March/April 2015

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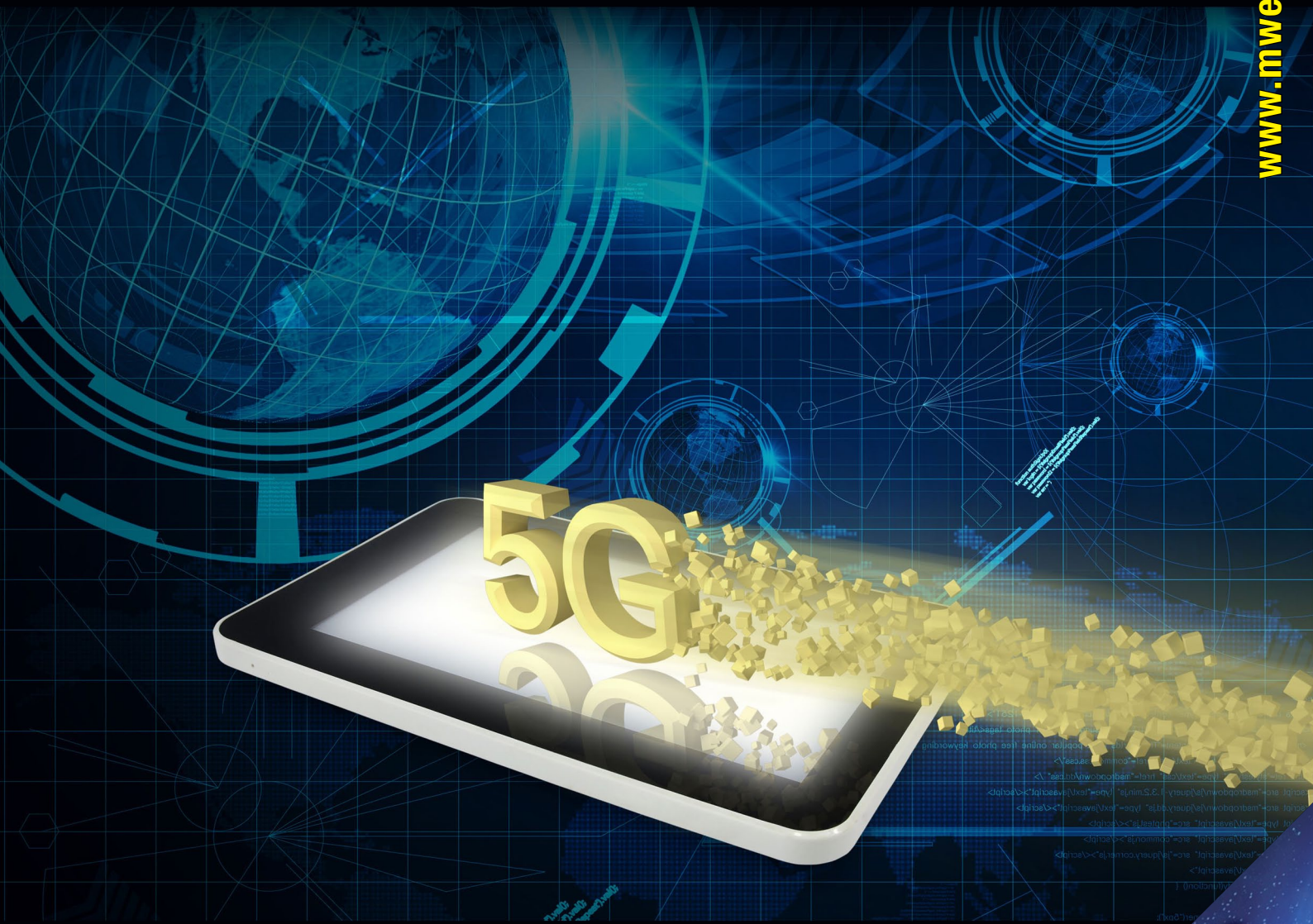
www.mwee.com

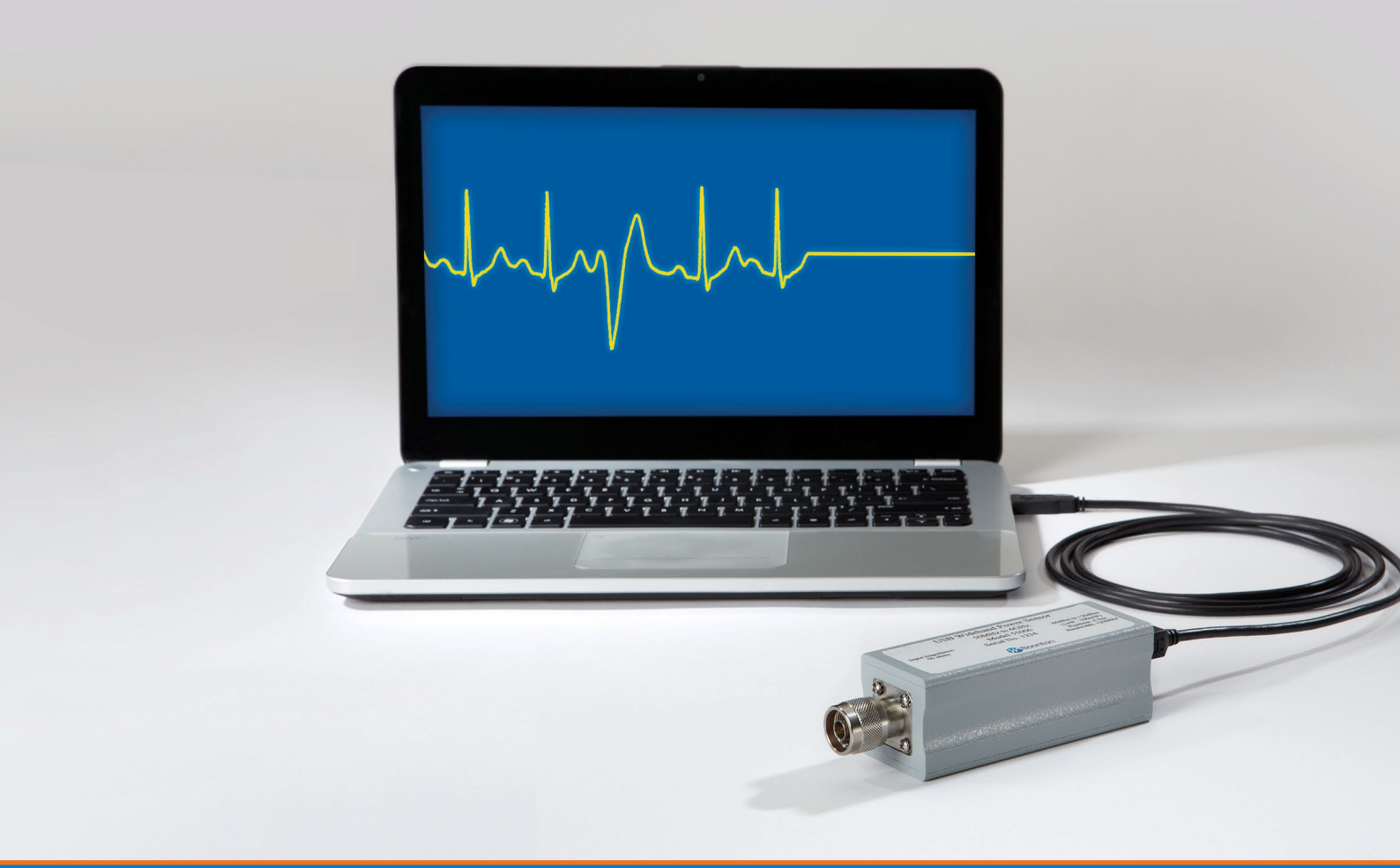


High Frequency CMOS

Emerging Wireless

The European journal for the microwave and wireless design engineer

Missing a Pulse Can Be Deadly.



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IoT revolution just getting started

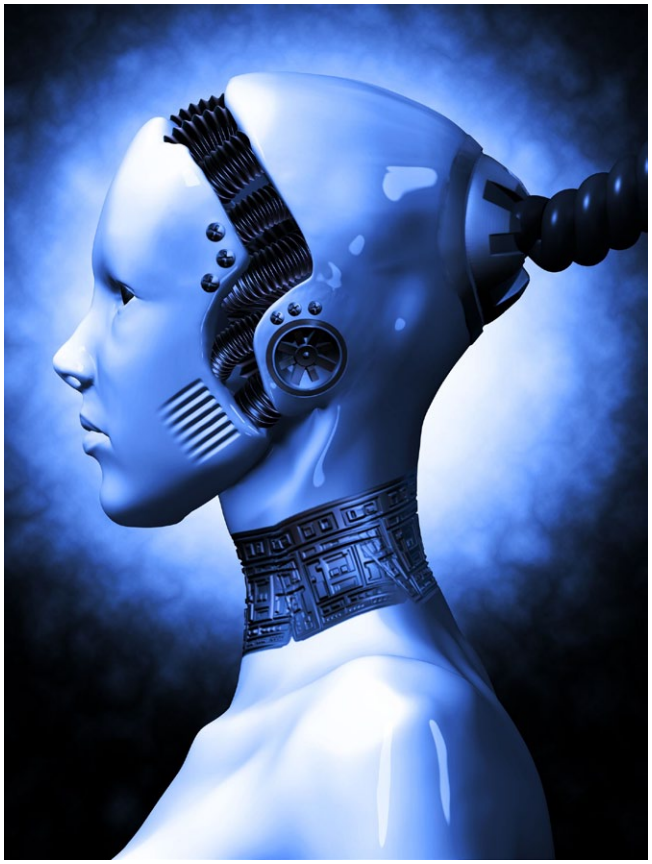
The Internet of Things or IoT has received a lot of press, but in reality the IoT is a nascent technology that has little grounding in the real world at the moment. It promises to change the way we work and live from enabling smart factories through to enabling monitoring and control of every machine on the planet.

However, one big issue is that a pervasive communications network is required before IoT takes off in a meaningful way, at least for the consumer. Whether LTE or LTE-A can provide the infrastructure required at the right cost or whether specialist networks need to be built remains to be resolved. The next step is 5G, and though this next generation communications standard is still in the research phase, the concept outline currently looks to integrate the needs of the IoT. It appears that a key enabler here will be a complete implementation of network virtualization. Network virtualization is also just beginning to gain traction, though not at the level required for 5G.

So for the IoT to become reality, the network infrastructure will need to put in place. Also, the technology will need to be standardized, much like 2G, 3G and 4G have required to be successful globally. To this end, we have just witnessed the launch of the Wireless IoT Forum, which aims to support and promote the deployment of the Internet of Things worldwide as well as to drive the widespread adoption of wireless wide-area networking technologies in both licensed and unlicensed spectrum. The forum will work with key stakeholders from across the value chain to agree requirements that inform and accelerate standards development and deployments.

