www.newelectronics.co.uk

newelectronics

28 June 2016

SEMICONDUCTOR MANUFACTURING • RAIL • 94GHz COMMS CHIPS

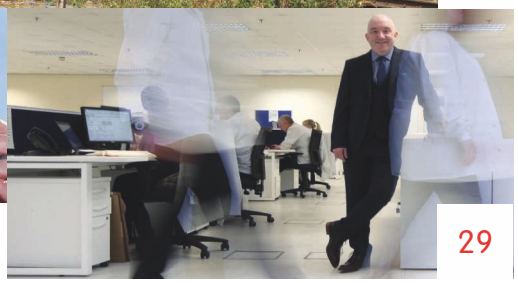
SQUEEZING MORE DOWN THE PIPE

Demands for higher data centre interconnect capacity are driving advances in optical module technology

15

18

25



29

12

Illustration: Peter Crowther

New Electronics' weekly eZine features the latest blogs, news, articles and more. To register for your copy, go to www.newelectronics.co.uk

Unrivaled RF and µW PXI solutions

Drive down the size of test

Unlock RF and µW measurement insights with PXI. Benefit from Keysight's 75 years of measurement expertise, worldwide network of metrology-grade calibration centers, application engineers – and drive down the size of test.

Download Keysight's PXI catalog
www.keysight.com/find/PXIcatalog

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

UK 0118-927 6201 Ireland 1890-924 204

Agilent's Electronic Measurement Group is now **Keysight Technologies.**

Acquire and survive?

DON'T RULE OUT FURTHER CONSOLIDATION IN THE DISTRIBUTION SECTOR

The dust is beginning to settle following the news that Swiss company Dätwyler was buying Premier Farnell for something like €1billion. It's another instance of consolidation in the electronics industry; last year, the so called M&A frenzy saw some $160bn spent on acquisitions galore. NXP bought Freescale, Avago bought Broadcom, Intel bought Altera and so on. But that was a drop in the ocean; some $5.4trillion was spent on all acquisitions last year.

Where some of the deals appeared to reduce the choice of suppliers, the Dätwyler/Premier Farnell deal looks to be more complementary. Dätwyler is, predominantly, involved in engineering products, although it owns a couple of electronics distributors. Premier Farnell, while having a reasonable interest in the maintenance, repair and overhaul – MRO –sector, is better known for electronics distribution.

We know that more and more electronic engineers are spending more time on engineering design and vice versa. So it makes sense to offer them a 'one stop shop'.

Dätwyler's move is, however, unusual for the electronics distribution sector, where we have become accustomed to one big electronics distributor buying a smaller one and reducing choice significantly.

The markets served by the broadliners and high service companies used to be well delineated and had reasonable space between them. Today, those boundaries have blurred significantly and overlapped in some areas, making previously 'safe' companies look vulnerable.

Pasquale Pistorio, the legendary ex CEO of STMicroelectronics, had a saying which sums things up. He said there were companies who were 'too big to be small and too small to be big'.

Quite a few companies meeting Pistorio's definition operated in something of a distribution 'no man's land' – the space between the broadliners and the 'high service' sector. Almost without exception, those companies have been picked off by one of the two big broadliners – who remembers Jermyn, ITT, Abacus, Macro, HB Electronics? Those left in the middle ground will face even tougher challenges.

One element that has been overlooked so far is Asia. Last year's M&A frenzy saw a number of companies targeted by Chinese and Asian groups. Two of the top five electronics distis in the world – WPG and WT Microelectronics –have yet to target the west. So will we see further consolidation in the distribution sector? The answer, in all probability, is 'yes'.

Graham Pitcher, Group Editor (gpitcher@findlay.co.uk)

The EBV-IoT

Smart, Secure, Connected – Everywhere

For years, EBV has been supporting customers' end products across EMEA which are called today – the Internet of Things (IoT). The EBV sales teams together with our technology and market segments enable customers to develop their IoT programs and add new functionalities such as security and wireless. In addition, the EBVchips program can offer new innovative solutions for white spots that have yet to be covered. For all information around IoT, please contact your EBV partner and visit us at ebv.com/iot.

EBV Elektronik
An Avnet Company

Distribution is today. Tomorrow is EBV!

www.ebv.com

newelectronics

Editor	Neil Tyler *neil.tyler@markallengroup.com*
Online Editorial Assistant	Tom Austin-Morgan *tom.austin-morgan@markallengroup.com*
Group Editor	Graham Pitcher *graham.pitcher@markallengroup.com*
Contributing Editors	Chris Edwards, John Walko Louise Joselyn *editor@newelectronics.co.uk*
Art Editor	Martin Cherry *martin.cherry@markallengroup.com*
Illustrator	Phil Holmes
Sales Manager	James Creber *james.creber@markallengroup.com*
Publisher	Peter Ring *peter.ring@markallengroup.com*
Executive Director	Ed Tranter *ed.tranter@markallengroup.com*
Production Manager	Nicki McKenna *nicki.mckenna@markallengroup.com*

ISSN 0047-9624 Online ISSN 2049-2316

Annual subscription (22 issues):
UK £108. Overseas; £163. Airmail; £199.
New Electronics, incorporating Electronic Equipment News and Electronics News, is published twice monthly by MA Business, Hawley Mill, Hawley Road, Dartford, DA2 7TJ.
T: 01322 221144 E: *ne@markallengroup.com*

Moving on?

If you change jobs or your company moves, please contact **circulation@markallengroup** to continue receiving your free copy of *New Electronics*

MA BUSINESS

A MARK ALLEN GROUP COMPANY

www.markallengroup.com

Better 'bendy' screens

GRAPHEXETER – A MODIFIED GRAPHENE MATERIAL – COULD ENABLE BETTER FLEXIBLE DEVICES. **GRAHAM PITCHER** REPORTS.

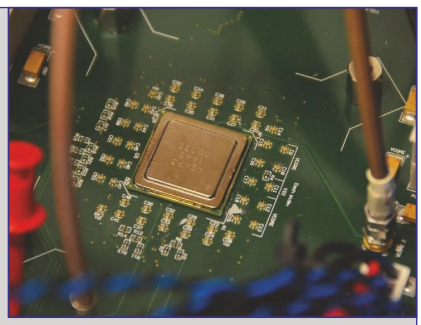
A team of engineers and physicists from Exeter has discovered that GraphExeter – a material adapted from the graphene – can improve the effectiveness of flexible lighting. The research team also believes the material could improve the viability of flexible screens.

GraphExeter was discovered in 2012 by teams from the University's Centre for Graphene Science, who sandwiched molecules of ferric chloride between two graphene layers. The material is said to be more than 1000 times better than graphene at conducting electricity and to be the best known transparent material capable of conducting electricity.

The research has shown that using GraphExeter makes lights 30% more efficient than existing examples of flexible lighting. Researcher Dr Saverio Russo said: "Not only are lights that use GraphExeter much brighter, they are also far more resilient to repeated flexing, which makes 'bendy' screens more feasible for day to day goods such as mobile phones."

By replacing graphene with GraphExeter, the team created a lit screen that showed greater and more consistent light than previously been possible. Furthermore, the screens were more resilient to continued flexing, meaning they have a longer shelf-life before needing to be replaced.

'Energy efficient' 1000 processor chip



A device containing 1000 independent programmable processors has been designed by a team at the University of California, Davis. Called KiloCore, the chip can perform 1.78trillion instructions per second and contains 621million transistors.

"To the best of our knowledge," said Professor Bevan Baas, "it is the first 1000 processor chip and the highest clock rate processor designed in a university." KiloCore was fabricated by IBM on a 32nm CMOS process.

Each processor core can run a small program independently; the idea is to break an application into many small pieces, each of which can run in parallel on different processors, enabling high throughput with lower energy use.

Because each processor is clocked independently, it can shut itself down when not needed. Cores operate at an average maximum frequency of 1.78GHz and transfer data directly to each other, rather than using shared memory.

Prof Baas said the 1000 processors can execute 115billion instruction/s while dissipating 0.7W, low enough for it to be powered by a AA battery.

Cambridge Consultants buys US developer

Cambridge Consultants is acquiring Synapse in a move that will create one of the largest product development companies.

Cambridge Consultants' CEO Alan Richardson said: "Synapse has a heritage in developing technology driven consumer products and this strengthens our reach, both geographically and in this key market segment."

Synapse specialises in solving complex engineering challenges and developing products that accelerate technology advances.

Faster Bluetooth, longer range

Bluetooth 5, launch later this year, will offer significantly increased range, speed and broadcast messaging capacity, according to the Bluetooth SIG. The organisation says Bluetooth 5 will quadruple range and double data transmission rates of low energy connections, while increasing connectionless data broadcast capacity by a factor of eight.

• Meanwhile, Blossom Group has been named as the 30,000th member of the Bluetooth SIG. The startup is building infrasound and low frequency noise relaxation products.

Data centre accelerator

A PCIe form factor accelerator board from Achronix is said to be the highest single FPGA memory bandwidth PCIe add-in card designed for high speed data centre acceleration applications.

Called Accelerator-6D, the board centres on a Speedster 22i HD1000 FPGA with 700,000 look-up tables that connects to six independent memory controllers, allowing for up to 192Gbyte of memory and a memory bandwidth of 690Gbit/s.

The board has six independent DRAM ports connected to the FPGA. Each port can be configured with up to 32Gbyte of DDR3 memory and there are four QSFP+ modules supporting 40G Ethernet.

100Gbit/s comms spec

The 25xN specification from rapidio.org is said to provide an open standard interconnect fabric for systems requiring heterogeneous coherent scale out and non volatile storage.

"With the release of the 25xN 100Gbit/s specification, our focus now shifts toward our Coherent Scale Out Task Group and our Non-Volatile Storage Task Group," said Rick O'Connor, executive director of RapidIO.org. "Work on [these] draft specifications is progressing and we invite members of industry to join us and participate in defining these key building blocks."

High efficiency hybrid photodetector

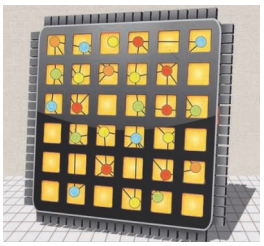
Researchers at the Institute of Photonic Sciences in Barcelona have developed a hybrid photodetector capable of attaining speed, quantum efficiency and linear dynamic range, not only in the visible spectrum, but also in the near (700 to 1400nm) and short wave infra red (1400 to 3000nm) parts of the spectrum.

The hybrid device features an active colloidal quantum dot photodiode with a graphene phototransistor. By including an 'active' quantum dot photodiode, the team could increase charge collection in a highly absorbing thick quantum dot film. This, in turn, increased quantum efficiency, as well as the photoresponse.

The design is based upon materials that can be integrated monolithically with silicon CMOS, as well as with flexible electronics.

Pushing parallel programming

MIT CREATES CHIP THAT MAKES PARALLEL PROGRAMMING FASTER AND EASIER. **GRAHAM PITCHER** REPORTS.



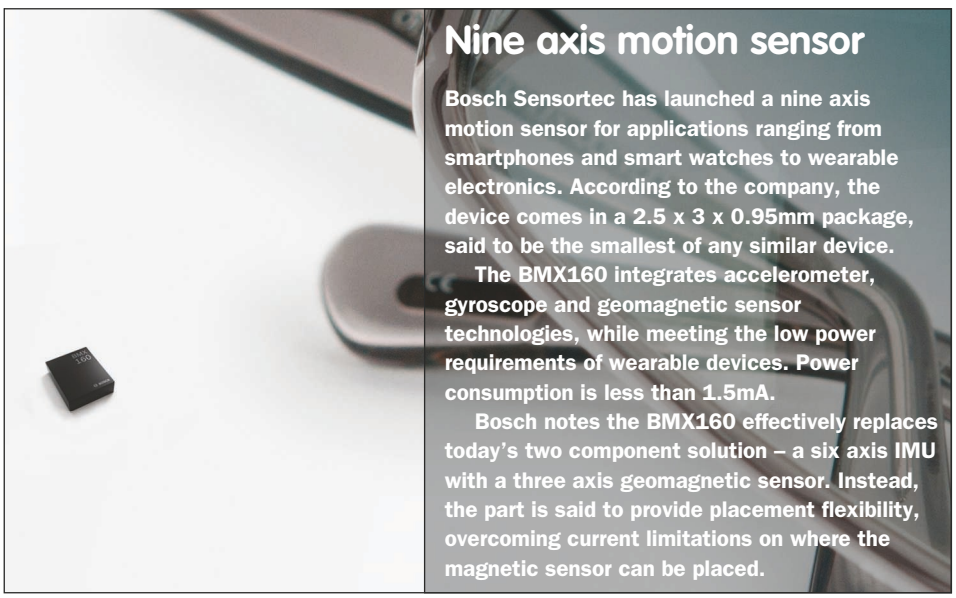
In theory, a program running on a 64 core device should execute 64 times as quickly as it would on a single core. But, according to a team from MIT, it rarely works out that way. Most computer programs are sequential, and splitting them up so that chunks can run in parallel can result in complications.

