = 0.1$
- $R3 = 39k$ (40.5 calculated)
- $V_{HACT} = 2.98V$
- $V_{LACT} = 2.46V$

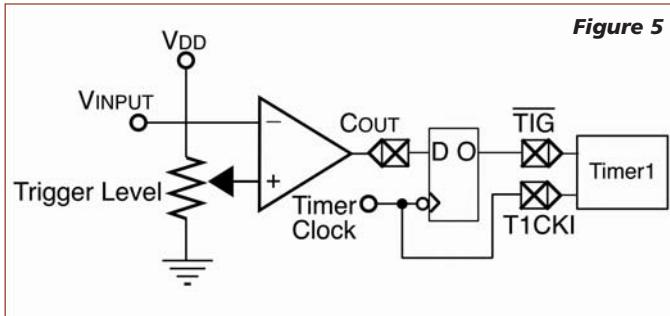
asynchronously with the Timer1 clock, only comparators with the ability to synchronise their output with the Timer1 clock





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should be used and their C2SYNC bits should be set.

If the on-chip comparator does not have the ability to synchronise its output to the Timer1 clock, the output can be synchronised externally using a discrete D flip-flop (see **Figure 5**).

Note: The flip-flop must be falling edge triggered to prevent a race condition.

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Living with RoHS – the big questions

Q: I have some concerns regarding the disposal of end-of-life and obsolete electronic equipment. I recently decided to dispose of a fairly large amount of the aforementioned material and asked two staff members to sort it into mechanical and electrical/electronic waste. We soon ended up with a large pile of PCBs, motors, transformers and battery packs most of which were of the NiCd and NiMh type, although there was also a fair quantity of sealed lead-acid units.

My next step was to phone my local waste disposal facility as I was keen that this waste should be disposed of correctly. They asked us to bring it to the site where it would be weighed and we would be charged a minimum of £57. On arrival at the site to pay the disposal charge, I asked the weighbridge operator what was going to happen to the waste and if it was going to be processed correctly, he then informed me that the material would be sorted and sent for processing, and that it was to be placed in "Skip 8".

Skip 8 contained old pallets amongst other waste and I find it very difficult to believe that all this material was going anywhere else than in the landfill! I am not knowledgeable in the laws concerning landfill operations, but this is surely not acceptable. The copy of the weighbridge ticket for 570kg of 'Trade and Other Waste' also included the usual landfill tax.

I feel very angry after putting so much time and effort into trying to ensure that this potentially dangerous cocktail of materials is disposed of safely, only to find out that it is to be buried in the ground along with everything else. It seems to me that although we are constantly told to be environmentally conscious, produce less pollution and recycle more, the local authorities have little or no interest in anything else but filling large holes in the ground and possibly even larger holes in their annual budgets with the profits from this environmentally-unfriendly activity.

I would like to hear your views on this and, if possible, the views of other readers if they have had similar experiences.

*Spencer Davis, Head of Department,
Service and Technical Support
Automatic Doors Ltd, UK*

A: This is a really good question and one that will be asked more and more as the WEEE deadline looms. Local waste disposal facilities typically aren't set up to handle business waste. Organisations need to call in recycling companies rather than use civic amenity sites (that are operated

around domestic collections in the main) if they want to responsibly dispose of electronic equipment. Recycling companies such as B2B Compliance (www.b2bcompliance.org.uk) or RID UK (www.getrid.uk.com) can handle this sort of collection. They will charge a fee to collect and recycle electronic equipment and can also provide a detailed description of what is done with the materials should, it be requested.

Q: I'm a bit confused about where test equipment falls. I thought it had been identified as Category 9 (control and monitoring equipment). This has been the view held by all the consultants I have asked in the past but recently I've heard rumours that test instrumentation was not Category 9 and was, therefore, not excluded from RoHS. Can you clarify this please?

A: Yes, it is confusing as there is no 'test equipment' category as such. However, most test equipment measures something, for example, by monitoring voltage, temperature, current or frequency, and indicating the value. This indication of the value may also be used to control it. One indicative example listed in Annex IB of the WEEE directive is "measuring, weighing or adjusting appliances for households or as laboratory equipment". Most people interpret measuring equipment for laboratories to be the same as test equipment, which is often used to measure things in laboratories. Therefore, it is the generally held opinion that most test equipment is in Category 9, although it might be unwise to say that all test equipment is in this category.

For further reading on this I'd recommend downloading the latest report on Categories 8/9 from the European Commission's website, www.europa.eu.

Q: People are starting to talk about EuP. Will the classifications be similar to RoHS?