One area where the IoT is heating up is in the Enterprise. Here potential cost savings are a key driver. For example, IBM has announced that it will invest $3 billion over the next four years to establish an Internet of Things (IoT) unit, and that it is building a cloud-based open platform designed to help clients and ecosystem partners build IoT solutions. IBM has pioneered work based on practical applications of IoT in the enterprise that has led to a broad set of systems, ranging from water management to optimizing retail and customer loyalty to alleviating traffic congestion. The company claims to lead in enterprise IoT implementations that securely combine and analyze data from a wide variety of sources.

Also recently, Microsemi entered into an agreement to acquire Vitesse for its carrier, enterprise and industrial-IoT markets. In another development, Telensa, a leader in smart street lighting, and Senaptic, which provides end-to-end systems for smart cities, have merged. The combined company will operate under the name Telensa, building on its reputation as a company with real-world, large-scale experience in private networks that monetize opportunities in the IoT space.



Lastly, SIGFOX, and early IoT pioneer continues to roll out its network with the latest announcement that NarrowNet, a network operator launched by Kaisaras Group will become the exclusive SIGFOX network operator in Portugal. Under the agreement, NarrowNet is deploying the SIGFOX network and developing the Portuguese IoT ecosystem for device manufacturers and service providers. It will offer IoT connectivity nationwide this year. During the rollout, NarrowNet will showcase a variety of projects that are being offered with the SIGFOX network in other countries.

The SIGFOX global network has been deployed in France, the Netherlands, the U.K. and Spain, as well as in major cities in other countries.

NarrowNet CEO Enrique Zorzano said the partnership is expected to spur Portuguese entrepreneurs, engineers and others to create new IoT applications and projects that are easily justified by SIGFOX's extremely cost-effective connectivity.

"Our motivations for joining the SIGFOX network include tapping into Portugal's deep pool of talent for developing new technologies, and providing IoT services to all segments of Portuguese society, including those who cannot afford broadband services," Zorzano said. "Moreover, we foresee an intense collaboration with major telecommunication companies to provide M2M services in those areas where they are unavailable, as well as to help them to extend the range of connectivity services they offer. Soon we will be happy to announce the integration in NarrowNet's project of well-known Portuguese infrastructure companies."

The IoT has caught the imagination of the technology world and as a nascent technology faces many hurdles. Potentially, the IoT could enable unprecedented control and automation of the world and resources as well as change the way we interact with everyday machines from cars to fridges. It will also optimize healthcare and enable large corporations to micro-manage their assets and significantly reduce costs. The first steps towards this future have been taken, now we need standards and a pervasive communications infrastructure.

By Jean-Pierre Joosting
Editor MWEE

Wireless IoT Forum to drive standards, counter fragmentation

The launch of the Wireless IoT Forum aims to support and promote the deployment of the Internet of Things worldwide as well as to drive the widespread adoption of wireless wide-area networking technologies in both licensed and unlicensed spectrum. The forum will work with key stakeholders from across the value chain to agree requirements that inform and accelerate standards development and deployments.

The Wireless IoT Forum will strive to ensure market representation for companies building the ecosystem and work to promote and market the benefits for the complete ecosystem including: fixed and wireless network operators, infrastructure providers, app developers in utilities, government and specialist SMEs, semiconductor vendors, radio technology providers, module developers, systems integrators and vertical end-users.

"The wireless Internet of Things is bringing connectivity and control to an order of magnitude more devices, however there is a very real risk of fragmented standards and technologies holding back the development of the market," said William Webb, CEO of the Wireless IoT Forum. "There has also been a tremendous amount of work done in the IoT world across a wide range of technologies. As in the cellular world, the success of this will lie in the promotion of open standards."

"Successful wireless technologies have always been founded on interoperability, open standards, and a focus on the demands of end-users," said Will Franks, Chairman of the Wireless IoT Forum.

www.wiotf.org

Patent boosts mobile upload speeds by tenfold

A patent held by Universidad Carlos III de Madrid enables a jacket to increase the speed at which mobile devices can upload content by by tenfold. The aim of the patented device is to increase the flow of the link's digital data upload in mobile communication systems, thanks to the intelligent integration of numerous antennas in a piece of clothing that the user does not even notice. The prototype that has been developed has just one interface for its connection to the terminal whose capacity the user wants to increase.

This development is part of one of the main lines of research in telecommunications: the development of 5G, the fifth generation of mobile communications. This objective entails a great challenge: in five years time, to multiply by 1,000 the capacity of the current mobile communications wireless networks, according to one of the researchers who has developed this patent, Ana García Armada, of the Communications research group at UC3M.

With the "technological revolution" that 5G will bring, high speed data uploading will have to be offered to the network's users, and this is precisely the focal-point of this innovation, points out García Armada.

Right now, the patent, which consists of a group of antennas developed using textile technology, will allow for "a tenfold increase in the uploading speed of a normal mobile terminal" explains another of the inventors of this device, Eva Rajo, of the Applied Electromagnetism Research group at UC3M.

https://youtu.be/1DJ_841aktA

MACOM and Kaiam demo 400G capability

MACOM is consolidating the high speed semiconductor content in 100G/400G transceivers, optimizing the chips to provide highly differentiated performance, power, size and cost benefits. The MAOM-002304 quad directly modulated laser (DML) driver and M37049 quad CDR have been demonstrated in Kaiam's 400G over single-mode fiber module at OFC 2015. These ICs have the lowest power in their class, which is critical for a 400 Gbs multi-channel system.

Kaiam's module is compatible with a CDFP connector and provides 50% higher density per 100G than QSFP28. While 16x25G is the IEEE standard proposal for multimode 400G, this cliams to be the industry's first demonstration of a single-mode 16x25G system. The module is enabled by Kaiam's unique laser packaging technology that has been deployed for 40G and 100G. The approach is aimed at leading edge 100G and 400G applications.

www.macom.com
www.kaiam.com

SIGFOX, NarrowNet roll IoT network in Portugal

SIGFOX and NarrowNet, a network operator launched by Kaisaras Group, have announced that NarrowNet will become the exclusive SIGFOX network operator in Portugal. Under the agreement, NarrowNet is deploying the SIGFOX network and developing the Portuguese IoT ecosystem for device manufacturers and service providers. It will offer IoT connectivity nationwide this year.

The SIGFOX network is a cost-effective and energy-efficient, eliminating the cost and energy-use barriers to widen implementation of IoT systems by providing small-message communication and greatly extending the battery and service life of connected devices.

NarrowNet CEO Enrique Zorzano said the partnership is expected to spur Portuguese entrepreneurs, engineers and others to create new IoT applications and projects that are easily justified by SIGFOX's extremely cost-effective connectivity.

www.SIGFOX.com
www.narrownet.pt

NI acquires BEEcube to build on 5G leadership

NI has announced its acquisition of BEEcube, a technology innovator and supplier of high-performance FPGA prototyping and deployment products for advanced wireless research, wireless infrastructure and military/defence applications.

Charles Schroeder, NI Director of RF Communications says, "NI and BEEcube share a common philosophy and vision of platform-based design, and we believe the combination of the two companies will strengthen our leadership position as 5G progresses toward commercialisation."

Chen Chang, BEEcube's Founder and CEO, added, "For many years, BEEcube has been at the forefront of technology innovation in telecommunications applications. By joining NI, we will have the resources to continue to drive 5G research and provide our customers solutions which enable infrastructure deployment on a global scale."

www.ni.com
www.beecube.com

WDM spec for intra data center connectivity

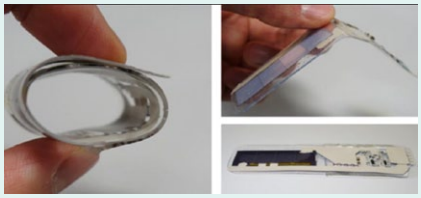
RANOVUS Inc., a provider of multi-terabit interconnect solutions for data center and communications networks, has announced the OpenOptics MSA publication of the industry's first foundational Wavelength Division Multiplexing (WDM) specification for an interoperable 100G WDM standard for 2 kilometer reach, addressing the challenges with the explosive growth in data center connectivity requirements.

The WDM specification brings together 1550 nm WDM laser and silicon photonics for QSFP and optical engine based solutions, enabling lowest-cost, highest density, and highest bandwidth with single mode fiber pair connectivity, to enable data centers to use up to 32 or more channels per fiber strand.

The OpenOptics MSA specification summary and a membership application form for interested companies are now available.

www.OpenOpticsMSA.org
www.ranovus.com

Thin light-powered Bluetooth LE beacons wrap around objects



Fujitsu Laboratories Ltd has announced a Bluetooth LE beacon weighing only 3 grams and only 2.5 mm thick, that does not require battery replacement or any other maintenance. The beacon is flexible enough to be wrapped around round objects, corners, and curves and it is solely powered by an integrated solar cell.

Previously, beacons that did not require battery replacement needed power-supply components, such as power-management ICs and secondary batteries, as control circuits to ensure adequate power on activation. These components, which are relatively thick and occupy a large area, make the beacons themselves rigid and large.

Such thin beacons could be attached to fluorescent bulbs in a ceiling, or to the surface of an LED light, hence doubling lights as information points, for guidance or any other purpose.

For this flexible autonomous beacon, Fujitsu Laboratories has developed power-control technology that temporarily deactivates the power monitor once it has detected that enough energy has been accumulated. The saved power makes it possible to supply the power needed to activate the wireless-communications module using a small storage element connected to a solar cell, only one-ninth the size of those used with previous technologies, according the Japanese lab. Reducing the power consumed just before starting communications also has the effect of reducing voltage fluctuations when power is being used, obviating the need for a power-management IC.

www.fujitsu.com

End-to-end encryption app for the masses

When Facebook bought WhatsApp last year, Swiss company Threema saw millions of secure messaging WhatsApp users flee to adopt its Threema secure messenger, being cautious about Facebook's endeavours.

Mostly, users feared for their privacy, and to this day "Threema" is the most downloaded paid app in Apples App Store, claims the Swiss company.

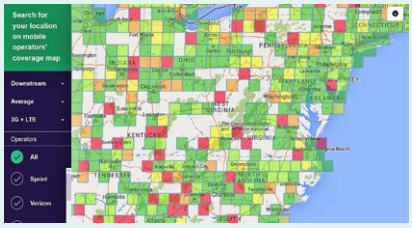
While a number of companies claim to offer end-to-end encryption, some imply that one end is their secure server, which really means that users' messages can be read by the company providing the encryption service. Now with "Threema Gateway", the Swiss company wants to give the same ease of use and security in communication to start-ups and other small and medium sized companies, providing an API that allows companies to encrypt messages to their employees and customers in order to communicate without privacy or security concerns — no matter what software they use to send messages.

Based on the reliable open source library NaCl, Threema is claimed to be the first crypto messenger providing an end-to-end encryption API.

It supports the forwarding of encrypted emails, confidential customer communications, mTAN, OTP (One-time passwords), alarms for emergency services, secure password exchange, and secure news channel for internal company communications, just to name a few features.

https://threema.ch

Fastest mobile Internet in Denmark, Singapore and Switzerland



The fastest mobile Internet connections in the world are found in Denmark (22.3 Mbit/s), followed by Singapore (16.9 Mbit/s), Switzerland (16.6 Mbit/s), Norway (14.8 Mbit/s) and Korea (13.0 Mbit/s).