Researchers from MIT's Computer Science and Artificial Intelligence Laboratory have created a chip called Swarm, said to make parallel programs more efficient and easier to write.

In simulations, the researchers compared Swarm versions of six common algorithms with the best existing parallel versions. Swarm versions were found to be up to 18 times faster, but generally required only 10% of the code.

Swarm is said to differ from other multicore chips in that it has extra circuitry for handling prioritisation. It timestamps tasks according to their priorities and begins working on the highest priority tasks in parallel. It will also ensure higher priority tasks run first and will maintain synchronisation between cores accessing the same data.

"Multicore systems are really hard to program," said project leader Daniel Sanchez. "You have to explicitly divide the work that you're doing into tasks, then enforce synchronisation between tasks accessing shared data. What this architecture does, essentially, is to remove all sorts of explicit synchronisation to make parallel programming easier."



Nine axis motion sensor

Bosch Sensortec has launched a nine axis motion sensor for applications ranging from smartphones and smart watches to wearable electronics. According to the company, the device comes in a 2.5 x 3 x 0.95mm package, said to be the smallest of any similar device.

The BMX160 integrates accelerometer, gyroscope and geomagnetic sensor technologies, while meeting the low power requirements of wearable devices. Power consumption is less than 1.5mA.

Bosch notes the BMX160 effectively replaces today's two component solution – a six axis IMU with a three axis geomagnetic sensor. Instead, the part is said to provide placement flexibility, overcoming current limitations on where the magnetic sensor can be placed.

CCMOSS acquired by ams

Cambridge CMOS Sensors (CCMOSS) has been acquired by sensor specialist ams in an all cash transaction. Founded in 2008 as a spin off from Cambridge University, CCMOSS has built expertise in micro hotplate design and manufacturing for gas and infrared sensing.

Alexander Everke, ams' CEO, said: "The addition of CCMOSS makes ams the clear leader in gas and infrared sensor technology and completes ams' portfolio of products and technologies for the environmental sensor market."

CCMOSS' micro hotplates are MEMS based devices with applications in the automotive, industrial, medical, and consumer markets. Its technology is said to complement ams' capability in detecting gases such CO, NOx, and VOCs.

Are 450mm fabs still needed?

IN THE SPACE OF FIVE YEARS, IT LOOKS LIKE 450MM MANUFACTURING HAS BECOME SURPLUS TO CURRENT REQUIREMENTS. BY **GRAHAM PITCHER**

Five years ago, the semiconductor industry was getting excited about what looked like the next step in its evolution; manufacturing chips on 450mm diameter wafers. And the plans called for 450mm manufacturing to be mainstream today.

There were a couple of drivers for the migration, including the ability to increase throughput and a potential reduction in cost per die. Intel was one of the companies leading the campaign for 450mm manufacturing, with support from TSMC and, less enthusiastic, Samsung. But there was also interest in 450mm from the European Commission, which commissioned a report into whether it might be feasible to build such a fab in Europe.

One of the authors of that report was Malcolm Penn, chairman of industry watcher Future Horizons. Who better to ask about where 450mm is today?

"The world has changed," he said. "At the time, Intel believed it couldn't build enough fabs, but its market has changed and so has industry's desire to go to 450mm."

Nevertheless, Intel did some 450mm exploratory work in Oregon, while TSMC built a pilot plant in Taiwan.

In Penn's view, equipment manufacturers didn't want to do 450mm because they didn't see any reason, but agreed to investigate, so long as it was a coordinated project with a single agenda. "However," he said, "R&D work has carried on and equipment manufacturers have used that to improve 300mm manufacturing – something not intended."

One factor which influenced progress was the economics. "It doesn't bring a universal cost per die improvement," Penn pointed out. "It depends on the process being used and the more lithography there is, the less the cost benefits because it's a stepper process. But etch and deposition are per wafer processes and do bring benefits."

But one technology might rescue 450mm manufacturing – 3D flash. "There's a lot of etch and deposition involved in 3D flash," Penn said, "perhaps 128 steps, and that could bring a serious cost advantage over 300mm manufacturing. But the process isn't working well yet.

"If Samsung – and maybe Intel – can get 3D flash sorted, there will be the need for 450mm and there will be a baseline for it to expand into logic."

Meanwhile, Europe's appetite for 450mm has disappeared. The idea was part of Neelie Kroes' 10:100:20 project – where €10billion of EU funding and €100bn from industry would capture 20% of the global chip business – but, said Penn, European chip companies have 'vetoed' the idea. "The world has changed in three or four years," he concluded.

Weightless, ETSI to collaborate on IoT comms standards

In a move which it describes as a 'significant inflexion point' in the ultra narrowband (UNB) market, the Weightless SIG has announced that it will work with ETSI on standards development.

As part of the collaboration, designed to bring consolidation to the low power WAN (LPWAN) sector, Weightless will offer its Weightless-N standards activities into ETSI's Low Throughput Network (LTN) initiative. This, it says, will ensure that all those interested in ultra narrowband solutions are represented in one forum.

Weightless' CEO Professor William Webb said: "In order to reduce fragmentation and enable critical mass in the marketplace, we are bringing these two initiatives together, providing a platform around which industry can coalesce."

Prof Webb told New Electronics: "The significance of this move is we're trying to fix a serious block in the implementation of the IoT. If you want to connect something, you have to

use a chip, but which one? You can't put them all in; it's too expensive and too complicated, so companies are likely to do nothing. Until we get to where there's certainty, it's difficult to see the anticipated growth in the IoT."

It's likely that, under the new arrangements, ETSI will continue to do standardisation work, while Weightless SIG will undertake complementary activities. "It'll be similar to how the Wi-Fi Alliance works alongside IEEE802.11," Prof Webb explained. "We will help companies to reach consensus outside of ETSI meetings."

The SIG has also appointed Telensa to its board. "We are delighted to welcome Telensa to the burgeoning Weightless ecosystem," said Prof Webb.

Will Gibson, CEO of Telensa, said: "We're delighted to be extending our ETSI standards work by joining the board of Weightless. This partnership signals a growing maturity in the LPWAN market."

ETSI's LTN initiative is developing an LPWAN standard and this work is supported by a range of companies, including Telensa and Sigfox. Currently, only ETSI and Weightless have developed IoT specific standards for unlicensed spectrum based on UNB technology.

"There's a lot of similarity between Weightless-N and LTN," Prof Webb said, "so it won't be too difficult to consolidate the approaches into something that works for everyone.

"We hope that, by the end of 2016, ETSI will have published a standard," he concluded.

Have you entered yet?

IF NOT, THE DEADLINE FOR ENTERING THIS YEAR'S BRITISH ENGINEERING EXCELLENCE AWARDS IS JUST TWO WEEKS AWAY. BY **GRAHAM PITCHER**.

In an impromptu speech to the 2014 Awards luncheon, Dr Peter Poon of Romax Technology, winner of the British Engineering Excellence Awards (BEEAs) Grand Prix, asked the audience: "Can you do it better?" And that encapsulates the spirit of the BEEAs. If you have developed a breakthrough technology, grown an innovative business or excelled in your specialist field, then we'd like to hear from you.

However, if you are looking to enter this year's awards, but haven't started your entry, then you need to get busy as entries close on Friday 15 July.

Since the BEEAs were launched in 2009, the winning entries have ranged in size from chip designs to pipe laying systems, with the Grand Prix – the best of the best – awarded to entries as varied as an engineer who designed a system to save water on a massive scale to a start up company developing deployable space structures.

Winners from the 2015 Awards included the developer of a prosthetic hand addressing the needs of those with small hands, an innovative test system that makes sure the video you see on your screen is what you should see and a design team which created the world's first radar controlled traffic management system.

The winners demonstrate the breadth of the UK's engineering and innovation capabilities and every year the quality of entries improves. But the BEEAs don't only reward innovative companies, they also recognise the design engineers who made those innovations possible.

The 2016 categories are:

Consultancy of the Year
Design Engineer of the Year
Design Team of the Year
Green Product of the Year
Materials Application of the Year
New Product of the Year (Electronic)
New Product of the Year (Mechanical)
Small Company of the Year
Start-up of the Year
Young Design Engineer of the Year

The judges will then select the winner of the British Engineering Excellence Grand Prix from the winners of each category. They also have the opportunity to make a Special Award.

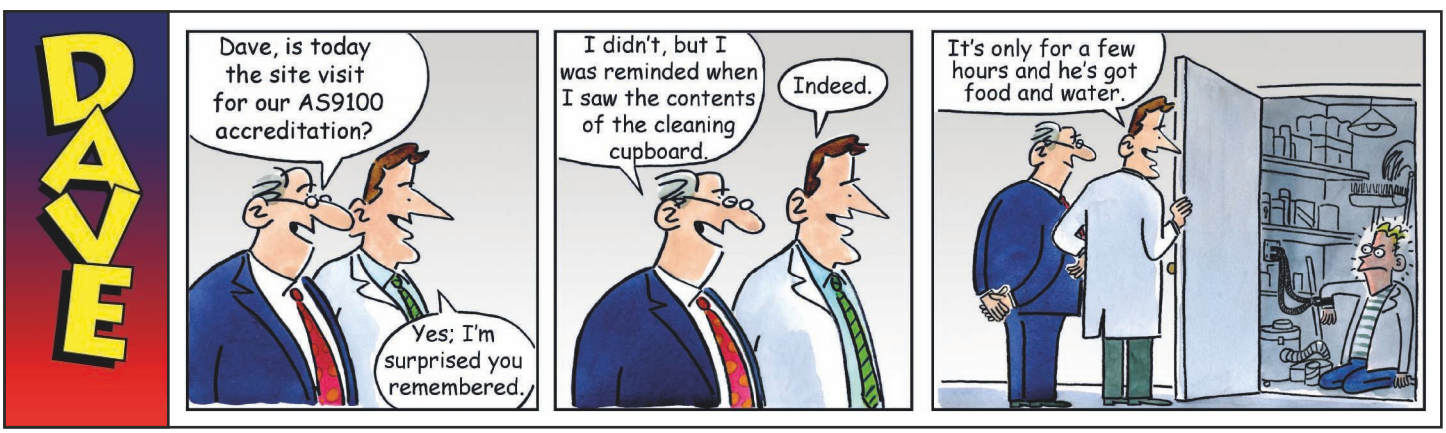
The Awards are not a rubber stamping exercise; entries are scrutinised by a high quality panel of independent judges (see box) and the companies that make it to the shortlist will have had to impress them.

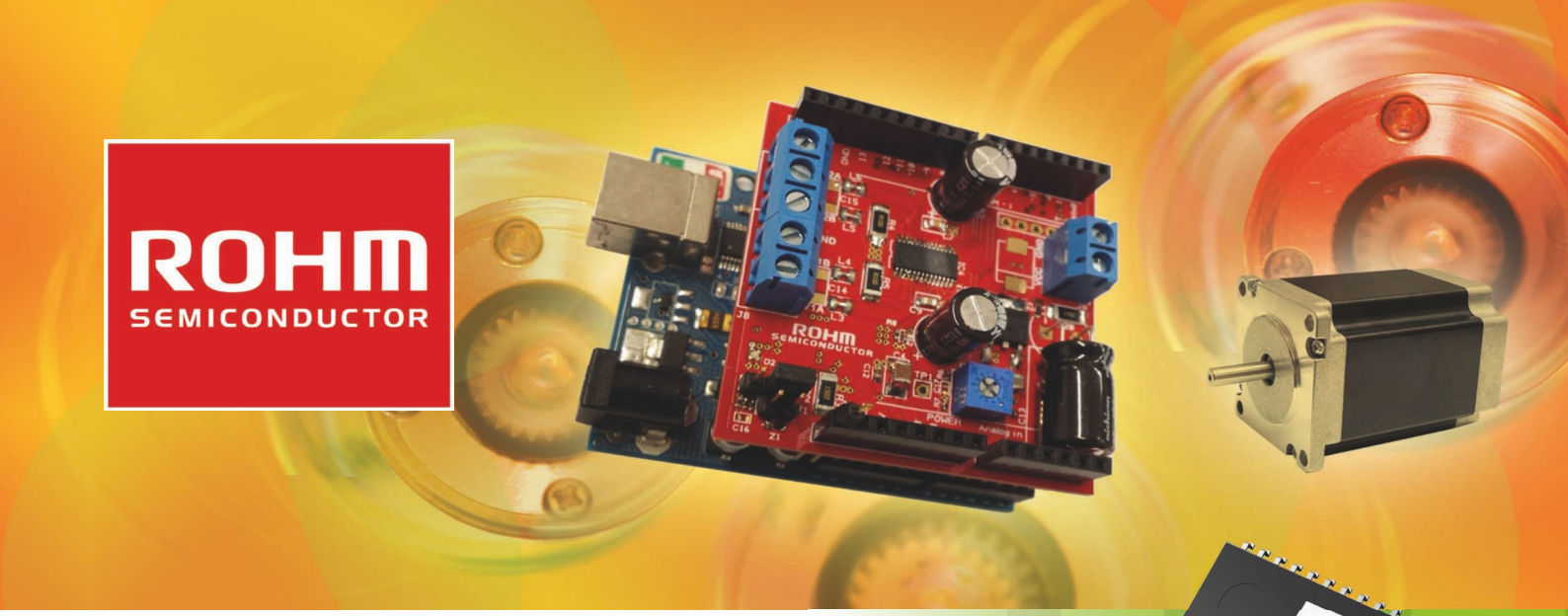
The online entry forms are very easy to complete and entry into the BEEAs is FREE. For more information and to obtain your online entry form, visit **www.beeas.co.uk**

The winners will be announced at a gala lunch at The HAC, the London home of the Honourable Artillery Company, on 6 October.