A: RoHS applies to the eight categories from WEEE. EuP (the Energy-Using Products Directive) does not refer to RoHS or WEEE at all. It is attempting to reduce environmental impact in a wide range of product sectors. Beyond the broad scope of the directive (energy using products excluding transport), nothing is fixed yet. Eventually, there will be implementing measures defined with specific product scopes and requirements. These do not exist as yet. For more information on the scope of EuP and how it will be implemented, please visit Electronics Design World at www.farnellinone.com.



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

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The Scourge of the FLAT PANEL DISPLAY DATA SHEET

By Chris Williams, UKDL

If you walk into your local electrical retailer's showroom, you will see a wide range of flat panel TVs on sale. Most of them will have a statement on the sales literature to the effect of "this TV has a contrast ratio of 1,000:1", or "5,000:1", or even "10,000:1".

Which one to choose? Faced with just this information, how can any consumer tell which is better and which is best? Answer – they can't! – because the information is downright misleading and, generally, useless. Let's explore what this actually means.

The technical term 'contrast ratio' can have a number of different definitions, depending on which learned society or institute is reporting the data, but a general 'rule of thumb' definition would be:

$$CR = \frac{\text{brightness of a segment that is "on"} }{\text{brightness of a segment that is "off"}}$$

In a plasma or LCD TV, where the screen brightness of an illuminated pixel is 400 candelas/metre², and the brightness of the "off" pixel next to it is (say) 0.1 candelas/metre², then we have an apparent CR of $400/0.1 = 4,000$.

Pretty good display, huh! The whites will be bright and the blacks will be black. Just the job! Hold on though, life isn't that simple. If you choose to view the TV in a room with the lights off and with blackout curtains in place, so there is absolutely no ambient light whatsoever in the room, the above rule works and the manufacturers' claims are "true".

In real life, most people don't have a totally dark room, and as soon as there is ambient light around (room lights on, curtains are open, sunlight getting into the room), then the rules change, because as soon as any ambient light shines on to the display screen, the contrast ratio calculations change dramatically. The new calculation then becomes:

$$CR = \frac{\text{brightness of "on" segment + light reflected from screen}}{\text{brightness of "off" segment + light reflected from screen}}$$

So, the contrast ratio is suddenly dependent on how much of the ambient light in the room can reflect off the screen back towards the viewer. As the level of this reflected light increases, so the contrast ratio reduces. Let's do the numbers:

For a glass screen at the front of a display, there is typically 4% reflection of the incident light from each surface. For a plain glass screen at the front of a plasma or LCD TV, up to 8% of the incident light will be reflected. Of course, manufacturers can improve this figure by treating the front screen to improve the anti-reflection and anti-glare properties, which will reduce the figure down from 8% towards 4%, or even 2%, but these measures are expensive. As a comparative, aircraft cockpit displays have front surface optical filters that result in less than 0.5% of incident light being reflected,

but these can easily cost over £10 per square inch. This is not suitable for a TV where the cost of the front filter would be more than the total cost of the rest of the set.

In a typical room, during a sunny day, the brightness of the incident light on the screen directly from the windows, or reflecting off the walls and ceilings, may be between 1000 lux and 10,000 lux. This incident light will then reflect off the screen and compete with the light from the TV image itself. Look at the numbers below and remember that this fictional TV has a calculated contrast ratio of 4,000:1.

In a dimly lit room, there may be 25cd/m² reflected light from the screen. Using our TV set from above:

$$CR = \frac{\text{brightness of "on" segment + light reflected from screen}}{\text{brightness of "off" segment + light reflected from screen}} = \frac{400 + 25}{0.1 + 25} = 450:1$$

In a very brightly lit room, there may be 150cd/m² (or more) reflected light from the screen. The contrast ratio will now become:

$$CR = \frac{400 + 150}{0.1 + 150} = 3.66$$

So, surprise, surprise, the maths shows why we see what we know to be true – we can't see a TV properly in very bright sunlight. So, if the real-life contrast ratio is going to be somewhere between 450 and 3.6, why do we have manufacturers claiming 4,000:1 and higher?

The same story above is true of every application using displays in high levels of ambient light. It explains why often a display at the "through the wall" cash machine cannot be read when it is sunny, and why passenger information displays at Waterloo station can be difficult to read. As human beings, we need to see an adequate contrast ratio in an image, in order for our brain to distinguish what is going on. The actual contrast ratio we need changes according to the task. If we are simply reading text, we need a contrast ratio of about 10:1 to read it without discomfort. If we are watching a video, we need a contrast ratio of about 40:1 if we are to gather all of the information in the image.

So, we should not be taken in by advertisers' spurious claims about the performance of their displays. What we need is a TV display with a contrast ratio of just 40:1, but measured when the TV set is at home, placed just about anywhere, with the lights on or the curtains open.

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

Sink Box Back On The Menu At Hammond

Hammond Electronics has re-introduced the seven-strong Sink Box range of extruded aluminium cases, designed for the horizontal mounting of PCBs or chassis. The four larger sizes are designed for the direct horizontal housing of 3U Eurocards, 160, 220 or 280mm deep.