The result is based on measurements by ordinary mobile phone users using Netradar, a free mobile application to analyze the quality of mobile connections and devices. When using the application, users are presented with data about the quality of their connectivity. Simultaneously, this data is uploaded anonymously to the Netradar database to be used in public coverage maps and further research. The impartial Netradar application is developed and globally run by Aalto University in Finland.

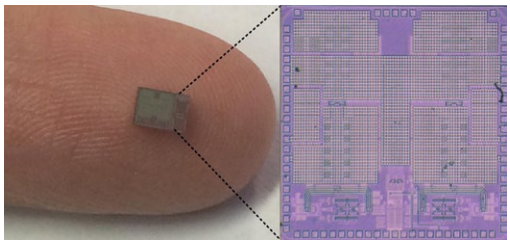
"Several factors explain why mobile phone users reach different Internet speeds in different countries. Mobile Internet speed depends not only on mobile network operators and the congestion of the networks, but also on used devices, speed limitations in the subscriptions, user's distance from the operator's antenna, landscape, and available radio technologies," says Professor Jukka Manner, leader of the Netradar project at Aalto University.

The free Netradar app measures mobile network quality in terms of download and upload speed, latency and signal strength, network problems and the performance of individual brands of smartphones and tablets. Users can download the Netradar app for Android, iOS, Windows Phone, Blackberry, Nokia X, Meego, Symbian and Jolla/Sailfish.

www.netradar.org

Nanoscale IC may double radio frequency data capacity

Full-duplex radio ICs that can be implemented in nanoscale CMOS to enable simultaneous transmission and reception at the same frequency in a wireless radio have been developed by a team of Columbia Engineering researchers.



Up to now, this has been thought to be impossible: transmitters and receivers either work at different times or at the same time but at different frequencies. The Columbia team, led by Electrical Engineering Associate Professor Harish Krishnaswamy, is the first to demonstrate an IC that can accomplish this. The researchers presented their work at the International Solid-State Circuits Conference (ISSCC) in San Francisco.

"This is a game-changer," says Krishnaswamy. "By leveraging our new technology, networks can effectively double the frequency spectrum resources available for devices like smartphones and tablets."

Consequently, the ability to have a transmitter and receiver re-use the same frequency has the potential to immediately double the data capacity of today's networks. Krishnaswamy notes that other research groups and startup companies have demonstrated the theoretical feasibility of simultaneous transmission and reception at the same frequency, but no one has yet been able to build tiny nanoscale ICs with this capability.

"Our work is the first to demonstrate an IC that can receive and transmit simultaneously," he says.

50 GHz Ge waveguide modulator demonstrated

At the OFC 2015 global conference and exposition for optical communications, imec, its associated lab at Ghent University (Intec), and Stanford University have demonstrated a compact germanium (Ge) waveguide electro-absorption modulator (EAM) with a modulation bandwidth beyond 50 GHz.

Combining state-of-the-art extinction ratio and low insertion loss with an ultra-low capacitance of just 10 fF, the demonstrated EAM marks an important milestone for the realization of next-generation silicon integrated optical interconnects at 50 Gb/s and beyond.

Future chip-level optical interconnects require integrated optical modulators with stringent requirements for modulation efficiency and bandwidth, as well as for footprint and thermal robustness. In the presented work, imec and its partners have improved the state-of-the-art for Ge EAMs on Si, realizing higher modulation speed, higher modulation efficiency and lower capacitance.

www.imec.be

Public Wi-Fi hotspots to hit 7.8 million in 2015

According to ABI Research, worldwide public Wi-Fi hotspot deployments have reached a total of 5.69 million in 2014, and will grow at a CAGR of 11.2% between 2015 and 2020.

This includes public Wi-Fi hotspots deployed by mobile and fixed-line carriers as well as third-party Wi-Fi service providers. The marketing research firm expects the number of worldwide carrier Wi-Fi hotspots will reach 13.3 million in 2020.

"Wi-Fi hotspot deployments have been surprisingly robust; more and more public locations have signed up on a free or 'freemium' basis. This has discouraged the participation of third-party operators in some locales," comments Lian Jye Su, Research Associate at ABI Research, "because there is a need for the upgrade of service, coverage and legacy equipment, which is only beneficial for operators with significant economies of scale."

www.abiresearch.com

Wireless applications: OS consideration for Zynq all programmable SoCs

By Yuan Gu, Sr. Business Manager, CBU Wireless, Xilinx

With the explosive increase in wireless data throughput, there is tremendous pressure on improving digital signaling processing technology and radio equipment. Currently, the focus is on 4G LTE. The 4G networks are being deployed on a large scale all over the world. And we are now seeing the early research and development into 5G networking, which targets to have more than 1000 times the data capacity than 4G networks. This emerging technology development drives new and evolving requirements for system vendors: better system integration, improved system performance, lower system BOM cost, increased design flexibility and faster time to market.

Traditional ASIC-based devices support hardware solutions that may meet power and cost goals, but may suffer very high NREs (non-recurring engineering costs), lack of flexibility, and very slow time to market. In order to meet these requirements and address these challenges, Xilinx introduced the All Programmable SoC (APSoC) architecture and successfully implemented it in the Zynq®-7000 product family.

Based on the Xilinx APSoC architecture, Zynq-7000 devices enable extensive system level differentiation, integration and flexibility through hardware, software and I/O programmability (figure 1). Since its announcement in 2011, Zynq-7000 devices have been adopted in a wide range of markets such as communications, data centers, automotive, industrial and aerospace and defense. For the communication market, especially for wireless applications, Zynq-7000 devices provides key unique advantages: Its integrated programmable logic (PL) is highly optimized for digital signal processing; and its ARM® Cortex™ A9 based processing subsystem (PS) enables the very effective implementation of control functions of typical wireless equipment such as remote radios and wireless backhaul units.

When architecting a wireless application based on Zynq APSoC devices, it is necessary to select the operating system

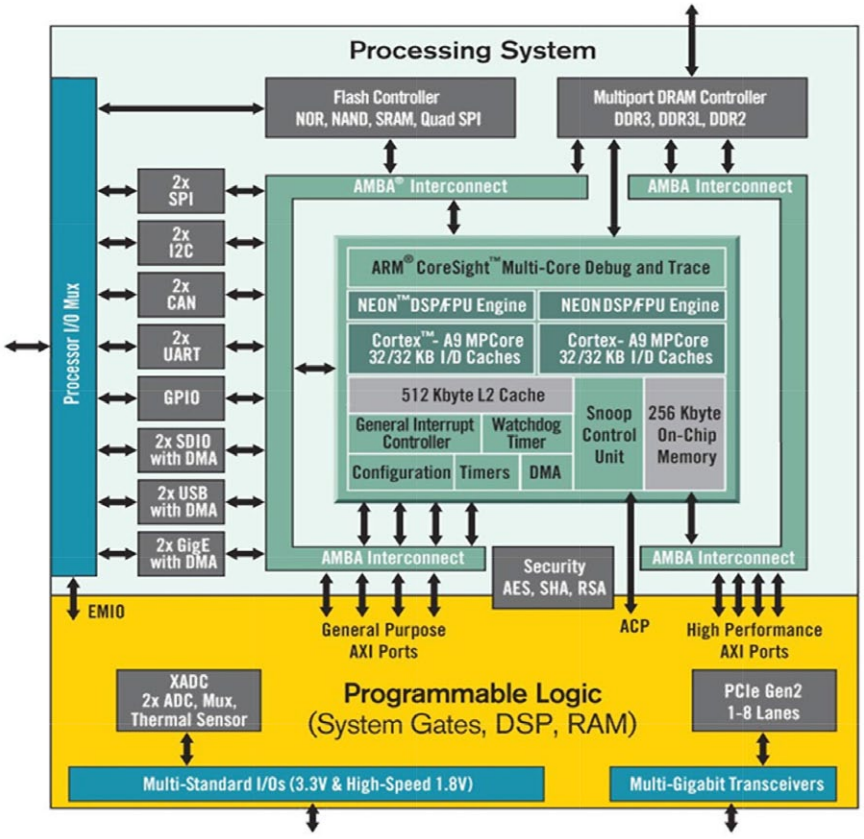


Figure 1: Zync-7000 all programmable SoC architecture.

that meets the needs of the application. In order to do so, there are several key factors associated with different wireless applications that need to be considered:

- Carrier grade operations: System reliability (99.999%) is a common requirement for carrier grade systems. It defines the amount of uptime necessary for the unit. Operationally, it means the support for system features, such as cold/warm restart, fault monitoring, detection and handling, and redundancy.
- Real time processing: Real time means a predictable response time, not just "very fast". A remote radio has different real time requirements compared to wireless backhaul processing. Radio equipment is signal processing heavy and the processor supporting signal processing must meet stringent timing budgets.
- Diagnostics: To support in-field and post-mortem diagnostics, considerable performance measurements and logs need to be collected and stored. Hence some key indexes that are important for wireless application can be traced and managed such as performance measurements and statistics, CPU utilization and fault monitoring, OS task switching, and event history, etc.
- Tools and protocol integration: A comprehensive integration of debug and diagnostic environment, and some specific network protocol stacks provided by some OS venders could facilitate the designer to develop and maintain an efficient system.

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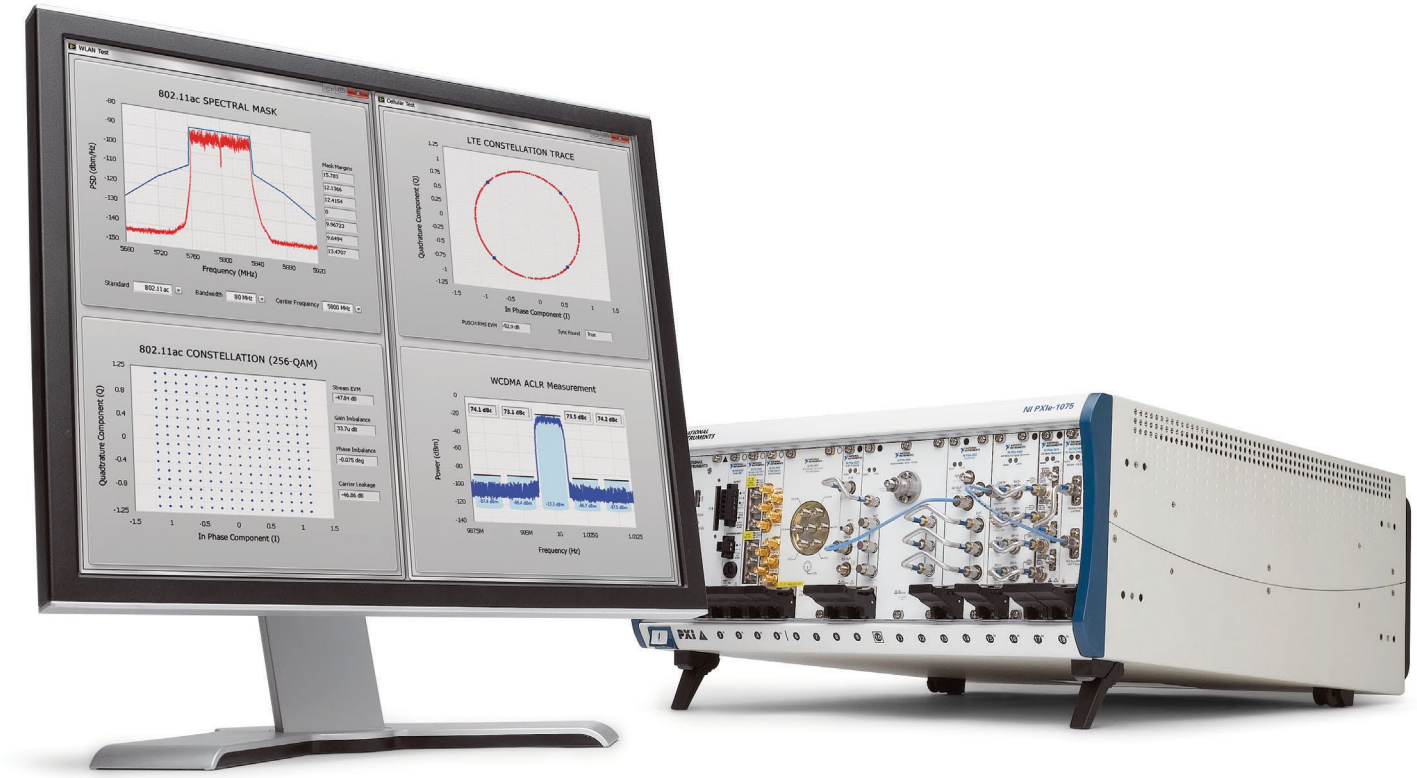