This year's judges

Mike Lawton, CEO, (above, last year's winner), Oxford Space Systems
Pete Lomas, Trustee, Raspberry Pi Foundation
Phil Mayo, Managing Director, Premier EDA Solutions
Philippa Oldham, Head of Transport and Manufacturing, Institution of Mechanical Engineers
Richard Poulton, Hardware Team Leader, Navtech Radar
Andy Sellars, Lead Technologist, High Value Manufacturing, Innovate UK
Eric Wilkinson, Chief Operations Officer, Cambridge Consultants
Graham Pitcher, Group Editor, *New Electronics*
Tim Fryer, Editor, *Eureka*
Justin Cunningham, Editor, *Engineering Materials*





ARDUINO MOTOR SHIELD

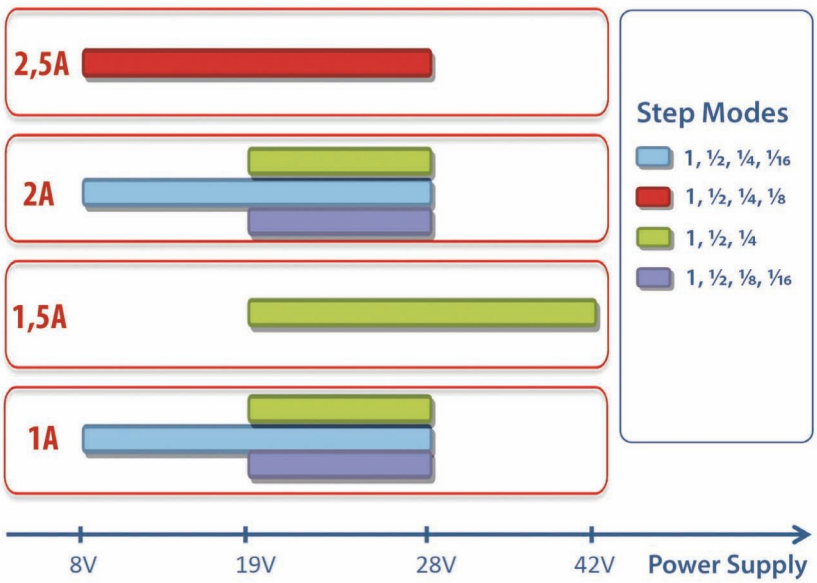
- High Efficiency
- Easy to Adapt
- Fast Prototyping

ROHM Semiconductor provides a new Arduino based evaluation kit to support the evaluation of its motor driver devices as well as to enable, facilitate and accelerate customers' developments.

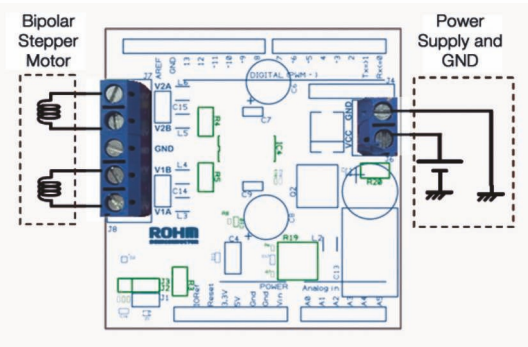
Key Features

- Stepper Motor Shield for Arduino platform
- Support of bipolar or unipolar stepper motors
- Max Voltages: 28V or 42V
- Max Currents: 1A / 1.5A / 2A / 2.5A
- 15 versions with different ratings
- Adjustable current limit
- Adjustable current decay mode
- Single supply operation
- Stackable to drive two motors
- Reverse power supply protection
- Software library for Arduino IDE
- Arduino example programs (Sketches)

Start Designing Stepper Motor Application with our Arduino Motor Shield



it's easy just like this!



Squeezing more down the pipe

Demands for higher data centre interconnect capacity are driving advances in optical module technology. By **John Walko**.

The huge growth in demand for video, cloud services and social networking is changing almost everything about the way the networks are built and used, not least the interconnect technologies within data centres and the 'top of rack' network switches that shift packets between the optical internet boxes – or Data Centre Interconnect (DCI) – and the servers that store and process the data.

The high bandwidths and low latencies demanded by operators are also having a huge impact on the way data centres are networked over both short and long distances.

This fast shifting landscape is challenging optical transceiver and module suppliers to change their pace of innovation. Companies that focus on these devices – such as Oclaro, Finisar, JDSU, NeoPhotonics, Sumitomo and Source Photonics – have to use a mix of vertical integration and merchant supply to keep up with rapidly changing data centre demands while remaining competitive.

The brightest prospects are in the coherent dense wavelength division multiplexing (DWDM) modules sector. "This is the fastest growing portion of the market," Matthew Schmitt, founder and CEO of consultancy Cignal AI, told *New Electronics*. "Non coherent solutions will be used by some large web scale providers, but coherent has a much longer runway in terms of cost reduction and, ultimately, is much easier to deploy." Until earlier this year, Schmitt was a research director at IHS Infonetics.

Perhaps the biggest challenge – and certainly the biggest opportunity – is the shift from 40G to 100G Ethernet networks. "Shipping of 100GbitE and coherent WDM modules has started in earnest," said Adam Carter, chief commercial officer at Oclaro, "and it is the demand from data centre operators that is fuelling the shift from 10G and 40G."

Oclaro's roots go back to the late 1980s, when it was founded in the UK as Bookham Technology. The company grew incrementally, having absorbed the optical components activities of GEC Marconi and Nortel Networks, amongst others. Over the years, it merged with Avanex to create Oclaro, which still operates the old Caswell fab in the UK as a pilot manufacturing line for InP based devices.

The move to 40G should not be such a great surprise, suggests Carter. After all, when you are focusing on applications inside the data centre, most already run a significant percentage of their high bandwidth data over optical fibre, making use of some serialiser/deserialiser circuits such as Broadcom's Tomahawk and Jericho circuits to pack data from the serial buses used inside processors into a single stream for each link.

"These are now driving the density on the line card face blades to, for instance, 32 QSFP ports on the front panel. If you double stack this and use the QSFP28 format, that bandwidth is equivalent to 3.2Tbit/s for a 1RU line card." That trend will only continue, Carter suggests, and he anticipates that, by the second half of this year, we might see some data centres rolling out 100Gbit/s in those switches.

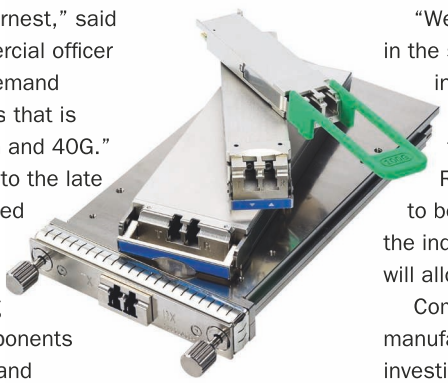
Carter suggests this is good news for the optical components companies and network equipment manufacturers because the anticipated volumes should result in a very healthy industry for many years to come, with demand likely to outstrip supply at some point. However, he questions whether the industry can continue its rapid pace of innovation.

"We're all set to deploy 100G in the second half of 2016 and the industry is already talking about 400G. The amount of money that will need to be spent in R&D to enable 400G is going to be substantial and it's not clear the industry is set up in a way that will allow that to happen naturally."

Component and module manufacturers are already investing heavily to support data centre volumes and when this does not get amortised, it has a negative financial impact on these companies, Carter suggests

This is further compounded by the fact that the industry wants these innovations to appear faster than ever, placing enormous pressure on the entire distribution chain.

"Since hyperscale data centre operators and cloud providers own the boxes at both ends of the network," he added, "we are seeing a rapid proliferation in the number of optical interfaces and connection choices."



Oclaro's optical interface portfolio now features a 100GbE QSFP28 transceiver module, designed for high port densities

At 10G, there were two choices; at 100G, this has increased to eight. From a component supplier's point of view, this makes leveraging economies of scale across operations much more difficult, warns the Oclaro executive.

With 100G in sight, the industry still wants modules to be better, faster, cheaper and to consume less power – and it wants these products to be brought to market more quickly. This is likely to place enormous pressure on the core optical components industry, which has been undergoing significant change.

Carter suggests the optical components and modules sector faces other big challenges and issues. For instance, higher data rates and new innovations, such as on-board optics, will require a level of investment that will only be possible with a stable and healthy optical component industry with funds available for significant R&D investment. This will require an industry with competitive gross margins that allow it to continue funding the move to higher bandwidth, smaller form factors, higher density and lower power. This, Carter maintains, is not a given at the moment.

The question of the sector's profitability has very much become a 'hot topic', according to Vladimir Kozlov, CEO of consultancy LightCounting. He notes that pricing of 100Gbit Ethernet modules has become very aggressive and that, at the recent Optical Fibre Communications Congress, 'the target of $1/Gbit/s set out in 2015 by Yuval Bachar – formerly of Facebook and now with LinkedIn – was revised to $4/Gbit/s'. He suggests that, between them, Amazon, Google and Microsoft spent $250million on Ethernet transceivers last year.

"The amount of money that will need to be spent in R&D to enable 400G is going to be substantial and it's not clear the industry is set up in a way that will allow that to happen naturally."
Adam Carter

Oclaro's Carter notes the rapid adoption of many different form factors and packaging formats is increasing, so the industry urgently requires more standardisation effort in order to make it easier to develop products that work through the entire supply chain. And he adds that, as bandwidth

demands increase beyond 100G, it is becoming increasingly important for optical companies to have the ability to manufacture the high speed lasers and receivers capable of supporting those higher data rates.

Carter warns that, currently, there are fewer than five laser fabs in the world with this capability (at more than 25G) and this represents an opportunity for the industry to undergo much needed consolidation.

Seeding the cloud

Internet service providers and social networking companies such as Google, Microsoft, Facebook and LinkedIn are beginning to call most of the shots when it comes to how data centre interconnection (DCI) is designed and implemented.

The companies are shaking up the business by designing custom hardware and software and by sourcing much of the hardware, even components such as optical modules, directly from suppliers, bypassing the way in which DCI has been implemented previously.

An important recent example of this strategy was the announcement in March at the Optical Fibre Communications Conference (OFC), when Microsoft and component supplier Inphi said they were collaborating on modules that will plug directly into switches and routers. The move could spell trouble for those developing dedicated DCI systems and boxes.

The idea is that large data centre operators can 'stitch together' regionally distributed data centres so – when appropriate – they can work like a hyper data centre. The approach allows data centres 80km or less apart to be connected almost switch to switch, essentially by running Ethernet directly on a dense wavelength division multiplexing (DWDM) link, with only amplifiers and multiplexers/demultiplexers in between.

Inphi has released what it calls the ColorZ reference design for a DWDM QSFP28 form factor pluggable transceiver that, importantly, uses the PAM-4 (pulse amplitude modulation) signalling specification for single wavelength 100Gbit/s transmission, delivering up to 4Tbit/s bandwidth over the single fibre

"We are very excited to be working with Microsoft on this project and believe it was a combination of a deep knowledge of PAM-4 and on-going projects in silicon photonics that clinched it for us as these enable a module that is low cost, low power – just 4.5W consumption – and the right form factor," Loi Nguyen, co-founder and head of Inphi's optical interconnect group told *New Electronics*.