The cards or chassis can be mounted directly into slots in the sides of the enclosure or, for heavier components or assemblies, three T mounting slots, one in the top and two in the base, are provided. Further two T slots are provided in the base to enable the enclosure to be fixed to wall brackets, a belt loop

or another enclosure.

The top of the units have heat sink fins across the entire surface; both aluminium end-panels are removable with plastic bezels which can be fitted or discarded as required. The units are supplied in natural or black anodised finish. Drawings in PDF and AutoCAD format can be downloaded from

www.hammondmfg.com



Standard RFI Shielding Cans On Convenient Pick-And-Place Reels



RFI screening specialist, Tecan, is now offering a select range of standard cans on pick-and-place tape reels for the convenience of small, medium and high-volume OEMs and CEMs. They are exclusively available in the UK from Hitek Electronic Materials. The standard

pitch screening cans offer design engineers a fast and effective means of sourcing radio frequency interference (RFI) screening solutions at optimum cost for pick-and-place manufacturing.

The range offers many sizes and options, allowing users to select components which assure both maximum RFI performance and compatibility with individual production requirements. Based on standard component pitches, the cans can be supplied in either fence and spring-finger lid or five-sided can formats.

Within the two formats offered for pick and place, Tecan offers 20x20mm, 30x20mm, 30x30mm, 50x25mm and 50x50mm in three heights of 2.5mm, 5mm and 10mm.

www.tecan.co.uk

Miniature Capacitors For Better Sound Quality

Passives specialist AVX is offering its high TLJ series of capacitors – known for its high capacitance versus voltage ratio – in a yet smaller size, allowing for increased sound quality at miniature dimensions in smaller handheld devices.

Displaying a maximum height of 1.2mm, the parts offer a capacitance versus voltage ratio of 220 μ F 4V in a miniature 1210 footprint. The devices are the first on the market to offer this degree of capacitance in T case size. Parts also deliver a capacitance tolerance of $\pm 20\%$ and an operating temperature range between -55°C and +125°C. Complying with RoHS requirements, the TLJ consumer series is ready for 3x reflow, 2600C peak temperature lead-free assembly systems.

Designed for high audio performance in PDAs, mobile phones, MP3 players and digital cameras, the new capacitor should bring deep bass, low frequency performance into smaller designs.

Also available in standard EIA case sizes A, B, C D and the low profile W.

www.avx.com



Watch "ur" PCB

PCB-POOL has spent the last 18 months to develop a new information service, called 'Watch "ur" PCB'. Customers can find out about their order and monitor the progress of their PCB through each manufacturing stage. They can log into their personal account and view high resolution photographic images of their current order.

Whether drilling, exposure, tin stripping, UV curing or hot air levelling (surface finish), customers can view the process as a large picture.

The images available are exact representations of what the customer will receive. Pictures of the boards can be sent as a Zip file, and notifications of new images sent by e-mail, which will allow for speedy information.

As such, if there is a layout problem or a data issue, then the users can discover this long before the board arrives to their premises. This way, the customer can react much quicker and send PCB-POOL new files for an immediate restart of production. The customer can plan in advance to remedy any errors and prepare for redesign, hence saving valuable time and money.

wwwpcb-pool.com or freephone UK: 0800 3898560

Acoustics Module Simulates Sounds

Scientists and engineers interested in creating and measuring sound or acoustic waves will find new simulation capabilities in the COMSOL product line – the Acoustics Module. It is ideal for examining linear mechanical wave phenomena in structures and fluids. It is designed specifically for those who work with devices that generate, measure and use acoustic waves. Users can easily model wave propagation in solids and stationary fluids, as well as study aeroacoustics in moving fields.

The module provides a variety of application modes, which offer tailored user interfaces loaded with predefined settings important for acoustics applications. Users create or import geometries, fine-tune the physics settings and solve the problem.

Several features make the Acoustics Module particularly adept at addressing this range of applications. For instance, the theoretical domain of most acoustic problems is infinity, but modelling that domain is beyond the capabilities of any computer. To allow the successful modelling of a truncated well-defined space, the Acoustics Module uses perfectly matched layers (PMLs), a technique that has emerged as perhaps the most convenient yet accurate way to truncate an open acoustic environment.

A PML is an additional domain that absorbs incident radiation without producing reflections; it provides good performance for a wide range of incidence angles and is not very sensitive to the shape of the wave fronts.

Another key element of acoustic studies is damping, and the Acoustics Module offers three ways of introducing absorption in both solids and fluids: using the Delany-Bazley method where the user enters a flow resistivity; by entering a specific absorption coefficient; or with a general absorption method where users can import complex material data from measurements on a damping material.