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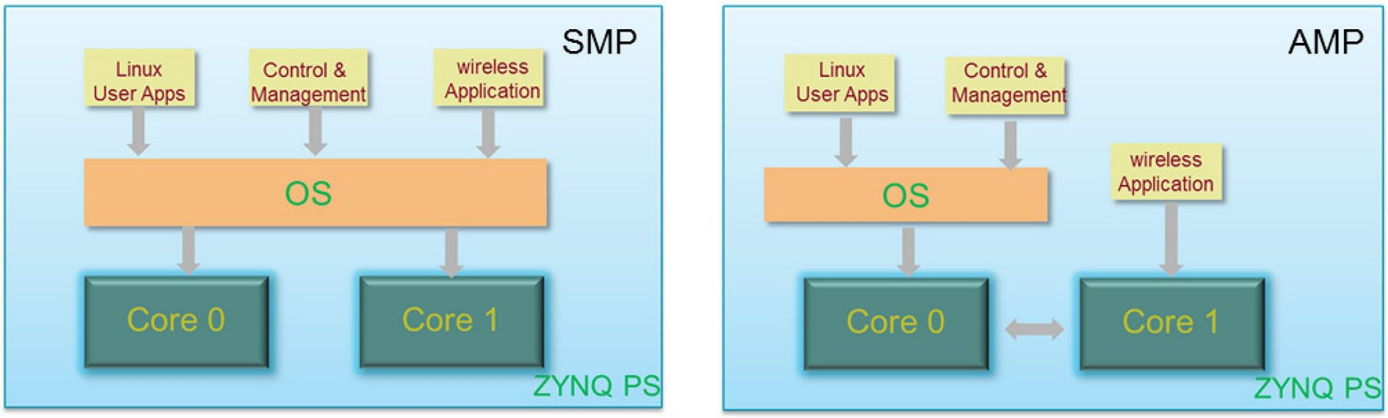


Figure 2: SMP versus AMP.

Zynq SoC integrates two ARM Cortex A9 cores. Software architects will need to make a selection between supported multi-processor architectures: SMP (Symmetric Multi-Processing) or AMP (Asymmetric Multi-Processing). As shown in Figure 2, SMP is a system architecture where two or more identical processors have shared resources with a single OS instance running. This architecture theoretically treats all processors equally under the same OS instance. On the contrary, AMP architecture treats processors separately – with or without the OS instance and unaware of each other. The core without an OS running may be executing a piece of micro code is regarded as "bare metal" instance.

In general, SMP provides a unified OS platform to higher-level applications. A software architect does not need to consider resource sharing between two cores and inter-process communications when building an application on top of the OS. Furthermore, there is performance overhead for SMP which could impact the performance of time-critical wireless applications. Comparing SMP with AMP, AMP's light weight software with an OS instance has little to no overhead but it needs careful custom software design of shared processor resources and inter-processor communications.

Several key wireless applications can be implemented very efficiently in one of the Zynq APSoC devices; including radio and wireless backhaul. Each wireless application has different performance requirements and needs the OS to support different features. The radio application is a good case in point where Zynq can be used to implement a fully-integrated, hardware and software solution encompassing all the digital front-end processing.

The radio digital front-end application is the major part of a typical Remote Radio Head (RRH) in the 4G wireless network. The processing requirements here can be split into the signal processing and the control processing. In the signal processing domain, Zynq can be used to implement high sample rate filters for digital up-and-down conversion, Crest Factor Reduction (CFR) and Digital Pre-Distortion (DPD). In the case of DPD, it needs to utilize both Zynq PS and Zynq PL.

DPD processing can be broken down into the high-speed data path and the update path. The update path is used to update the filter bank coefficients periodically and is well-suited to being implemented in an ARM Cortex A9 core. Typically the coefficient update must be completed within several to 10's of milliseconds. Because the arithmetic complexity of the calculations, the A9 core and embed NEON SIMD vector computing unit may be used to meet the required high performance. In addition, the Zynq PL can also support hardware acceleration of processor clock cycle intensive functions and hence the Zynq PL, ARM A9 core, and the NEON co-processor may all be used collaboratively.

The control processing side of radio is typically used for initial radio calibration, configuration, alarms, scheduling, and message termination from the networks. This in a radio application is typically not high performance and as such is easily able to be managed with a single ARM A9 core in Zynq-7000 SoC.

Selecting the appropriate architecture for supporting both the DPD application and control processing application is highly important as it will define the overall performance, reliability, and ease of maintenance.

A common architecture selected for wireless Radio application is AMP mode. This devotes a full ARM core to DPD processing when it is running in bare metal mode and provides more computing head room to meet time requirement of DPD coefficient updates. All other applications such as control and OAM run on the second OS controlled ARM A9 core. In this architecture, since the OS only has control of one of two ARM cores, an inter-processor channel has to be established between the applications in the two separate cores, such as using the OCM (On Chip Memory) or shared memory. This is especially important for some key control applications, for example, the application for monitoring the DPD module health. Such Inter-Process Communication (IPC) solutions are none standard and have to be developed separately in the AMP mode.

The SMP architecture is very straightforward with a single OS instance controlling both ARM cores and thus all applications. IPC, debugging and the supporting tool chain are all under the same OS. In order to ensure resources are devoted to DPD application, specific techniques such as core affinity and interrupt shielding can be applied in the software application. In the former case, the DPD application will be running on one core only, potentially no other tasks sharing resources (other than OS scheduler overhead). In the latter case, interrupt services (other than those triggered by the DPD application) are directed to the second core. Thus resources are fully utilized by the DPD application.

Based on the facts stated above, the Zynq APSoC is the ideal platform to support either AMP or SMP architecture. As shown in Figure 3, Zynq

integrates two ARM core processors, 12.5 Gb/s SerDes and 500 MHz+ DSP with higher reliability, and provides whole digital front-end functionality such as DPD, CFR, DUC/DDC and CPRI/JESD interfaces. This solution removes the need for interfaces between the processors and separate FPGA, simplifies the PCB design.

The migration from discrete multi-chip solutions to a single-chip integrated solution on the Zynq platform is fairly straightforward. Xilinx provides a smooth migration path to Zynq devices with comprehensive hardware and software solutions. This includes a DSP (digital signal processing) IP library for the DUC, DDC, CFR and DPD. Additionally, multiple OS solutions are supported including device drivers, boot loaders, BSP template and common tools. With a successful migration onto the Zynq platform, this solution can significantly increase the system performance, save total power consumption and lower the BOM cost.

Throughout the article, we discuss key considerations of operating system selection for wireless applications, the implementation architecture and considerations for those (AMP vs SMP),

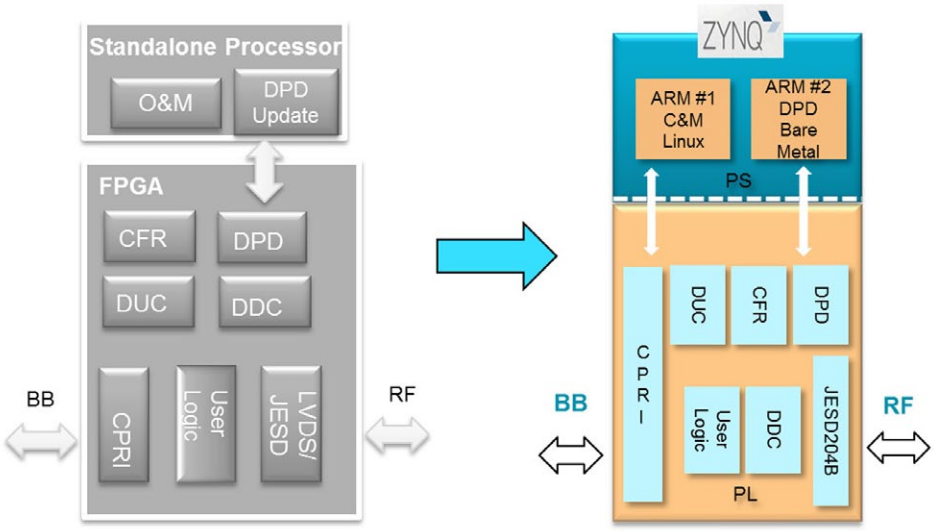


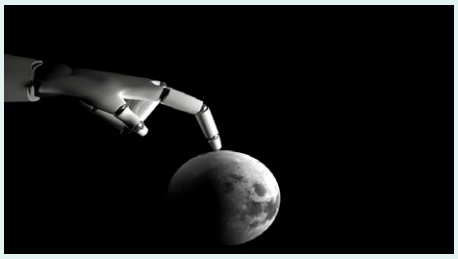
Figure 3: Migration from discrete solution to Zync solution.

and the direct application of those on a Xilinx Zynq-7000 All Programmable SoC device. In conclusion, these advanced devices from Xilinx enable infrastructure equipment designers with improved performance, increased system integration, lower total BOM cost and lower total power, high reliability and improved time to market while also enabling full programmability of both software and hardware. Designers can now not only develop equipment faster, but also continue to provide updates to the field long after the equipment has been deployed, removing the risk involved with devices such as ASSPs and ASICs.

Silicon Labs and ARM to collaborate on driving mbed IoT device platforms

Silicon Labs is collaborating with ARM to define and deliver the first power management application programming interfaces (API) for ARM® mbed™ platforms. Adding power management APIs to mbed will bring energy efficiency to standards-based solutions optimized for ultra-low-power, battery-operated connected devices. The new APIs will enable the mbed community of more than 100,000 registered developers to optimize their mbed-enabled ARM Cortex®-M architecture-based designs for the utmost energy efficiency and longer battery life.