As well as making use of silicon photonics based functional integration of modulators, photodetectors and multichannel muxes and demuxes, the design incorporates the in-house developed InphiNity Core DSP engine.

Microsoft outlined three years ago how it saw its data centre needs evolving in the medium to long term, and this included a 100G capable solution for distances of up to 80km. But it realised this was not available for deployment in the late 2016 time frame and decided to put out a tender to component suppliers to spur development.

There were 100G standard optical modules and work on technologies such as IEEE802.3ba, 100GBase CR4 and LR4 for point-to-point links of less than 10km in the required QSFP packaging, as well as solutions for long-haul solutions (traditional coherent QSPK, 16QAM) suitable for links of more than 100km.

Microsoft's director of network architecture, Jeff Cox, said at OFC that the company could not use established 100G coherent solutions as they would not scale economically for the shorter links, so it went for the so-called 'direct detect' approach, specifically for those intermediate distances. Cox said Microsoft chose Inphi because its proposal seemed the most straightforward.

"We are very excited to be working with Microsoft on this project and believe it was a combination of a deep knowledge of PAM-4 and on-going projects in silicon photonics"
Loi Nguyen

The companies demonstrated the module at the OFC plugged into switches from regular suppliers to Microsoft, including Cisco and Arista Networks, working with amplification and multiplexing units from ADVA's CloudConnect line.

Nguyen said the modules would be packaged by a 'non traditional supplier' and that volume production is scheduled for Q4 2016. Both he and Cox stressed the deal is non exclusive and that both companies hope to work with others on the modules. And other web-scale companies could adopt the same approach, if it fitted their needs.

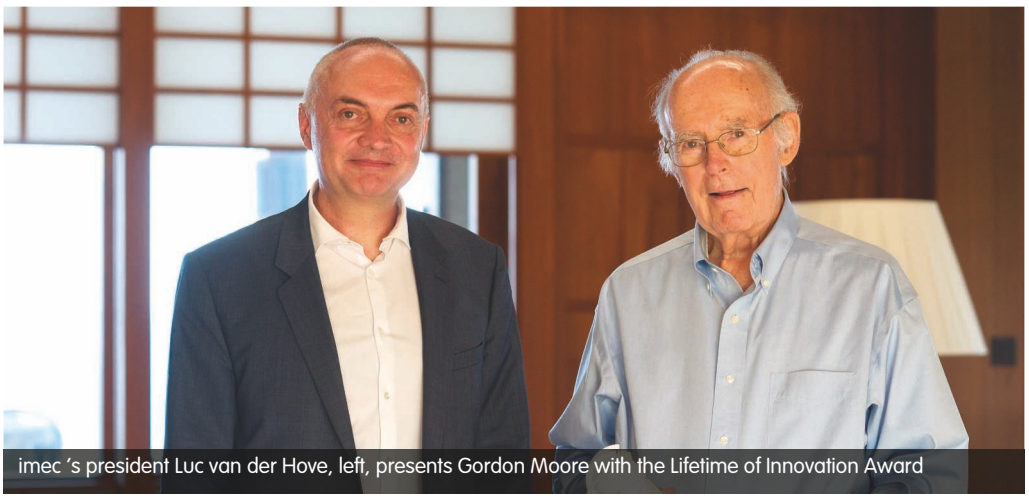
Following the OFC announcement, some suggested this made existing optical DCI/coherent DWDM solutions obsolete, but this seems most unlikely. Nguyen himself believes coherent will not go away and told *New Electronics*: "We believe we will have a significant power and cost advantage for a few, maybe three, years, by which time something newer, better and maybe more cost efficient will come along. That is the nature of this business."

Neither does the development mean the end of DCI boxes, as Jim Theodoras, VP of global business development at ADVA, stressed. "The optical line shelf is not going away any time soon. While an exciting development, it is a niche application for a specific case defined by one player in data centres, admittedly huge."

One major drawback is that Inphi's solution requires dispersion compensation on the fibre because it relies on PAM – an analogue transmission scheme – whereas coherent DWDM techniques will not. Dispersion compensation costs would include capital equipment and operational expense.

Continuity and disruption

Is the semiconductor industry entering a new phase when it comes to scaling? By **Neil Tyler**



imec 's president Luc van der Hove, left, presents Gordon Moore with the Lifetime of Innovation Award

Within a few years, engineers will have reached the limits of their ability to build working CMOS systems. In fact, Gordon Moore, the creator of Moore's Law, has admitted that it is likely the road towards smaller transistors has come to an end.

According to Moore: "Making the steps from one technology node to the next is becoming increasingly difficult and more expensive. I don't know how much longer it can continue."

Could we be seeing the 'end of scaling' within the next 10 years?

At this year's imec Technology Forum, which awarded Moore its 'Lifetime of Innovation Award', the focus was on how the semiconductor industry should respond to the end of traditional scaling.

For more than 50 years, scaling has addressed issues such as cost, area, power and performance. Until recently, Moore's Law held firm; new systems built from smaller chips delivered more functionality and performance.

Harder after 28nm

Consensus was that scaling had become far harder beyond the 28nm node and that chip manufacturing was not only becoming more expensive, but scaling itself was also becoming increasingly difficult. As a result, there has been a focus on the use of new materials, of double and quadrupling patterning and the development of new architectures, such as FinFETS.

"The semiconductor industry is mature and research and development spending is under pressure," suggested Gary Patton, GlobalFoundries' CTO and senior VP of worldwide R&D. "Scaling has slowed dramatically as the cost of design has gone up, but our customers continue to scale at the leading edge."

Qualcomm's VP of global operations Roawen Chen said that pursuing Moore's Law was no longer unconditional. "We no longer have to move to the latest node; that decision is more dependent on the company's business model. The move to smaller nodes is slowing, but it is not over. EUV and material innovations will be key drivers."

Luc van den Hove, imec's president, warned that, should semiconductor innovation slow significantly, the impact would be profound.

"Scaling will have to continue if we want to deliver the enormous computing power the IoT calls for," he said. "Traditional growth drivers are no longer working."

According to Chen: "5G is going to be as disruptive as data was to the mobile phone. It offers an explosion of connectivity and will fuel growth going forward. Whether it's high performance image processing or real time decision making, there are a lot of people out there looking for a different value proposition."

"Making the steps from one technology node to the next is becoming increasingly difficult and more expensive. I don't know how much longer it can continue."
Gordon Moore

Engineers have to work harder to get additional gains out of new nodes and have developed 'scaling boosters', which take into account the requirements of design units such as standard cell and memory bit cells, as well as developing different combinations of fin heights and widths, for example.

Another option has been stacking multiple front end layers, although enabling more devices to be stacked in the same space comes with more complex fabrication and expense.

These techniques have helped keep the gap between true Moore scaling and the actual gains to an acceptable level, but that is becoming harder to achieve. So is Moore's Law dead?

"Traditional scaling is 'morphing'

to allow for growing complexity and several technology options are available," according to van den Hove. "We will evolve from FinFETS towards horizontal and even vertical nanowires, which will bring us down to the 3nm generation, if not a few generations more. To achieve this we will need effective lithography and I believe EUV is the only effective lithography going forward."

According to An Steegen, imec's senior VP for process technology: "Why would Moore's Law be dead? While there may not be the application drivers of the past, just look at the explosion in data traffic enabled by the IoT.

Application drivers

"This will require CPU power and storage capacity; even IoT devices will need a degree of CPU capacity. So I think there will be more than enough drivers for the more advanced nodes, especially in the server and mobile domains.

"From the application driver perspective, Moore's Law remains very much alive. I think the problem is the technology itself. Are the expectations for power, performance and area now becoming unobtainable with current technology and does this mean there is not enough incentive, from a design perspective, to move to the next node?"

Steegen suggested that while designers like heavy scaling, where devices shrink while doubling the number of transistors, over the past 10 years or so, the industry has not followed that path. "Instead," she said, "we have been confronted with dark periods – dark silicon – where both voltage and transistor scaling have not gone hand in hand. In fact, we are having to look at turning off certain cores in order to meet power density targets.

"So, from a technical perspective, how can we include the necessary features to support future technology roadmaps?"

"Looking at the near term, we can innovate at many levels, including advanced lithography, novel architectures and innovation at the circuit level.

"We need EUV lithography now. The industry wants a 50% die cost reduction per node, but multipatterning immersion lithography will only give a 30% reduction. Scaling boosters – intermediate metal levels – will help to shrink die size, but they will increase cost.

"Getting that 50% die cost reduction will need innovation at the design level and extra effort. If we put it all together, we can achieve a 50% cost reduction from 10nm to 7nm."

Solutions exist, such as stacking multiple front end layers, new materials and circuit level innovations.

However, within a few years, it is likely that we will have reached the limit of how small critical features can be made while still retaining working CMOS transistors.

Steegen asked: "How long can FinFETs last? They will be adopted for 10nm because they bring a 25% performance increase, as well as a 40% reduction in power. But they can't meet performance-power requirements at 7nm. We will need devices which can improve the electrostatics of transistors. At imec, we're looking at lateral horizontal nanowires, which will open the design space and provide a migration path to 5nm."

Traditionally, scaling has been focused on transistors. "In the future," Steegen contended, "there will be a need for more intense co-design of systems and technology and a move towards specialised high level functions or building blocks. We will need to develop speciality technologies for devices like mobiles, cameras and sensors."

To that end, imec is looking beyond traditional CMOS transistors and at spinwave devices, for example, that exploit an electron's spin. With these approaches, it may be possible to create devices that are both more compact and energy efficient, as well as using fewer components.

Going forward, scaling is expected to be more of a system level concept, according to Steegen. The more abstraction levels you cross, the higher the potential wins.

"Further out," she asked, "are there more disruptive features? In memory caches, for example, we can replace 6T SRAMs with one transistor and a stacked magnetic tunnel junction. This brings a fourfold area benefit. Other drastic changes include vertical FETs."

"There are devices beyond CMOS and the industry has always managed to emerge from periods of 'dark silicon'."
An Steegen

There needs to be a move away from a 'one size fits all' concept and as applications are upgraded, so the focus is likely to change. Some systems will benefit from lower power, others from more memory or higher I/O throughput.

"Stacking can also bring advantages," Steegen contended. "We could start thinking about using the right technology for the right block, then stacking dice."

Developing these technologies will depend on it being done cost effectively and will require new business models and the growth in specialised blocks could result in a whole new ecosystem.

"There are devices beyond CMOS," Steegen concluded, "and the industry has always managed to emerge from periods of dark silicon."

The advent of the **digital railway**

With record sums of investment planned for the UK's rail network what will the future network look like? By **Neil Tyler**.

Over the coming five years, more than £25billion will be invested in the UK's rail network. While that includes 'big ticket' items like High Speed 2 (HS2) and Crossrail, there is considerable innovation taking place across the network – from traditional heavy urban rail networks to innovative city centre mass transit systems.

This investment is vital: the UK rail network is the fastest growing in Europe, with operators carrying twice as many passengers as they did 20 years ago and many key routes are overcrowded.

The market for suppliers is huge. Based on figures for 2014-15, Network Rail spent upwards of £887million on track, £644m on signalling and almost £400m on information technology, asset management and intelligent infrastructure.

Current enhancements to the rail network are costing Network Rail £3.3billion each year.

Rolling stock renewal

The UK rolling stock market has been estimated to need between 3000 and 3500 new carriages in the foreseeable future. Given that each carriage can cost upwards of £2m, there are billions of pounds at stake.

From Wales to the North East of England, investment is accelerating as the UK's regions look at a mix of cheaper, more flexible rail solutions capable of carrying more passengers.

In Wales, for example, there is a clear proposition to replace the existing heavy rail network with a combination of light rail and trams.

Longer-term plans include proposals for a rapid transit in and around Cardiff, new routes within the city, a new light rail system and new rail lines on an existing disused rail corridor.

"Many of these projects are still in the planning phase," admits Richard Jones, business sector director, rail, at the Transport Systems Catapult. "Most of the investment is at a very early stage or a concept stage. In London, Crossrail, a high capacity, high frequency service, is about to open and Crossrail 2 is now in the planning phase."

Schemes such as Crossrail and HS2 are seen as crucial to meet spikes in demand in key economic regions, but investment in new tracks, trains and facilities can't happen fast enough to meet rising demand. Can technology play a role?

There has been a perception that the rail industry has been overly conservative when it comes to embracing new technology and innovation and Jones tends to agree.