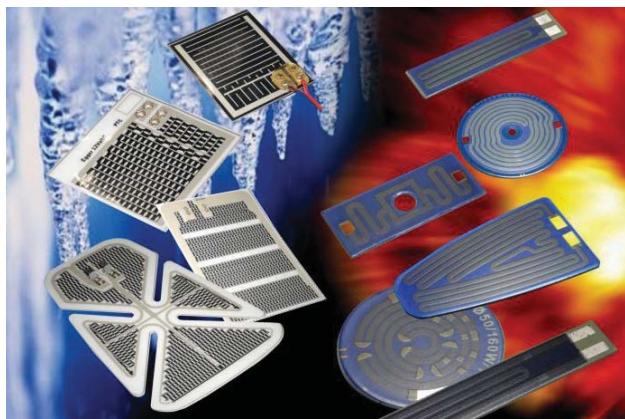
www.comsol.com

Cost-Effective Heating Pads For Custom Needs

To meet the needs of the most demanding heating applications, a comprehensive custom heating pad design and manufacturing service is offered by electro-mechanical thermal management specialist ACAL Radiatron. The capability has recently been further expanded with the introduction of high power density printed-element heater pads, operating at temperatures up to 65°C and 'smart' self-regulating heater mats for lower temperatures.

The pads can be produced in virtually any shape or form and may be flexible or rigid depending on end-user needs. With extremely low thermal mass they can be designed to offer fast-acting or steady heatflow, evenly distributed right across the pad surface avoiding excessive thermal gradients, cold spots or can be zoned into selective areas.

In addition, the company now offers self-regulating heat pads which change their resistance in proportion to the surrounding ambient temperature – so the colder it becomes the harder the



heater works. They are manufactured using a specialised PTC polymer printed ink element which features interleaved bus bar technology to produce multiple parallel circuits across its surface. Ideal for lower temperature start-up, anti-condensation or defrost requirements – examples include self-governing automotive, scientific and industrial heating requirements. The pads respond quickly to ambient temperature variations to cost-effectively maintain an optimised and regular operating temperature, typically from -60°C to 70°C.

www.acal-radiatron.com

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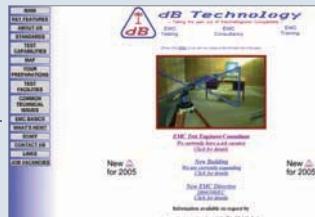
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www.microrobotics.co.uk

Micro-Robotics is a Cambridge-based manufacturer of custom and off-the-shelf embedded control solutions and components. The company's VM-I credit-card-sized control computer is ideal for a wide range of applications.

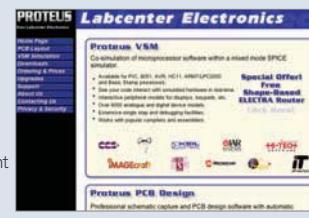
When used with the Micro-Robotics proprietary Venom-SC object-oriented programming language, the VM-I controller can handle analogue and digital I/O, graphical user interfaces, communication protocols, data and text files and many other functions. This combination of powerful processor, easy to use application software and comprehensive I/O resources will make the VM-I highly suitable for applications such as intelligent instruments, hand-held devices, industrial automation and process control systems, security systems and similar other applications.



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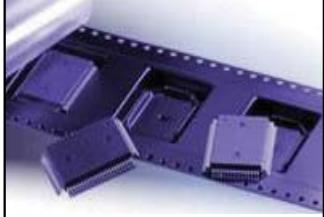
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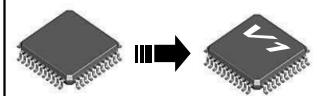
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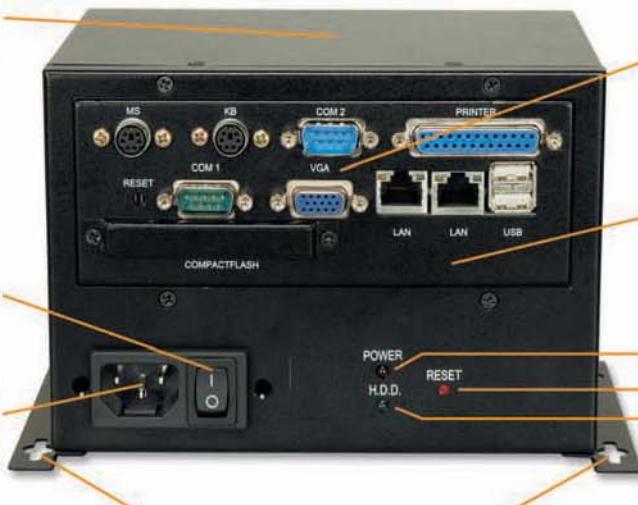
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