In addition to enabling developers to manage processor and peripheral states, the mbed power management APIs are designed with real-world, low-energy application scenarios in mind. A new feature exposed by the APIs on Silicon Labs' EFM32® Gecko microcontrollers (MCUs) automatically determines and enables the optimal sleep mode based on the MCU peripherals in use, which can dramatically reduce system-level energy consumption. Low-energy optimization is achieved by enabling I/O operations to be executed in the background and by allowing those operations to continue even while the



MCU core is in sleep mode or during other processing tasks.

The automatic selection of the optimal sleep mode, combined with low-energy, autonomous MCU peripherals, enables developers to significantly reduce the energy consumption of their IoT applications with minimal effort. For example, energy profiles of an application updating a clock display every second on a memory LCD — a common use case for IoT devices — have shown a current consumption reduction from 1.03 mA to 0.100 mA.

"The new power management APIs for ARM mbed make it possible for developers to create applications that take advantage of the low-power features of ARM Cortex-M based microcontrollers," said Zach Shelby, vice president, IoT business marketing, ARM. "This is an important step toward enabling full energy-awareness in IoT devices, and it is one of the key building blocks for mbed OS that is due for public release later this year."

Silicon Labs plans to provide mbed-enabled EFM32 Gecko starter kits in April 2015. Initial platforms supporting mbed will include the Wonder Gecko, Leopard Gecko, Giant Gecko and Zero Gecko starter kits. Developers with existing EFM32 kits will be able to mbed-enable their hardware through a simple software update.

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The next gallium nitride wafer: GaN-on-Diamond

By Felix Ejeckham, Element Six Technlogies, et al

Introduction

Transistor engineers have long struggled to surpass thermal barriers in achieving the intrinsic performance limits of Gallium Nitride (GaN); typically, when a GaN device delivers very high RF power and efficiency, lifetime degrades as heat is unable to evacuate the device's channel [1].

In 2003, the authors [2] introduced an idea for the first time that heat could most efficiently and effectively be extracted from a Gallium Nitride (GaN) transistor's channel (the primary heat-generating layer) by replacing GaN's entire host substrate – such as Silicon (Si) or Silicon Carbide (SiC) – with a directly deposited CVD diamond substrate. The core of the idea stems from the novel combination of two key elements: a) that diamond is the commercial world's most thermally conductive material – reaching 4-5X greater thermal conductivity (1000-2000 W/mK) than the next best semiconductor substrate, silicon carbide (SiC), and b) that diamond could be grown to within hundreds of nanometers of the GaN channel enabling effective thermal conduction. Table 1 compares the physical properties of various materials with diamond. Note the strength of diamond's thermal conductivity and electrical resistivity compared to other popular materials.

Simulations, modeling, and experiments indicate that GaN-on-Diamond could enable GaN to perform like never before – operating at reduced channel temperatures, and delivering about three times more areal power density than state-of-the-art GaN-on-SiC RF power amplifiers (PAs) [3-7].

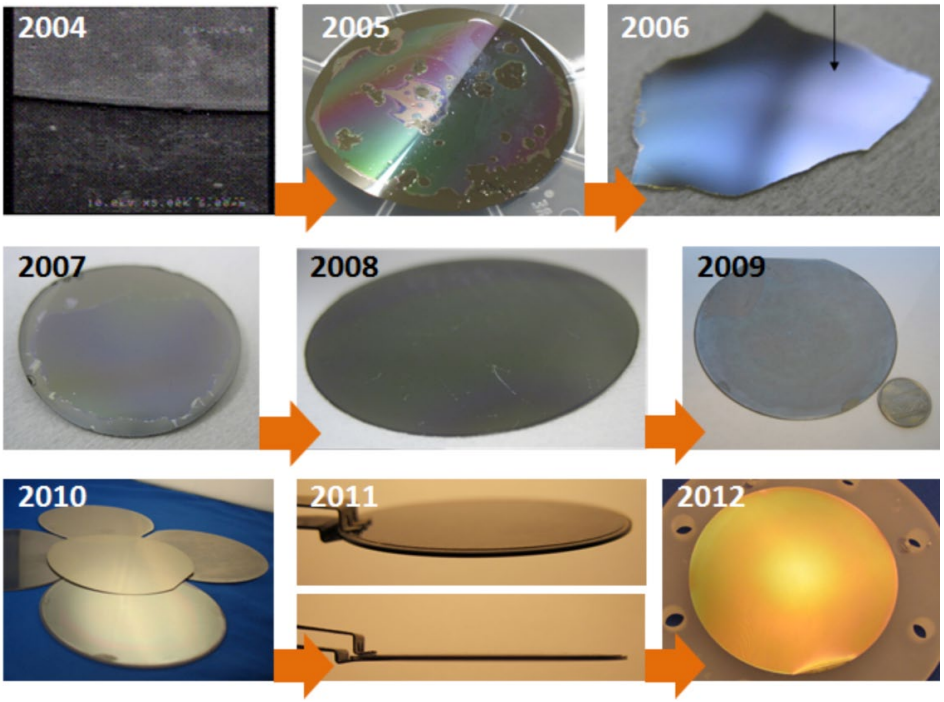

Figure 1: Photos illustrating the development of GaN-on-Diamond wafers over the years. The 2011 photo shows a carrier mounted 3" GaN-on-Diamond wafer. The 2012 photo shows a 4" free-standing GaN-on-Diamond wafer.

More than ten years since introducing the idea, the authors have advanced state-of-the-art GaN-on-Diamond technology to include large area wafers (3" and 4") and RF Power Amplifier demonstrations [15]; numerous mechanical/materials [8], electrical [5], thermal [4-6], and reliability [7, 16] measurements have been obtained clearly indicating the advantages of GaN-on-Diamond wafers over GaN-on-SiC in RF electronic devices. GaN-on-diamond devices could replace GaN-on-SiC devices or traveling wave tubes (TWTs) in defense radar, weather and communication satellite, and electronic warfare (EW) systems. Additionally, commercial systems such as cellular base stations, weather and communications satellites, and power devices would enter a new generation of greater energy efficiency and reduced size/weight because of GaN-on-Diamond.

	PHYSICAL PROPERTIES OF VARIOUS BULK MATERIALS PROPERTIES					
	Si	GaAs	SiC	GaN	Sapphire	CVD Diamond
Thermal Conductivity (@300K) (W/m-K)	135-150	35-50	390-450	150-250	35	1000, 1500, 2000
Electrical Resistivity @300K (Ω-cm)	~ $2.3x10^5$	~ 10^4 - 10^8	~ 10^4 - 10^6	~ 10^6	~ 10^{17}	~ 10^{13} - 10^{16}
Young's Modulus (110) @ RT (GPa)	130	~ 83	~ 390-700	~ 180-200	~ 250-400	~ 1,100
Diameter Availability Today	12"	6"	6"	1.2"	2" – 4"	6"

Table 1: Electrical and thermal properties of various commercially available substrates commonly used in RF electronics or that may be used to host GaN.

A Historical Perspective of GaN-on-Diamond's Development

Unusual for a new semiconductor technology, the authors have only rarely changed the general GaN-on-Diamond wafer formation process since development began in 2003 (see next section for description). Figure 1 shows photos of GaN-on-Diamond wafers at various stages of development over the years. Virtually every aspect of the GaN-on-Diamond wafer has been exhaustively refined and optimized many times over the years; these optimized parameters include wafer size, GaN coverage yield, choice of, and thickness of interfacial

material between the GaN and diamond, diamond deposition conditions, wafer bow and warp, selection, thickness, and method of depositing/removing protection layers on top of the GaN epitaxy, among others.

Several external parties were critical in advancing GaN-on-Diamond in the early years. Among the authors' earliest partners was Wright Patterson Air Force Research Labs (AFRL) who demonstrated in 2006 the first ever operational transistor on a GaN-on-Diamond wafer [9]. DARPA awarded the first seed contract to the authors in 2005 to demonstrate a 10-mm x 10-mm piece of GaN-on-Diamond wafer [10]; DARPA would provide instrumental funding later on (via the Near Junction Thermal Transport effort under DARPA's Thermal Management Program) to optimize and characterize the thermal benefits of the new technology. P1 Diamond and Crystallume Corporation grew the first diamond wafers for the authors in 2005 [9-10]. The US Missile Defense Agency awarded the authors the first of many SBIR programs. TriQuint Semiconductor [11] and Raytheon Company [12] were the first commercial entities to demonstrate operational GaN-on-Diamond transistors. The US Navy SBIR program was the first to fund a reliability-related program with the authors in 2009. One of the authors (Element Six SA) – the largest synthetic diamond maker in the world – became an instrumental backer of GaN-on-Diamond in 2009, later enabling scale-up of the technology after it acquired Group4 Labs, Inc., in 2013.

In this paper, GaN-on-Diamond high-electron mobility transistors (HEMTs) are compared to GaN-on-Si HEMTs to assess the impact of the diamond growth process on the GaN epitaxy; note that the GaN on diamond originally comes from a Si substrate. The authors also compare GaN-on-Diamond with GaN-on-SiC HEMTs since GaN-on-SiC is the industry's prevailing state-of-the-art GaN technology.

Making GaN-on-Diamond Wafers

The authors prepare GaN-on-Diamond wafers according to the process flow shown in Figure 2. The AlGaN/GaN High Electron Mobility Transistor (HEMT) layer structure is grown by metal-organic chemical vapor deposition (MOCVD) on a high resistivity Si (111) substrate. Starting from the Si substrate, epitaxial layers included a 1.2 µm thick proprietary transition buffer, an 800 nm thick undoped GaN buffer layer, a 17 nm thick $Al_{0.26}Ga_{0.74}N$ Schottky barrier, and a 2 nm GaN cap layer. A 100 µm thick CVD diamond layer was grown on a dielectric-coated GaN epitaxial substrate (GaN buffer, AlGaN barrier and GaN cap). The process for diamond growth is as follows: the host Si (111) and transition layers beneath the AlGaN/GaN epitaxy are removed, a 50 nm thick proprietary dielectric is deposited onto the exposed AlGaN/GaN and finally a 100 µm thick CVD diamond substrate is grown onto the dielectric adhering to the epitaxial AlGaN/GaN films.