"When it comes to urban rail, there has been an attitude of 'build it and they will come'. The industry has been painted as being overly conservative, but you need to put that approach in context; every morning this large, interconnected industry has to support up to 15m people who expect their service to run on time and without incident. Change is not necessarily seen as a great idea – if it works, why break it?"

Safety related or safety critical directives and regulations – at the European and National levels – impose a burden of proof on the person making the changes and, as a result, the rail industry tends to be wary of too much technical change.

"Safety constraints have certainly impeded and slowed innovation," suggests Jones.

Across a network of more than 22,000 miles, Network Rail has to maintain more than 6500 level crossings, a large signalling infrastructure, 43,000 bridges, viaducts, tunnels and 17 key stations.

The UK rail network is the fastest growing in Europe, with operators carrying twice as many passengers as they did 20 years ago and many key routes are overcrowded.

The Digital Railway

"The Digital Railway concept is the plan to tackle the UK's capacity crunch by accelerating the digital modernisation of the railway. It will see more trains running on existing tracks, helping to increase the impact of vital upgrades like HS2 and Crossrail. It is key to the future development of the rail network in the UK and Network Rail (NR) intends to start implementing it by the end of 2019," argues Jones.

"The UK has an ageing infrastructure, while there is a growing need for more capacity – these are the two main challenges facing the railway industry."

To tackle this effectively, the rail network is looking to upgrade signalling and traffic management, with the aim of bringing forward by decades the replacement of signalling so more trains can run on the existing network.

"The network will be more reliable and more resilient as a result," suggests Jones.

The project is not without its critics, who warn that more trains on the existing infrastructure will only solve part of the problem; what is needed, they contend, is further investment in the country's infrastructure.

Network Rail is also deploying technology to better manage its assets. Across a network of more than 22,000 miles, NR has to maintain more than 6500 level crossings, a large signalling infrastructure, 43,000 bridges, viaducts, tunnels and 17 key stations. To do this, it has invested £330m in asset information – the Orbis programme – designed to help NR better manage its assets with the aim of providing real time infrastructure traffic management.

"Using Orbis, NR will be able to better map the network's infrastructure, know where all its assets are and the configuration of trains. It will be able to distribute data to operations staff to maintain and repair assets, but also to anticipate maintenance needs," says Jones. "Orbis will effectively turn maintenance on its head."

Better data for better management

NR is looking for more consistent and authoritative data in order to better manage and operate the company's assets.

"Traditionally, the network runs on a maintenance period of three months. All equipment is visited, calibrated and tested on a regular basis, whether it has been used frequently or not – that is both expensive and time consuming.

"Orbis offers more accurate and reliable information that will enable more informed business decisions and a more innovative approach to asset management, planning and execution which will benefit the rail industry as a whole."

Alongside better asset management, NR is investing in new signalling technology.

"Traffic Management and the European Train Control System (ETCS) will greatly increase capacity on the existing network by allowing trains to run faster and closer together without comprising safety," Jones explains.

"ETCS will remove the need for lineside signals, with a control mechanism in the driver's cab meaning that railway signalling will be managed wirelessly from inside the train. Information from one of just 12 regional operating centres around Britain will be sent to the driver instantly," Jones explains.

ETCS will allow for automated routing and 'conflict detection' so more trains will be able to be run across the network.

"This will enable predictive planning and proactive incident management," Jones added, "which means more capacity, greater reliability and a safer network."

It is a major project and a pilot of the system is currently running between Norwich, Lowestoft and Yarmouth.

"This new signalling system is expected to be rolled out within the next 15 years and is likely to enable 30% more trains to run on the network. Safety will be based on the actual speed of trains, rather than a 'worst case' scenario, in which each train enters or leaves a section of the track," Jones suggests.

Rail companies are also investing in systems to advise the driver on speed and braking strategies. "There is a real difference between an aggressive and an intuitive driver," said Jones. "Drivers that brake excessively are up to 30% less efficient when it comes to electricity consumption – and energy consumption is becoming increasingly important. New rolling stock is being designed to provide energy storage and electrical energy recovery, much like hybrid cars. It's important that the next generation of trains is designed to be lighter so they use less energy and keep systems cooler."

In 2014-15, Network Rail spent upwards of £887million on track, £644m on signalling and almost £400m on information technology, asset management and intelligent infrastructure.

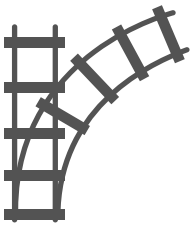
Embracing automotive technology

The Warwick Manufacturing Group, for example, is focused on the very light rail sector developing solutions that embrace technology transferred from the automotive industry focusing on self-powered vehicles with energy recovery and storage systems as standard and reduced infrastructure operational and maintenance costs.

Technology is helping to transform the rail network, whether that is through intelligent signalling or through proactive maintenance.

"The rail industry is evolving and looking to use technology to improve people's and business' experience of train travel, making journeys easier, faster, and cheaper and making the overall experience more intelligent, helping to transform how we use the rail network," Jones concludes.

Digitisation and new technologies are the key drivers in this new world.



The UK rolling stock market has been estimated to need between 3000 and 3500 new carriages in the foreseeable future. Given that each carriage can cost upwards of £2m, there are billions of pounds at stake.

Packaging pushing portfolio

Intel's Programmable Systems Group takes its first step towards an FPGA based system in package portfolio. By **Graham Pitcher**.

Speaking in 2012, Danny Biran – then Altera's senior VP for corporate strategy – said he saw a time when the company would be offering 'standard products' – devices featuring an FPGA, with different dice integrated in the package. "It's also possible these devices may integrate customer specific circuits if the business case is good enough," he noted.

There was a lot going on behind the scenes then; already, Altera was talking with Intel about using its foundry service to build 'Generation 10' devices, eventually being acquired by Intel in 2015.

Now the first fruit of that work has appeared in the form of Stratix 10 MX. Designed to meet the needs of those developing high end communications systems, the device integrates stacked memory dice alongside an FPGA die, providing users with a memory bandwidth of up to 1Tbyte/s.

"A few years ago," said Jordan Inkeles, director of product marketing for high end FPGAs, "we partnered with Intel for lithography and were very excited. We also looked at Intel's packaging technology and asked 'can we use that?'. The answer was 'yes'. The combination has allowed us to do things we thought were not possible."

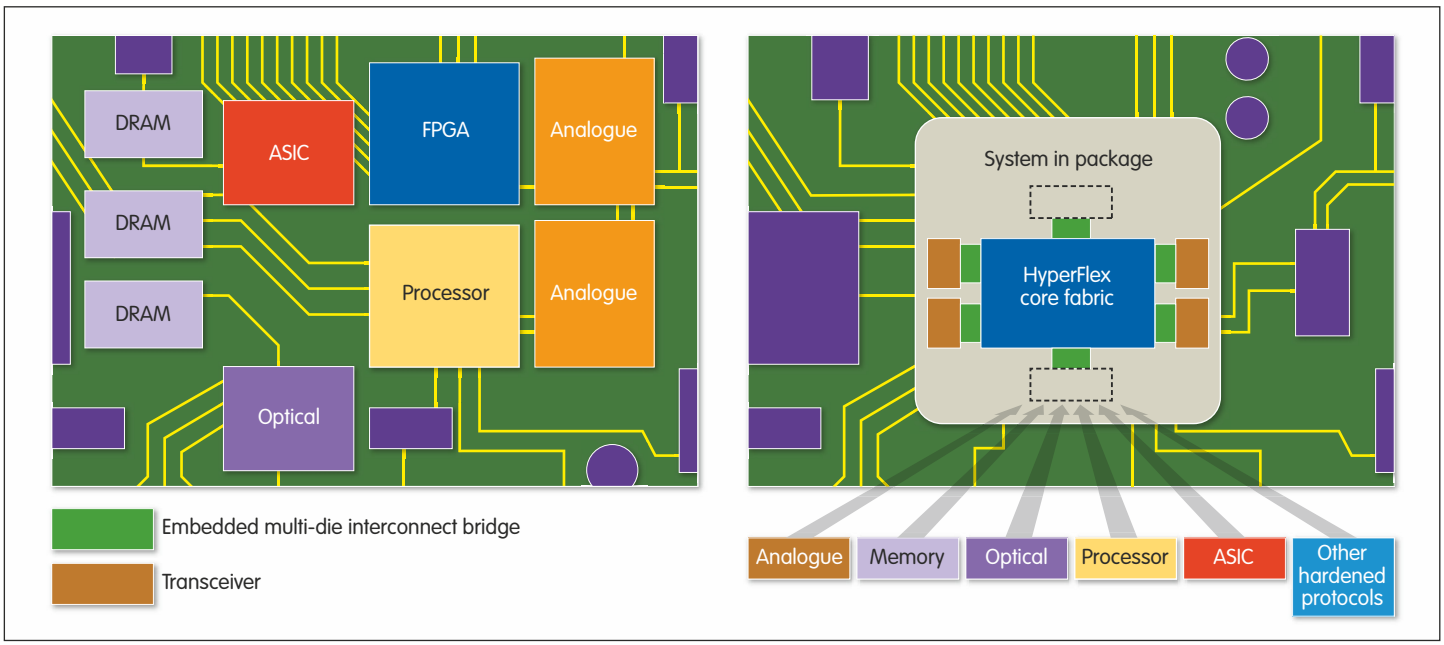
The concept is based on what Altera – now Intel's Programmable Systems Group (PSG) – calls 'tiles'. Essentially, these are the dice which sit alongside the FPGA. Tiles are connected to the FPGA using Intel's EMIB – embedded multi-interconnect bridge – technology. "It's not a traditional silicon interposer," Inkeles explained. "It's a little bridge chip which is used where you need to connect two pieces of silicon."

Stratix 10 MX devices are designed to help engineers solve demanding memory bandwidth challenges which can't be addressed using conventional memory solutions. The parts integrate four stacks of HBM2 DRAM, each with up to four memory dice. PSG says the parts are suitable for use where bandwidth is paramount. Apart from providing 10 times more memory bandwidth than conventional solutions, Stratix 10 MX devices are said to be smaller and to use less power.

"This idea of integrated chips opens up things," Inkeles said. "FPGAs are trying to be everything to everyone. They have to support wireless, wired, networking, radar and high performance computing, amongst others. We saw divergence in what was possible."

PSG started thinking about transceivers. "If we had transceivers in separate tiles, we could come out with devices for different markets,"

Heterogenous 3D system in package integration could enable a new class of FPGA based products



Inkeles continued. “It also makes sense for analogue, which doesn’t move at the same pace as digital, and for design reuse. So we could use a tile that meets today’s needs – say a 28G transceiver – then come out in the future with a 56G PAM4 tile and a 28G NRZ tile. In the same process node time frame, we can deliver two very different types of product.”

This is the concept underpinning the MX. “Parallel memory is becoming a huge challenge,” Inkeles observed. “You can continue to use parallel interfaces, but with the memory right next to the FPGA to maintain signal integrity and reduce power. But, while Hybrid Memory Cube (HMC) is a good solution, it has to be serial,” he continued, “as you can’t get signal integrity on a 72bit wide datapath. Or you can put memory in the package.

“By providing up to four stacks of four DRAM dice, we’re providing a memory bandwidth never seen before. Each stack can run to 256Gbyte/s, so four stacks give 1Tbyte/s. That’s unprecedented and can’t be achieved with HMC.

“Power consumption is reduced because the memory is right next to the FPGA and drive strength is much smaller – only pJ/bit – because you’re not driving signals to a memory that could be 6in away.”

There is a downside, however; it’s an expensive solution. “You’re paying for bandwidth,” Inkeles admitted. “But customers complain about the effort it takes to do board layout and to get the DDR chips right. We’ve solved that without using any I/O or transceivers. And if 16Gbyte of DRAM in package isn’t enough, you still have transceivers and I/O available for use with external components.”

Inkeles pointed to three broad application areas for the MX device. “There’s high performance computing (HPC), cloud computing and data centres, but they all look for different things.

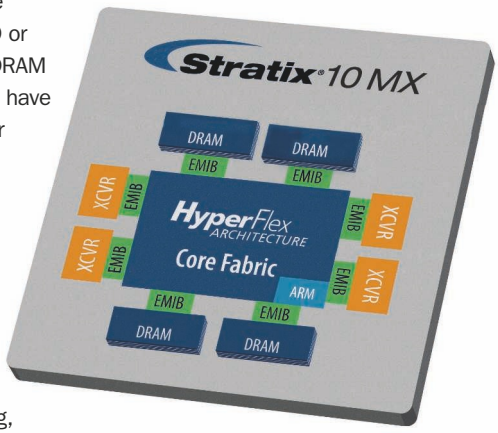
“HPC says ‘give me everything, while cloud says it’s worried about the cost per bit. Data centres can build algorithms in logic, which is quicker than a GPU, but need the memory bandwidth to ‘feed the beast’.”

Apart from imaging applications, such as medical and radar, Inkeles says there are applications in wireline communications. “Gone are the days of just routing traffic,” he said. “Everyone is now looking to differentiate their products, for example, by providing statistics on the data being handled. So they need to hold a piece of traffic for a moment to analyse what it is, then send it onwards. This couldn’t be done before because there wasn’t the bandwidth.”

MX is the first implementation of PSG’s strategy and the interesting thing is ‘what comes next?’. Optical functionality might appear at some point in Intel PSG’s Stratix 10 parts.

Five years ago, Altera announced plans to integrate optical interfaces into its FPGAs as a way to cope with increasing communications bandwidth. Despite demonstrating the technology later in 2011, the idea remained on the shelf. Inkeles said: “We have continued to evolve the technology, but haven’t gone public with the developments.”

Inkeles noted: “Although PAM4 offers a way to stay in the electrical domain, we will, at some point, run out of capability and we’ve been preparing for that transition. Now we have transceivers on tiles, we can take out one tile and replace it with an optical interface.



Stratix 10 MX is said to combine the programmability and flexibility of Stratix 10 FPGAs with integrated 3D stacked high bandwidth memory devices

“By providing up to four stacks of four DRAM dice, we’re providing a memory bandwidth never seen before.”
Jordan Inkeles

“We’ve been working behind the scenes,” Inkeles continued, “but the right time to put a product into the market will depend on the economics.”

Altera’s acquisition by Intel also gives it access to silicon photonics technology. “We have exciting capabilities,” Inkeles added.

Another potential step is integrating such components as analogue, ASICs and CPUs alongside an FPGA. Intel PSG says EMIB offers a simpler manufacturing flow by eliminating the use of through silicon vias and specialised interposers. The result, it claims, will be integrated systems in package that offer higher performance, less complexity and better signal and power integrity.

Inkeles sees this as potentially a new market. “ASICs have become smaller and faster, but not cheaper. Unless you’re going to sell millions, you will have a tough time,” he said. “ASSPs are going away, unless you can find more customers or more volume.”

Is it possible that Biran’s vision of ‘standard products’ might be close to reality and could that even include custom versions of a Stratix 10? “Will we do custom?,” Inkeles wondered. “It’s within our ability. It’s not something we’re promoting, but we are engaging with customers.

“We have a range of options. Now we’re part of Intel, the ‘sky’s the limit’. As Altera, we developed HardCopy and had an ASIC team, but it wasn’t our core competence. But Intel Foundry can do ASIC,” he concluded.

Boosting converter

Integrated capacitive PGAs can redefine A/D converter gain and range. By **Miguel Usach** and **Gerard Mora-Puchalt**.

Sigma-delta (SD) A/D converters are widely used in applications with sensors that have small responsivity and reduced bandwidth, due to their high dynamic range.

SD converters operate on two principles – oversampling and noise shaping. In general, and for a given band of interest, the dynamic range improves by 3dB for every oversampling factor of 2, assuming a white noise spectrum. Meanwhile, the noise transfer function shapes the noise to higher frequencies, further reducing quantisation noise at the band of interest.

One disadvantage of oversampling is the requirement for an input buffer to drive the SD modulator may become more stringent than for architectures operating at lower sampling frequencies. Moreover, presenting a very high input impedance with high precision to the sensing element is critical for measurement accuracy in sensing systems. This makes the requirement for input buffers even more critical.

Integrating an input buffer generates other challenges. The SD modulator offers very low noise at low frequencies, but any additional component – such as the input buffer – will add thermal noise and, more importantly, flicker noise at low frequencies.

The buffer's offset may also contribute to overall system error. This can be compensated for by system calibration, but if offset drift is relatively high, this approach may be impractical.

These two problems are typically solved by chopping the buffer's inputs and outputs; input frequency is modulated to higher frequencies, while buffer offset and flicker noise remain at their original low frequencies as they are not affected by input chopping (see fig 1a).

The output dechopper mechanism demodulates the input frequency back to baseband, which modulates the offset and flicker noise added by the buffer to higher frequencies that will be removed by the A/D converter's low pass filter.

In some cases, the input buffers are replaced by a resistor based instrumentation amplifier (resistive PGA) to accommodate a small sensor signal to the full modulator input range, maximising dynamic range. A resistor based instrumentation amplifier is preferred over a differential resistive amplifier, due to the higher input impedance required in discrete sensors (see fig 1b).

The main restriction in using this amplifier topology is the limitation on the common mode voltage, especially with gains other than unity; the resistive PGA has a floating common mode that depends on the input signal.

Resistive network mismatch and its drift is a concern in the overall error budget as it may have an impact on most of the precision specifications.

To avoid these limitations, recent SD converters from Analog Devices have employed a capacitive PGA, where the gain depends on the capacitor ratios (see fig 2).

In order to amplify DC signals, the capacitive PGA introduces a chopping mechanism at the PGA inputs; the DC input signal is modulated to the chop frequency, then amplified by the capacitive amplifier. Finally, the signal is demodulated back to DC by the output dechopper. Amplifier offset and flicker noise is modulated to the chop frequency and low pass filtered at a later stage.

There are some benefits associated with this approach:

- Better noise versus power trade-off as there are fewer noise sources.
- Capacitors offer a range of advantages over resistors; apart from being noiseless, they don't suffer from self heating and normally offer better matching and temperature drift
- The capacitors decouple the input common mode from the rest of the signal chain common mode.
- The capacitive PGA input common mode range may be rail to rail and beyond.

This capacitive architecture combines the benefits of an

How noise (top) and flicker noise are affected are affected by input chopping

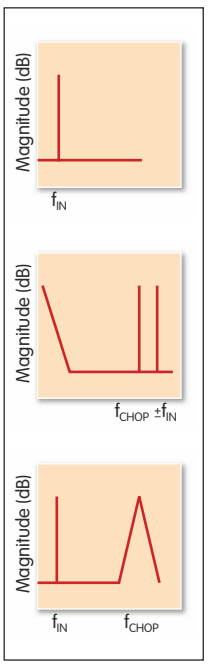


Fig 1a

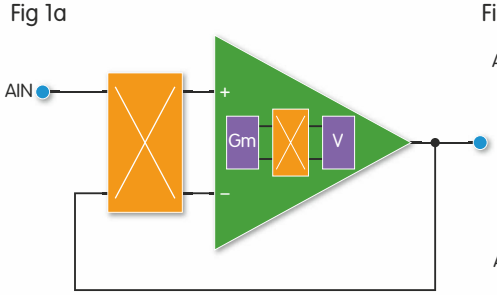
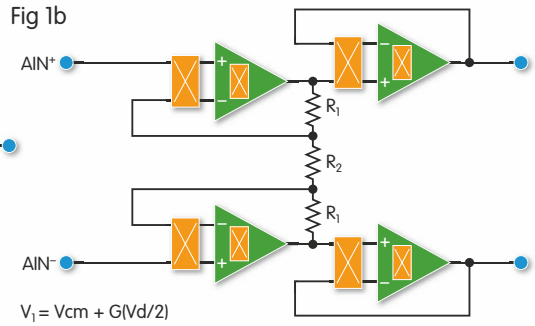


Fig 1b



$V_1 = Vcm + G(Vd/2)$
$Vcm = (AIN^+ + AIN^-)/2$
$G = 1 + 2(R_1/R_2)$
$Vd = AIN^+ - AIN^-$
$V_2 = Vcm - G(Vd/2)$

performance

instrumentation amplifier – which has a really high input impedance as the input impedance is a capacitor – with the benefits of capacitors over resistors as the gain element. This increases the amplifier's dynamic range, not only in terms of signal swing, but also noise efficiency.

In a Wheatstone bridge, common mode voltage is defined by the impedance connected in each leg and proportional to the power supply. Weighing scale applications implement this sensing topology due to the benefit of linear sensing.

Strain gauge sensitivity is typically 2mV/V and the higher the Wheatstone supply, the higher the sensitivity. To increase the strain gauge's dynamic range and maximise the signal to noise ratio, the bridge may be powered at higher supplies than the A/D converter.

In a resistive PGA, common mode limitation means the bridge should be powered at the same voltage as the A/D converter. However, it can be powered at almost twice the A/D converter supply voltage in a capacitive PGA as there is no input common mode limitation.

Assuming standard supply levels and powering the converter at 3.3V, the improvement of a capacitive PGA over a resistive PGA for the same same selected gain could be 5.2dB.

Another example is temperature measurement using resistance temperature detectors (RTD) or thermocouples. A popular RTD resistor, such as the PT100, may be used to sense temperature directly or to sense the cold junction of a thermocouple indirectly.

A conventional way to measure the temperature while cancelling the lead error in a three wire RTD configuration is shown in fig 3a. Here, the internal current sources of the AD7124-8, drive two wires of the RTD with the same current, generating an offset error equal in both leads and proportional to the lead resistance.

Due to the small value of the lead resistance and the currents provided by the AD7124-8 to minimise the self heating effect, the offset voltage generated is close to the negative rail. This reduces the maximum allowable gain in a resistive PGA significantly as its input common mode would also be close to the rails. A capacitive PGA will set the common mode voltage internally to half of the supply rails, allowing for a higher gain configuration and increasing overall dynamic range.

The proposed solution reduces system complexity and hardware connections, as the third cable may not be returned to the converter's PCB and can be connected to ground near the RTD.

To increase precision, four wire measurements are preferred. In this case, only one current reference is used. To avoid imprecision on the current source, ratiometric measurement can be used, with a precision resistance used as the A/D converter reference voltage generator (see fig 3b).

For a 3.3V supply in a resistive PGA, the voltage generated on the precision resistance should be around 1.65V, otherwise the PGA common mode voltage will limit the maximum gain. The consequence is the maximum gained signal should be equal to 1.65V.

In a capacitive PGA, there is no input common mode limitation, therefore the RTD common mode signal can sit close to the top rail. This allows the A/D converter reference voltage generated by the precision resistor to be maximised and, hence, the highest selectable gain and dynamic range.

Author profiles: Miguel Usach is an applications engineer, Gerard Mora-Puchalt is an analogue IC designer engineer. Both are with Analog Devices.

Fig 2

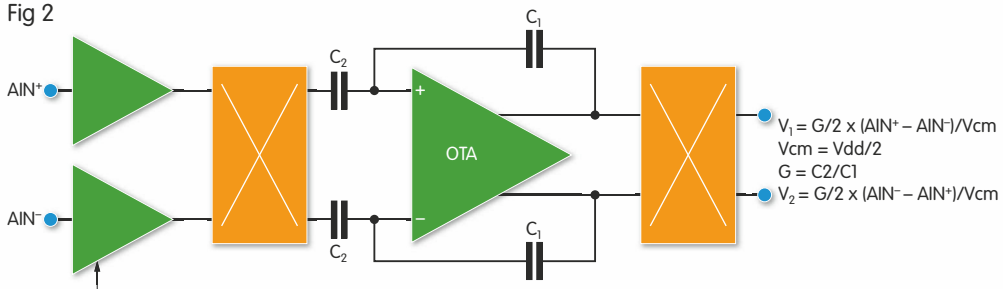


Fig 3a

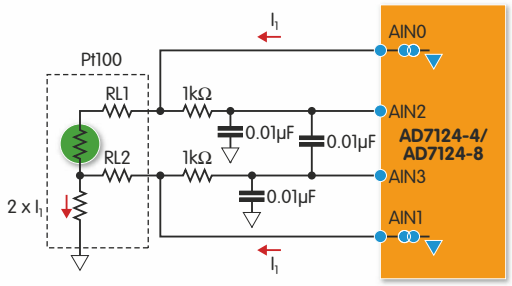
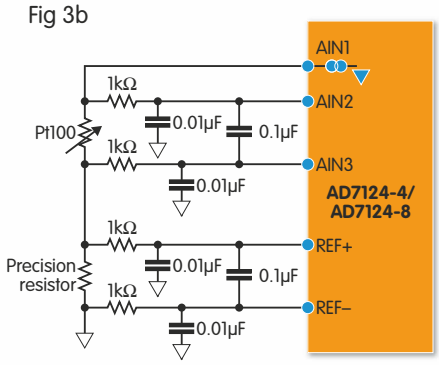


Fig 3b



Hertz so good

An Irish company is pioneering the development of 94GHz RF circuits for a range of applications. By **Graham Pitcher**.