GaN-on-Diamond versus GaN-on-Si HEMTs

Recently [6], engineers at AFRL undertook an independent project to understand whether the authors' GaN epi-flip

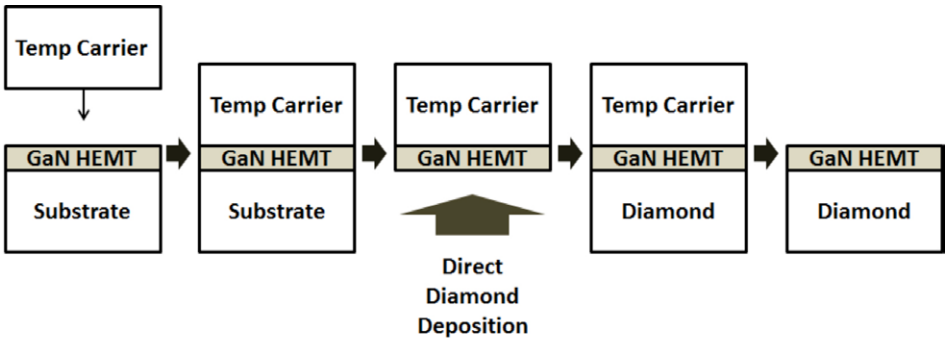

Figure 2: The flow diagram summarizes the general approach to building a GaN-on-Diamond wafer as prepared in this work. The GaN face is first bonded to a temporary carrier, the substrate and transition layers are etched away, a 50 nm thick dielectric is deposited on the GaN's backside, diamond is deposited on the dielectric on the GaN's backside, and then the temporary carrier is removed.

	GaN-on-Diamond	GaN-on-Silicon
Rc (Ω-mm)	0.36 (0.11)	0.49 (0.09)
Rsh (Ω/sq)	441 (39.4)	429 (17.8)
IISO@50V (mA)	89 (103)	226 (186)
GmPeak (mS/mm)	238 (18.6)	214 (5.3)
Vth (V)	-3.58 (0.04)	-3.81 (0.05)
Imax (mA/mm)	813 (56.3)	697 (39.6)
Idss (mA/mm)	707 (58.6)	617 (57.3)
Igl (mA/mm)	-5.66 (5.49)	-0.56 (0.84)
Vbk(V)	25.75 (10.64)	27.94 (5.02)
GLag@5V (%)	7.9 (NA)	7.1 (NA)
Dlag@5V (%)	10.0 (NA)	10.6 (NA)

Table 2: Shows a summary of average (and standard deviation) DC and RF measurements made by AFRL on identically designed GaN-on-Diamond and GaN-on-Si HEMT devices.

and diamond deposition process negatively affects the GaN epitaxy so as to deteriorate performance in any way. Indeed, the analysis would also look for any positive effects of the diamond on the GaN. It was desired that the authors' process leave the GaN epitaxy "unharmed" electrically whilst improving GaN's thermal properties as predicted by simulations.

In the AFRL work which has been described in detail elsewhere [6], thousands of GaN-on-Diamond and GaN-on-Si HEMTs were constructed with "sister GaN Epitaxy" wafers; the GaN-on-Si was grown at the same time as the GaN that was to be transferred to diamond. HEMT dimensions include gate widths of 300 µm (2x150 µm), gate lengths of 0.15 µm, and source-drain distances of 4.5 µm.

The materials and DC parameters that were measured and mapped across whole wafers include: sheet resistivity, carrier mobility, carrier density, contact resistance, sheet resistance, and buffer isolation current. On passivated devices, measured and mapped parameters include the transconductance, maximum DC drain current, saturated DC drain-source current, threshold voltage, gate leakage, and knee voltage. Passivated RF data that were measured and mapped include, breakdown voltage, f_{max} (MAG), f_t, I-V, and Transfer curves. With one exception (surface gate leakage), no statistically significant differences were found between the GaN-on-Si and the GaN-on-Diamond DC and RF measurements. Table 2 shows a summary of the results published in [6].

To assess the RF performance of the GaN-on-Diamond devices relative to GaN-on-Si, continuous wave (CW) Maury load pull measurements at X-band (10 GHz), were performed on the devices at various drain voltages (see device dimensions above). Select devices were matched for best PAE and biased at a quiescent drain current of 30 mA (100 mA/mm), class AB, with multiple drain voltage conditions from Vd=15-V to Vd=25-V. The wafers were held at 25°C on a vacuum chuck during all electrical characterizations. Figure 3 shows the load pull plots of output RF power versus drain voltage for various devices. GaN-on-Diamond devices exhibited higher output power by ~1 to 1.5 dBm and higher PAE by 7% compared to GaN-on-Si.

In another thermal-via-electrical assessment by AFRL, the current droop in GaN-on-Diamond HEMTs is compared to that of GaN-on-Si. Figure 4 shows the current droop measurements. The graphs show that GaN-on-Si HEMTs are more sensitive to pulse lengths than GaN-on-Diamond HEMTs – a feature widely attributed to increased self-heating.

In comparing the directly measured thermal performance of GaN-on-Diamond with GaN-on-Si HEMTs, infrared (IR) thermography and micro-Raman techniques were used. Details of the measurements have been published

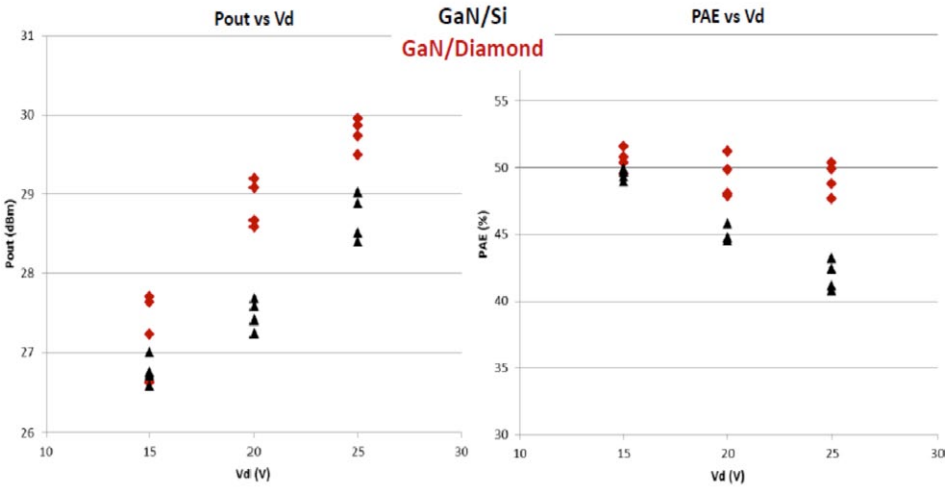

Figure 3: X-band Load pull measurements taken from GaN-on-Diamond and GaN-on-Si HEMT devices across multiple levels of power dissipation.

elsewhere [6]. Thermal resistance here is defined as the difference between the observed region's hottest temperature and the base of the substrate divided by the product of the drain voltage and current. These IR measurements were made on-wafer, un-attached to stage. The "spot size" of the IR technique was larger than the entire transistor device thus leading to the qualitative nature of the technique. In the IR analysis, with a drain-voltage of 25 V and drain current of 130 mA, the thermal resistances of GaN-on-Diamond, GaN-on-Si, and GaN-on-SiC are 7.44 K/(W/mm), 16.6 K/(W/mm), and 11.5 K/(W/mm) respectively. The temperature difference between the device's gate and the base of the substrate was used in the calculations. Figure 5 shows the IR image of the measurements.

Figure 6 shows the micro-Raman thermal analysis comparing GaN-on-Diamond HEMTs with GaN-on-Si. The spot volume measured with micro-Raman is about 1 μm^3 from the GaN surface into the buffer. On the GaN-on-Diamond wafer, temperatures were measured from near the gate region between the gate and drain, as well as near the edge of the diamond substrate. GaN-on-Diamond gate measurements exhibited a thermal resistance of ~8.0 K/(W/mm), GaN-on-Si exhibited ~21 K/(W/mm).

GaN-on-Diamond versus GaN-on-SiC HEMTs

As GaN-on-SiC is the industry's leading substrate technology for high-power GaN RF applications, the authors chose to compare GaN-on-Diamond HEMTs with GaN-on-SiC in a scenario where the two devices are virtually the same. This comparison was conducted by Raytheon Company. Details have been published elsewhere [4] and are summarized here. 10 x 125 µm HEMT devices were fabricated on standard GaN-on-SiC epi-wafers as well as GaN-on-Diamond epi-wafers using Raytheon's microwave GaN process. The gate temperatures of GaN HEMT devices with gate-to-gate spacing of 10 µm (GaN/Diamond), 30 µm (GaN/SiC), and 40 µm (GaN/SiC and GaN on Diamond) were measured in a common packaging configuration at multiple power dissipation levels (W/mm). Simulations suggested that for a similar peak channel temperature, with a 40% reduction in channel-to-substrate thermal resistance, a GaN-on-Diamond HEMT could feature 1/3rd the gate-to-gate spacing of a HEMT fabricated on GaN-on-SiC.

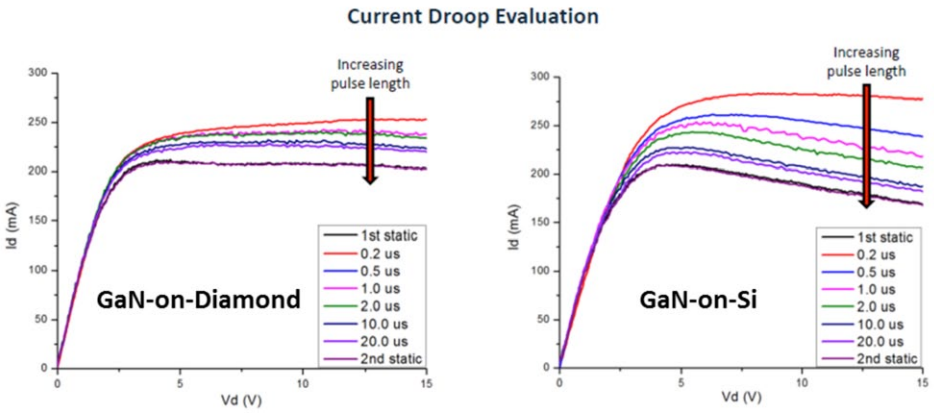

Figure 4: Current droop measured from GaN-on-Diamond (left chart) and GaN-on-Si HEMT (right chart) devices across various duty-cycles.

Thermal characterization was performed using Micro-Raman thermography and Gate Thermometry (Figure 8) [4]. Gate thermometry measurements were performed to obtain an effective HEMT temperature through measurement of gate forward bias voltage, which was calibrated to temperature. Figure 7 shows photos of the HEMTs discussed here.

There was good agreement between the simulations and the measurements obtained. At a dissipated power of 4.2 W/mm, the 10 µm gate-to-gate GaN-on-Diamond devices exhibited a peak junction temperature 6.3°C (6%) higher than the 30 µm gate-to-gate GaN-on-SiC devices.