It wasn't too long ago that GHz frequencies were regarded as exotic; few applications took advantage of that part of the spectrum as technology was not only difficult, but also expensive. That meant that military dominated the few applications there were. The Brimstone missile is believed to use 94GHz technology for targeting purposes, rather than the lasers used in previous missiles.

However, the lower end of the GHz spectrum is now in general use; 4G mobile phones, for example, use 1.8GHz, while some LTE devices may operate at 3.6GHz. And some applications are taking advantage of much higher frequencies; while automotive radar is now using 77GHz, the first deployments of terahertz technology have been discussed.

But one development – 5G – is likely to see mobile communications systems deploying so called mm wave technology at frequencies as high as 94GHz. And Irish RF specialist Arralis is looking to take advantage of the opportunities.

Barry Lunn, the company's CEO, said: "We are seeing a constant requirement for high frequency devices and believe that mm wave is becoming very important. Nobody else was addressing this area, so we decided to and got good results quickly."

Lunn believes mm wave technology offers a huge opportunity for Arralis. "There are no European companies involved in the sector," he noted, "and those in the US are subject to ITAR restrictions."

Arralis was established by Lunn and Mike Gleaves in 2013. "We decided to focus on cracking the difficult frequency of 94GHz," Lunn said. "Nobody had done this commercially and, if we could do it, the world would know who we were."

The 94GHz frequency is part of the W band, which extends from 75 to 110GHz. "It provides a good attenuation window," Lunn explained. "It's the perfect frequency in terms of trade offs with absorption. Better attenuation means better distance and the higher frequency allows more data to be transmitted. Meanwhile, mm wave means everything is smaller."

Arralis isn't the first company to address 94GHz. "The US Navy, for example, has developed a 94GHz radar," Lunn said, "but that device measured 2 x 1m. Apart from being expensive, that's not going to fit on the front of a car." We have taken 94GHz technology, moved it onto a chip and are making the devices at a commercial foundry, not in a boutique fab."

"We are seeing a constant requirement for high frequency devices and believe that mm wave is becoming very important".
Barry Lunn

In its early days, Arralis also offered RF design services. "We took a seed round of funding early on," Lunn said, "at which point, we stopped designing for others, focusing instead on our own products. While walking away from our service base was scary, we got the timing right."

It will come as no surprise to hear Lunn say that designing and integrating systems operating at 94GHz is 'a big challenge'. "But if we only designed and sold chips," he said, "we'd probably have only 10 customers. So we needed to diversify the customer base by addressing integration issues and by developing

packaging technology and antennas."

As Lunn implies, designing a chip to work at 94GHz is one thing. "Getting signals on and off the chip is just as important as what you do with them. One approach is to run systems up to the frequencies which a fab process will allow. Our view is that you need to work with the signals which people are trying to acquire and then work backwards from that point. We are focused on creating fully integrated front ends on a scalable process that can operate at high frequencies."

Arralis' parts are based on III-V materials and manufactured on a foundry process. "It's critical that everything we design is targeted at a foundry," said Lunn, "even the antenna. If we relied on in house manufacturing, it wouldn't be scalable; we have to ask ourselves whether we could build 100,000 units and still have the ability to develop the process."

One of Arralis' latest announcements came at the recent International Microwave Symposium, where it unveiled what it says are the first 94GHz transmit and receive chips. Applications for the parts include commercial radar, 5G communications and autonomous vehicles.

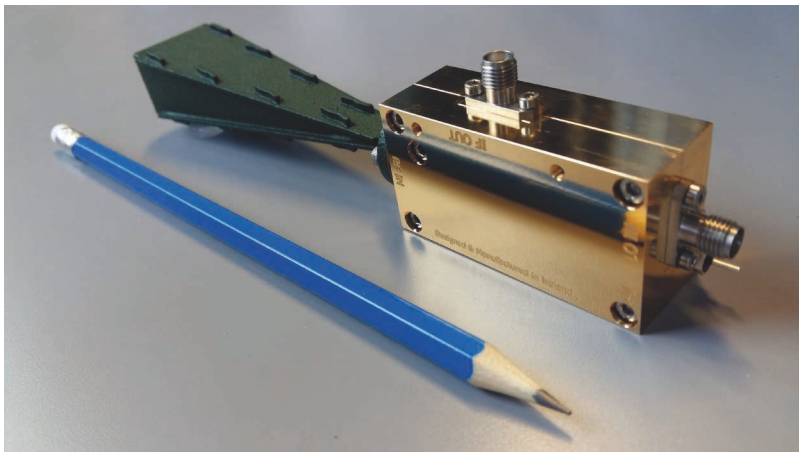
The parts – provided in the format of monolithic microwave ICs, or MMICs – are pseudomorphic high electron mobility transistor (pHEMT) based GaAs devices that measure 5.2 x 2.2mm. The devices can function as up- and down converters, which the company says, simplifies system integration and widens market access at the centre frequency of 94GHz.

The up converter consists of a mixer with an integrated medium power amplifier. It offers conversion gain, high image rejection and an output power of more than 13dBm. Meanwhile, the down converter consists of a low noise amplifier and a mixer, with a noise figure of less than 5dB and a gain of more than 10dB.

"Any time there are multiple devices," Lunn pointed out, "there are losses. So, we are doing a single chip instead of two."

MMIC design can be 'boring', Lunn said. "But if you're designing an entire front end for interesting things, that changes. MMICs have always been around, but the technology has been dominated by a couple of big players. With fewer hardware and microwave engineers nowadays, we're helping to solve problems."

As Lunn noted, one of the problems when working at such high frequencies is getting signals from the chip to the waveguide and vice versa. "We have a methodology that allows those signals to be moved on and off chip with practically zero loss," he said. "The losses associated with flip chip packages can be huge and antennas can often be an afterthought. We are 'dropping' fully encapsulated devices into systems, rather than 'fiddling' with chips."



Arralis' Tucana module range includes transmit and receive modules with WR10 antenna and SMA connections

Which market sectors will be taking advantage of 94GHz? Wireless communications looks to be one of the early adopters. "It's a hugely attractive market," Lunn said. "At this frequency, you can transmit data at 15Gbit/s over distance, even in bad weather."

He says 5G will be 'completely different' to anything that's gone before. "We don't know which frequencies will be used where, because 5G will be a mesh. But there will be bandwidth issues with 5G and the technology we're developing will be adopted. 5G will use frequencies of up to 94GHz."

Radar based landing systems

However, Lunn believes the biggest market will be radar based landing systems for helicopters and its attendance at forthcoming aerospace events underlines that.

The other market with potential is automotive; not only for 'conventional' cars, but also for autonomous vehicles. "It's not that big a jump from 77GHz to 94GHz," Lunn accepted, "but it's big enough. The benefit will be the ability to capture higher resolution data. Autonomous vehicles will need radar systems that provide as good a performance as possible, particularly in adverse weather conditions."

Lunn is in no doubt that 94GHz technology will play a major role in future systems. "Who would have thought companies like Facebook would have teams exploring mm wave?," he asked.

"What has held 94GHz back is the lack of commercial chipsets. No doubt other companies will emerge," he concluded, "but we're further down the line and we can offer entire front ends."

INNOVATE FASTER

WITH FIELD-DEPLOYED 5G PROOF-OF-CONCEPT SYSTEMS

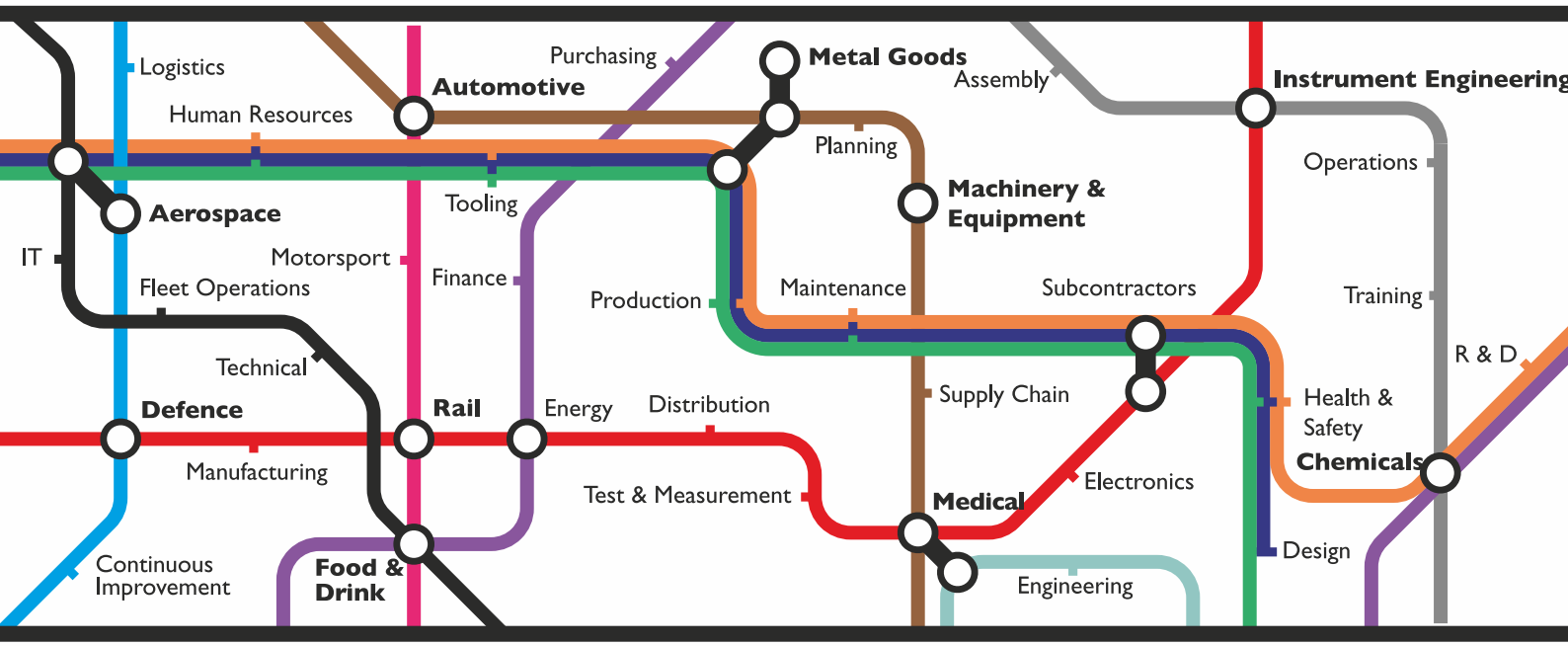
In the race to design next-generation wireless technologies, research teams must rely on platforms and tools that accelerate their productivity. Using the NI software defined radio platform and LabVIEW Communications, leading researchers are innovating faster and building 5G proof-of-concept systems to demonstrate new technologies first.

Accelerate your innovation at ni.com/5g

LabVIEW Communications System Design Software, USRP-2943R SDR Hardware

NATIONAL INSTRUMENTS™

The most comprehensive map for reaching UK manufacturing and engineering



Findlay Direct Marketing – providing the perfect route to new business

findlaydirectmarketing.com

Prospecting	**Data Cleaning**	**Emailing**	**Lead Generation**
Telemarketing	**Postal Marketing**	**Research**	**Data Enhance**

01322 221144

donna.shepherd@markallengroup.com
david.larner@markallengroup.com

fdm
findlay **direct marketing**

Much more than **box-ticking**

While achieving industry accreditation can be a challenge, it shouldn't simply mean box-ticking. By **David Davies**.

It's no secret that contract electronics manufacturers (CEMs) in the UK have been under increasing pressure in recent years to be global market leaders in terms of value and quality. Yet discussion around the challenges of industry accreditation when it comes to testing and quality assurance has often been sparse.

Accreditations, particularly in the case of SMEs, can be a difficult proposition. Even gaining 'standard' accreditations can present organisations with a steep learning curve and an even larger outlay in resources. Audits can disrupt normal business for days, if not weeks, and the pressures involved in meeting all specifications have the potential to push staff to their limits.

Yet accreditations are often nothing short of imperative for CEMs. Axiom Manufacturing Services operates across the aerospace, defence, medical and industrial sectors, so certifications such as ISO9001, ISO14001, AS9100 and ISO13485 are essential if it is to survive and compete – customers will often assume these standards are in place.

It's easy to see why manufacturers can treat accreditations as little more than a box-ticking exercise: a client wants a certain accreditation, or a competitor already has it, so they jump on the qualification bandwagon. This can lead to certifications being seen as little more than 'badges' to be collected, with the bare minimum done to attain them.

It's easy to see why manufacturers can treat accreditations as little more than a box-ticking exercise
David Davies

This is an inefficient, unsustainable and – ultimately – unbeneficial model approach.