At 4.2 W/mm dissipated power, a 40 µm gate-to-gate GaN-on-Diamond device exhibited a peak junction temperature of 8.5°C (9%) lower than a 40 µm gate-to-gate spacing GaN-on-SiC device. The GaN-on-Diamond result represents an approximately 3X increase in areal dissipation density (from 140 to 420 W/mm^2) with a small penalty in peak junction temperature. It should be noted that these results are for an early generation of GaN-on-Diamond material. Measurements on later generation material indicate that GaN-on-Diamond thermal performance has improved, which is expected to result in even better device thermal performance. We also note that

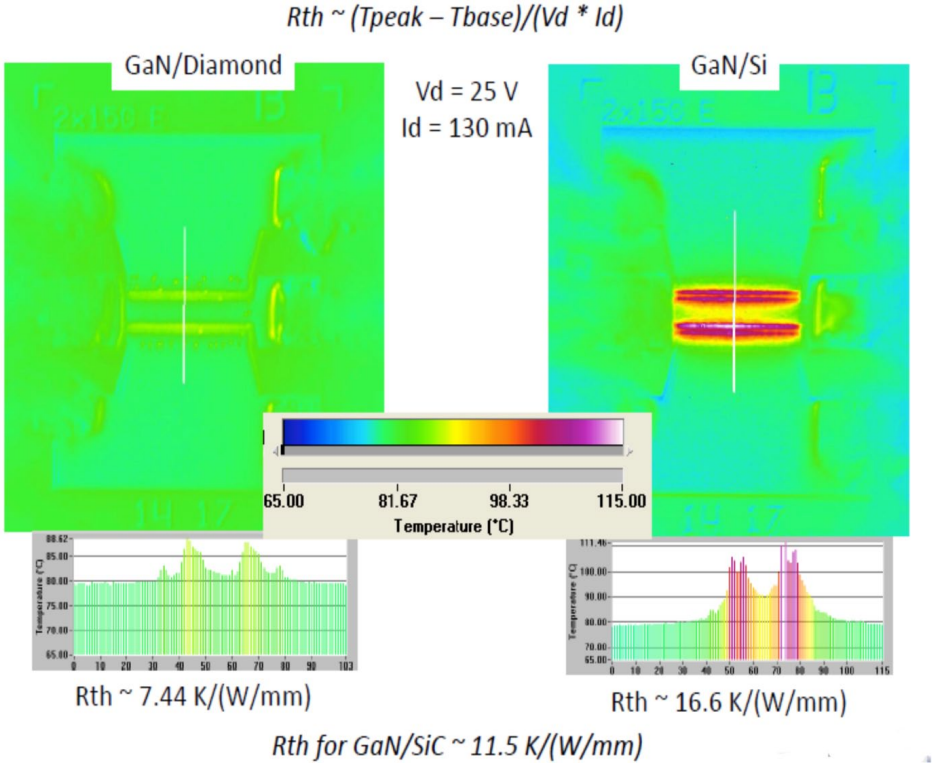

Figure 5: Infrared image of GaN-on-Diamond and GaN-on-Si HEMT devices under bias.

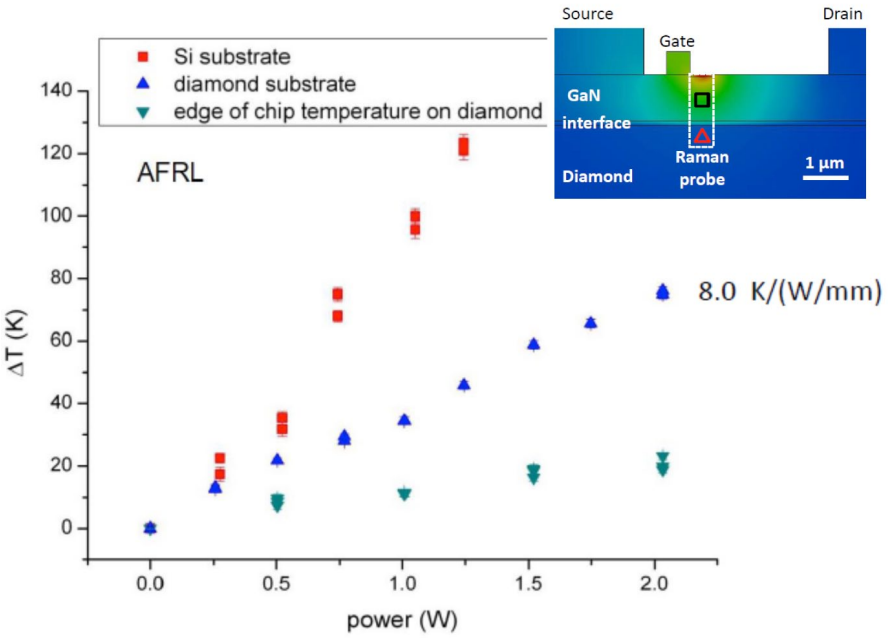

Figure 6: Temperature change measured for GaN-on-Diamond and GaN-on-Si HEMT devices using Microraman technique.

the peak temperatures cited above are simulated and represent the hottest nodal temperature in the HEMT finite element model. This is necessary because it is not possible to measure the true peak temperature that occurs in a HEMT device using either the Micro Raman or Gate Thermometry techniques. Confidence in the peak-temperature calculations derives from the good agreement between the model, the gate thermometry, and the micro-Raman measurements.

The Reliability of GaN-on-Diamond HEMTs

Reliability became a concern because the GaN is resting on a new foreign substrate – one whose thermal expansion coefficient, crystal structure, surface properties, and internal stress are very different from that of GaN. In determining the reliability of GaN-on-Diamond HEMTs, the authors subjected GaN-on-Diamond HEMT devices to channel temperatures of up to 350°C with a constant source-drain voltage of 24 V [7].

The source-drain current and the gate leakage current were monitored during the endurance tests. After 4,000 hrs at 350°C channel temperature for one batch, 9,000 hrs at 290°C for another batch, and 17,000 hrs at 210°C for a third batch, the GaN-on-Diamond HEMTs currents remained within 25% of their starting values; in contrast, all the control GaN-on-Si devices, sharing the same GaN epitaxy and device structure as the GaN-on-Diamond devices, catastrophically failed within a few hundred hours of the tests' start [7]. The authors suspect that the removal of the highly defective transition layers between GaN and Si before diamond deposition may contribute to the improvements shown in the GaN-on-Diamond endurance results here. More work is underway to understand these results.

System Benefits of GaN-on-Diamond HEMTs

In the design of radar, Electronic Warfare, defense radio, communications and weather satellites, cellular base stations, and naval avionics systems, the approximately 40% lower thermal resistance of GaN-on-Diamond devices relative to GaN-on-SiC devices [13] has two significant impacts: it can be used to reduce cooling complexity and cost, and it can be used to achieve a three-fold increase in the areal power density of the GaN transistor.

Impact on Cooling Complexity and Costs – A semiconductor's thermal resistance is an important parameter in the design of a microelectronic module and its associated thermal management system. The thermal resistance drives the entire design and sets the requirements for the ultimate coolant temperature. The reduced thermal resistance of GaN-on-Diamond can allow simpler, less expensive thermal management systems; it can also enable higher coolant temperatures because the temperature rise from the coolant to the gate is lower.

Impact on Power Amplifier, power density, and costs – The reduced thermal resistance of GaN-on-Diamond devices enables higher areal power densities. Various groups have recently shown that the GaN HEMT gate fingers on diamond can be brought threefold closer together on diamond than on SiC [4,5]. This means devices can be 1/3 the size resulting in smaller and less expensive GaN-on-diamond devices. To the power amplifier merchant seller, processing 3 times fewer GaN-on-Diamond wafers than GaN-on-SiC to achieve the same RF output power means significant reductions in fab costs – assuming that commercial GaN-on-Diamond wafers are competitively priced to GaN-on-SiC wafers. If the GaN-on-Diamond wafer price is low enough, then some of the power amplifier seller's savings could be passed on to the system maker in a reduced power amplifier price per watt.

Conclusions

In conclusion, GaN-on-Diamond has been demonstrated to provide significant thermal benefits relative to both GaN-on-Si and GaN-on-SiC, as affirmed through IR, micro-Raman and Gate Thermometry measurements performed on HEMTs. These results support the potential for GaN-on-Diamond to a) provide a ~3X increase in HEMT areal power density, and b) increase the ability for the GaN HEMTs to operate at increased ambient temperatures. Thus GaN-on-Diamond technology offers

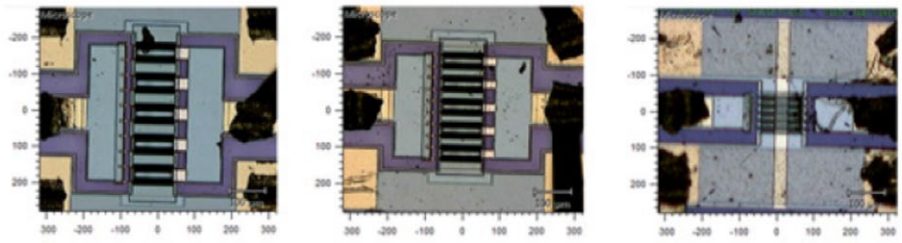

Figure 7: Photos of GaN HEMTs characterized by Micro-Raman and Gate Thermometry techniques. From left: GaN-on-SiC 40 µm g-g spacing, GaN-on-SiC 30 µm g-g spacing and, GaN-on-Diamond 10 µm g-g spacing.

revolutionary advantages for system performance and cost that make it the ideal choice for the next generation of device technology. The views expressed are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

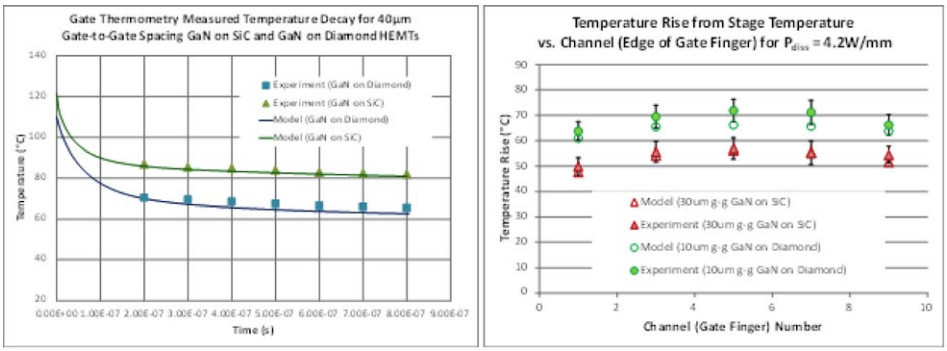

Figure 8: Model versus Experiment comparison of GaN-on-SiC and GaN-on-Diamond HEMT temperatures measured via Gate Thermometry (left) and Micro-Raman (right) techniques. On the left, GaN-on-Diamond and GaN on SiC HEMTs are compared with equivalent g-g spacing and dissipation (6.9W/mm). On the right, the GaN-on-Diamond HEMT features a 3X reduced gate-to-gate spacing relative to the GaN-on-SiC HEMT.

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ADCs for ultralow-power wireless applications: A compact, power-efficient and accurate SAR ADC for ultralow-power wireless applications

By Imec, Holst Centre

At the 2015 International Solid State Circuits Conference, imec and Holst Centre have presented a fast, compact and highly accurate successive approximation ADC (or SAR ADC). Consuming only 46 µW from a 1 V supply, the 13 bit ADC achieves the best power efficiency compared to similar work. The chip's SNDR (or signal-to noise and distortion ratio) is 64.1 dB. Key in the design is an ultralow-power on-chip background calibration that utilizes a redundancy facilitated error-correction scheme. Since the technique is broadly applicable, it can be used in many new ADC designs for ultralow-power wireless applications.