Demonstrating quality

There are several reasons for this, chief of which is that accreditations aren't the best way to demonstrate quality. They may help spark initial interest in your organisation, but the best way to prove operational quality is through in house product

yield, reconciled delivery and quality performance metrics. Even if accreditation plays a big part in getting on a contract shortlist, customers will put more stock into processes and data. When showing a prospective client around Axiom's Newbridge facility and pointing out a sought after certificate of quality, the client noted 'That certificate got me here, but an audit of your organisation is what matters to me now'.

It's not only potential clients that will place more emphasis on what goes on within your walls than what hangs upon them; different divisions and teams within clients and suppliers will have their own priorities and requirements and it's unrealistic to think that merely complying with industry standards will allow you to satisfy them all.

Linked to this is the fact that, in the highly competitive CEM sector, accreditations alone cannot be your unique selling point; there will always be another company who is more qualified than you on paper. Even with its list of accreditations, Axiom has yet to sign a customer simply because of them – and that will not change anytime soon.

Detracting from normal business

The other issue with compulsively pursuing accreditations is that they detract from normal business activity. Axiom recently attained Nadcap AC7120 – a 'gold standard' within the aerospace industry. The factory audit lasted almost a week, but the entire process lasted around six months. Naturally, operations don't come to a standstill during this time, but if you're always applying for accreditations, it may result in resources being taken away from the important task of servicing your clients' needs while growing and developing your organisation.

The counter argument is that accreditations form part of a growth and development strategy. However, the key is not to view accreditations through the prism of perceived short term value, but rather as part of a long-term commitment to quality.

If you want to see quality or improvement in a specific area, this means moving away from checking off criteria, using instead accreditations as a guide to establish what long-term changes need to be made. Decisions on accreditations at Axiom entirely driven by the customer-technology roadmap.

The journey starts with an examination of the future for each customer market sector. Each department – from procurement to test – will outline how the demands are likely to change and this future mapping involves asking questions around important trends within each market sector.

Is a particular sector placing great importance on green credentials, for example? Does supply chain security need to be enhanced? Will there need to be greater levels of tractability? As customers require CEMs to share more of their risk management burden, CEMs must look to see how they can best prepare to do so.

There are more exact questions about potential accreditations. Do the required standards match where the product and technology is heading? Will this shifting base create a gap not currently accounted for? Can accreditation help to fill that gap?

It's then time to sit down with clients and experts to cross-check the expectations of where their sectors are headed. Ultimately, the question is 'will confirming our best practices with this accreditation improve our offering or can it improve competitiveness in the future?'.

Will any resulting improvements offer customers a sufficient return on investment on any outlay and disruption caused in the process. Only by answering these customer and market-driven questions can strategic decisions be made. If consensus is reached – and the processes involved in meeting certain accreditations align with identified trends or gaps –the accreditation process can begin.

With Nadcap, for instance, Axiom saw the aerospace sector was placing more importance on quality control; as a result, Nadcap would likely become more important in the future. After weighing up whether the best practices from the accreditation could help the long-term commitment to quality, Axiom met with customers and explained why pursuing the accreditation and implementing the processes would help to improve the long term offering. As a result, customers agreed to sponsor some of the activities involved in pursuing Nadcap AC7120.

"It's not only potential clients that will place more emphasis on what goes on within your walls than what hangs upon them."
David Davies

Working with a mentor

This is the best model for attaining such accreditation; working with a mentor or sponsor to help identify gaps and help the process run as smoothly as possible.

The key question is 'what help is available from your supply or customer base?'. If the answer is there isn't any and others don't see the long term mutual benefit of certain accreditations, then re-evaluate whether going through the process is worth it. It's crucial to realise the journey towards quality doesn't stop if an accreditation is secured, or if an application is unsuccessful.

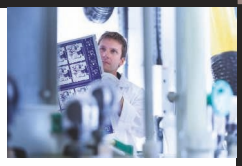
When quality is instilled from the top down throughout every layer of an organisation, it not only improves products, but also begins to meet many of the top industry standards, whether you are seeking accreditations or not. If the necessary long-term steps are in place, the accreditation you deserve will come. It's also important to recognise that encouraging the constant pursuit of quality creates a culture of stretching yourself. In the competitive CEM marketplace, what was great yesterday may only be good today and not even adequate going forward.

Author profile:
David Davies is managing director of Axiom Manufacturing Services

EuroTech Group plc awarded AS9100C certification

www.eurotech-group.co.uk

The EuroTech Group plc has been awarded AS9100C certification for the manufacture of PCBs at its UK manufacturing facility.



AS9100C is a standardised quality management system for the aerospace industry. It recognises excellence in operational practices and quality management, and reflects EuroTech's commitment to quality, safety and reliability.

"We are constantly looking for opportunities to improve because we know our customers need the best possible product, manufactured to the highest standard," commented Managing Director, David Douglas. "AS9100C is another step towards the ultimate goal: giving our customers the advantage in a competitive sector."

The EuroTech Group plc is based in Devon, and provides both onshore and offshore PCB manufacturing services, including a rapid turnaround service (lead times from 24 hours). For more information, call 01395 280100.

@: sales@eurotech-group.co.uk
✆: 01395 280100.

GradConn IP67 & 68 rated coaxial connectors

www.gradconn.com

Nautilus coaxial connectors tested to 5 meters underwater

GradConn recently announced the release of a new range of Nautilus panel mounted waterproof connectors which offer IP67 & IP68 protection from moisture and particle ingress mated and unmated.

Working with customers, GradConn developed interface connectors with internal seal and O-Ring, preventing ingress thru the inner contact and thru panel. Connectors are stringently and independently tested to IP67 & IP68 for both one metre and five metres underwater.

Nautilus connectors available are in SMA front and rear mount, RP SMA, TNC, RP-TNC & BNC. A huge variety of coax cable assemblies are available, with particular focus on Micro coax types such as Hirose, Murata and I-Pex.

Call Andy Hamlin to discuss your IP rated design projects today.

@: andy.hamlin@gradconn.com
✆: +44 (0) 208 2360005

Hi-Rel industries shift to jackscrew fixings

www.harwin.co.uk

Hi-Rel industries shift to jackscrew fixings for ultimate connection security

Robotics, Satellites & Motor Sport applications all benefit from Harwin's Datamate J-Tek in high shock and vibration environments

Harwin, the leading hi-rel connector and SMT board hardware manufacturer, has announced that several industries - satellites, robotics, motor sport – are now preferring to specify the company's 2mm pitch Datamate family of high reliability connectors with jackscrews, rather than latches or other fixing mechanisms, to ensure secure connection. As well as guaranteeing connector retention and signal integrity, the J-Tek jackscrew fixing is also being used to connect PCBs together in innovative configurations where space is at a premium.

Comments Scott Flower, Harwin's Global Product Manager for High Reliability Connectors: "As electronics becomes pervasive in harsh environments where high levels of shock and vibration are experienced, customers are demanding fixing solutions that provide the highest confidence levels.

@: bgreen@harwin.co.uk
✆: +44-2392 314 532

Hylec-APL launches new secure, maintenance-free DEDS Series

www.hylec-apl.com

Hylec-APL launches new secure, maintenance-free DEDS Series lockable IP66 IK10 Steel enclosures at ELEX 2016

IP66 and IK10 rated, protects exterior installations: cost effective solution for HVAC, lighting, and many other applications

Hylec-APL, the specialist supplier of electrical components, enclosures and rack systems, today announces its new DEDS Series of lockable, solid door steel enclosures specially designed to provide high-quality, secure, cost-effective protection for exterior electronic and electrical installations. The DEDS Enclosure Series is IP66 rated against water and dust ingress, meets IK10 specifications against impact and complies with IEC 60529 standards.

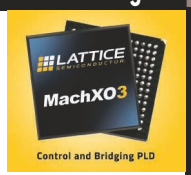
For superior robustness and longevity, DEDS enclosure housings are guaranteed against corrosion for three years and are fabricated from galvanised steel, powder-coated in grey RAL7035. DEDS Series enclosure back plates are manufactured from 2mm galvanised steel.

@: Mark@hylec-apl.com
✆: +44-1933 234400

Lattice Expands Award-Winning MachXO3™ Product Family

www.latticesemi.com

New Devices Offer 35 Percent Increase in LUTs and 15 Percent More I/Os, Continuing to Deliver on the Promise of Lowest Cost Per I/O FPGA



• Addition of largest density member, MachXO3-9400, delivers more I/Os and on-chip memory. • New features help reduce BOM cost, provide best value for I/O intensive, and high-resolution video applications. • Integrates support for improved security and reliability

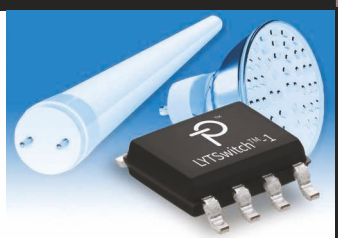
Lattice Semiconductor Corporation (NASDAQ: LSCC), the leading provider of customizable smart connectivity solutions, today announced the expansion of its award-winning MachXO3™ family of FPGAs with the addition of the MachXO3L-9400 and MachXO3LF-9400 devices available in multiple packages. Built in response to customer demand, the new devices bring expanded I/O and logic support for control PLD applications, while increased on-chip memory improves picture clarity for low cost video bridging in large monitor applications. The MachXO3 family targets the server, communications, industrial and display markets.

@: sherrie.gutierrez@latticesemi.com
✆: 408-616-4017

LYTSwitch-1 LED Driver ICs

www.power.com

LYTSwitch-1 LED Driver ICs from Power Integrations Reduce Complexity in Bulbs, Tubes and Ballasts up to 22 W



High PF, low THD LED driver ICs set a new standard in efficiency

Power Integrations (Nasdaq: POWI), the leader in high-efficiency, high-reliability LED driver ICs, today announced its LYTSwitch™-1 single-stage, non-isolated, buck topology LED driver IC family. Featuring a very compact footprint, the IC enables the design of LED bulbs and tubes with high constant-current accuracy while using a minimum number of components. A novel driver algorithm ensures high power factor (PF) and low total harmonic distortion (THD) while maintaining very high efficiency.

@: peter.rogerson@power.com
✆: (408) 414-8573

OMC's backlights now available with sunlight-visibility layer

www.omc-uk.com

OMC's backlights now available with sunlight-visibility layer

OMC, the pioneer in optoelectronics, today announced that its ProfiLED coloured LED backlights are available with a proprietary active backing layer that enables them to be viewed in much brighter ambient lighting conditions. This is especially relevant for makers of portable instrumentation which is used outdoors.

Complementing a standard product range which numbers over 250 different sizes, OMC can turn around bespoke-shaped ProfiLED backlights is as little as five working days with little or no setup costs. The company claims that this is often the only viable option for small to medium volume (fewer than 10,000 pieces) requirements. The high-visibility option – termed Royale Reflector – incorporates an active backing layer in the backlight's back reflector, which enhances contrast in high ambient lighting conditions, ensuring that the display remains visible.

@: Heathw@omc-uk.com
✆: +44-1209-215424

Smiths Connectors' high reliability products

www.ttiinc.com

Smiths Connectors' high reliability products now available Europe-wide through TTI

Hi-rel Hyperboloid connector range now in stock

TTI, Inc., a world leading specialist distributor of electronic components, now offer customers across Europe Smiths Connectors' world-renowned high reliability, high performance product range following a distribution deal between the two companies. The new agreement builds on a successful partnership between Smiths Connectors and TTI France, formerly Mateleco.

The partnership will provide TTI the availability of high reliability connectors featuring Hypertac® hyperboloid contact technology which delivers superior performance in demanding environments where performance and safety are critical.

Comments Ronald Velda, Supplier Marketing Director Europe - Connectors and Electromechanical, TTI, Inc.: "Smiths Connectors' high reliability solutions are field-proven in many applications and will be especially interesting for our European customers in our key focus markets of industrial, defense & aerospace and mass transit. We are delighted to extend our distribution to cover the whole of Europe following a successful engagement in France."

@: sales@de.ttiinc.com
✆: +49 8142 6680 – 0

ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

FIRST IN THE FIELD

KEYSIGHT AND ADI COMBINE BENCHTOP PRECISION WITH LANDMARK INNOVATION.

Multifunction; lightweight; MIL-rugged; with lab grade precision: Keysight Technologies, enabled by ADI, is bringing new possibilities in electronic design and test, with FieldFox—the industry's first integrated portable analyzer with extended frequency ranges to 50 GHz.

#ADIahead

SEE HOW ADI MEASURES UP

analog.com/AWP/KEYSIGHT