The need for ultralow-power ADCs

Today's wireless electronic systems store and process information in the digital domain. For these systems to interface with real-world signals, conversions between the analog and digital signals are required. Therefore, one of the keys to the success of these wireless systems has been the advance in analog-to-digital convertors (or ADCs). To be applicable for wireless standards, such as the 802.15.14g, the ADCs have to meet some stringent requirements: they need to be low power, have a high conversion rate (expressed in mega-samples per second or MS/s) and a high resolution (>10 bits). This resolution indicates the number of discrete values the ADC can produce over the entire range of analog values. Since the values are stored in binary form, the resolution is expressed in bits.

DAC matching, a challenge for accurate designs

Among the many ways of implementing an ADC, the SAR or successive approximation ADC is attractive because of its excellent power efficiency. A SAR ADC uses a comparator to successively narrow down the range that contains the input voltage. A key component in the design of the SAR ADC is an internal digital-to-analog convertor (or DAC) which drives the comparator. But the role of this DAC is also critical, since the accuracy of the SAR ADC is mainly defined by the DAC capacitor matching. This matching is mainly influenced by manufacturing processes and physical design. In modern CMOS technologies, the intrinsic accuracy of the SAR ADC is therefore limited to 10 to 12 bits.

Researchers look for solutions to improve the DAC matching. One way is to scale up the device dimensions, but this is at the expense of power efficiency and speed. Alternatively, calibrations are introduced to correct the circuit imperfections by measuring and correcting the induced errors. These calibrations are mostly implemented off-chip, since the power for the calibration circuit is relatively high when implemented on chip.

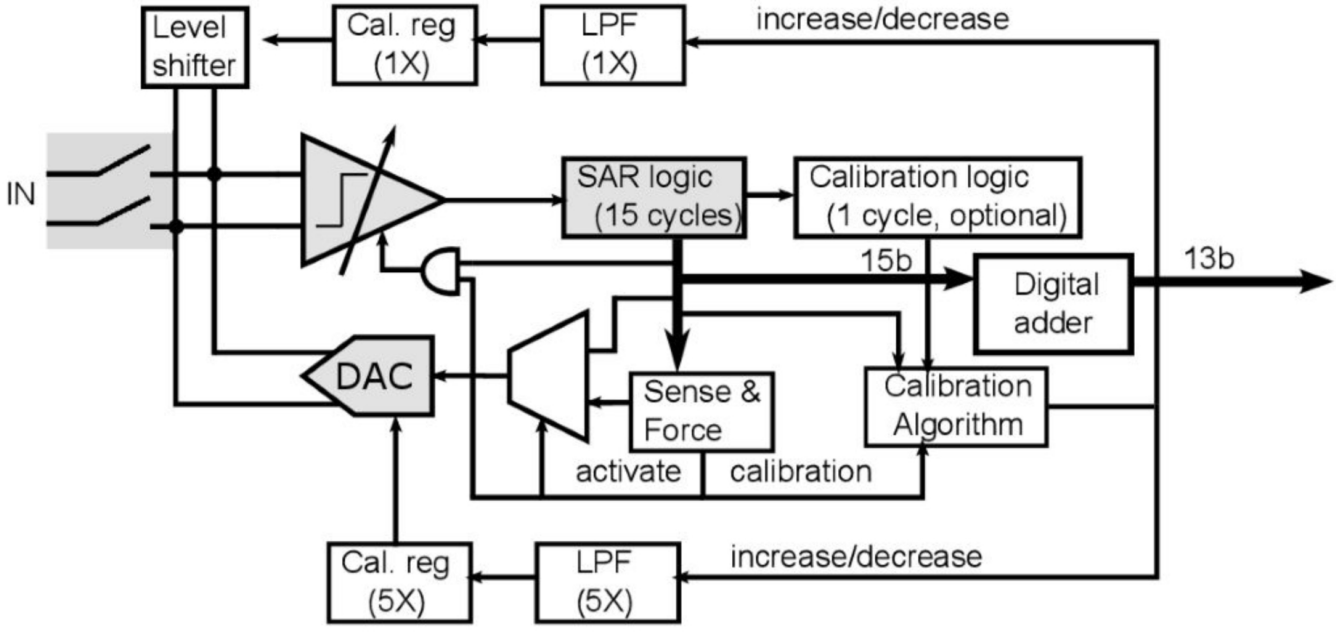


Figure ADC architecture: The ADC architecture, including the comparator, the SAR logic, the feedback DAC and the calibration logic.

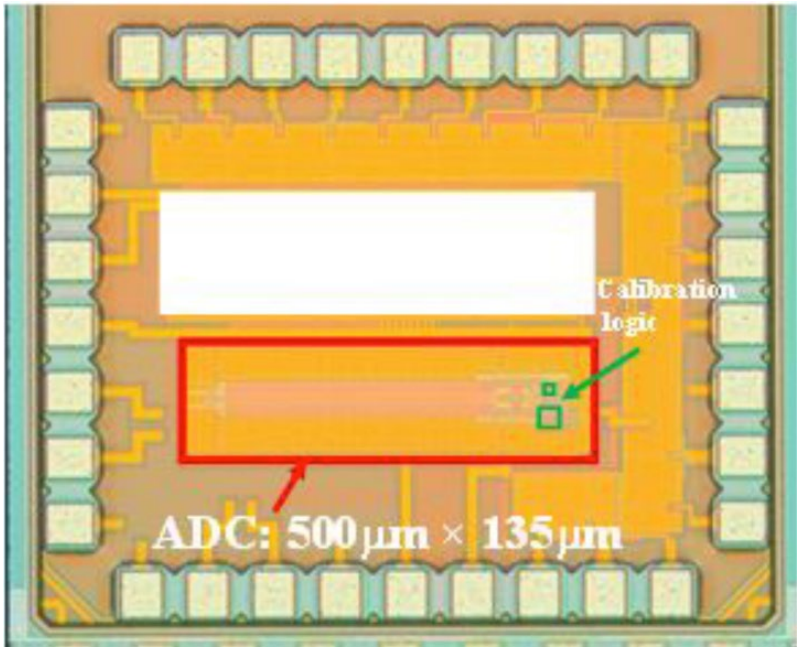


Figure ADC chip: Photo of the ADC chip.

Our solution: an on-chip redundancy-facilitated background calibration

Imec and Holst Centre have presented an innovative solution, which successfully implements, on chip, a low-power fully automated background calibration. This calibration utilizes a redundancy-facilitated error-detection and correction scheme.

Introducing redundancy in the analog-to-digital conversion process is another popular solution to deal with errors. It differs from calibration in the sense that the errors are neither measured, nor corrected, but simply tolerated and rejected by the conversion algorithm. Combining calibration and redundancy is often required to make certain calibration techniques work. In our design, the redundancy not only facilitates the proposed background calibration, it also relaxes the DAC settling requirements and saves power by using a two-mode comparator.

The proposed ADC uses a total of 15 cycles to perform a 13 bit conversion. The two-mode comparator works in low-power mode first (mode 1), and switches to high-precision mode (mode 2) in the last 5 cycles, resulting in a two-fold energy reduction. However, two errors are still present. First, the DAC matching is limited to <10 bits, which is due to the presence of small elements (0.3 fF) used in the DAC capacitor to save area. Second, a dynamic offset occurs when the comparator switches from mode 1 to mode 2.

The automated background calibration successfully suppresses both errors, with negligible overhead in area or power. The calibration logic is only enabled for a limited set of SAR codes which are suitable for DAC or comparator calibration. As a result, the large initial DNL (or differential non-linearity) errors caused by the dynamic comparator offset are effectively reduced, and the INL (or integral non-linearity) errors due to DAC mismatch are suppressed.

An ultralow-power 6.4 MS/s 13 bit ADC in 40nm CMOS

By using this innovative design, the researchers at imec and Holst Centre have realized a 6.4MS/s 13 bit ADC in 40nm CMOS. Thanks to the low-power calibration, this ADC achieves an effective number of bits (or ENOB) of 10.4 bit and a state-of-the-art power-efficiency of 5.5 fJ per conversion step at 6.4 MS/s. Overall, the chip consumes 46 µW from a 1 V supply. The ADC achieves 64.1dB SNDR (or signal-to noise and distortion ratio). In combination with the ENOB, this gives a good indication of the overall dynamic performance of the ADC. When compared to similar work, our ADC achieves the best power efficiency, while also integrating, on chip, a background calibration technique for comparator offset and DAC mismatch.

What's in it for industrial partners?

Imec and Holst Centre's SAR ADC is available for interested parties through IP licensing. For more info, visit www2.imec.be.

	[2]		[3]	[4]	[5]	**This work**
Architecture	SAR		Pipelined SAR	Pipelined SAR TI	Pipelined SAR TI	SAR
Technology (nm)	130		40	28	28	40
Area (mm^2)	0.059		0.042	0.35	0.1369	0.0675
Resolution (bit)	12		12	14	14	13
Supply voltage (V)	1.2		1.1	0.9	1.0	1.0
Reference Voltage (V)	1.2		1.0	0.9	1.8	1.0
Sample rate (MS/s)	22.5	45	160	200	80	6.4
Power (uW)	2790	2820	4960	2300	1500	46
INL (LSB)	-	-	-	2	-	3.79
DNL (LSB)	-	-	-	2	-	1.08
Nyquist SNDR (dB)	70.11	67.09	65.3	65	66	64.1
Nyquist SFDR (dB)	90.31	84.71	85	-	74	81.9
FOMW_Nyquist (fJ/conv.step)	50.8	36.3	20.7	7.9	11.5	5.5
Calibration	Off-chip		Off-chip	Off-chip	On-chip	On-chip
Cal. Circuit Area (mm^2)	0.01*		Not included	Not included	Included	0.0026
Cal. Circuit Power(uW)	200*		100**	Not included	Included	Included

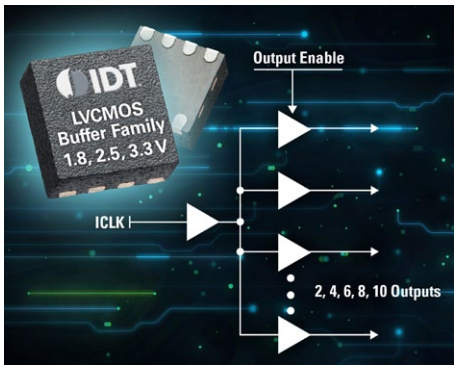
*Estimated by SPICE

** Estimated power by software

Figure ADC results: Performance summary and comparison with state-of-the-art.

LVCMOS clock buffers

offer best-in-class litter



Integrated Device Technology has introduced a family of clock buffers that deliver best-in-class jitter performance in a compact package.

The 5PB11xx family of LVCMOS fanout buffers provides low-jitter metrics of sub-50 fs RMS additive phase jitter (12 kHz to 20 MHz), offering system designers greater jitter margin than competitive products to help them meet system clock requirements. The small die size enables the chip to fit within a DFN 8-pin package as small as 2 by 2 millimeters. The buffers are ideal for high-end consumer, industrial, data communications, telecommunications and computing applications where both timing budget and board space are at a premium.

The buffers are available with 2, 4, 6, 8 and 10 LVCMOS outputs and can support 1.8 V, 2.5 V and 3.3 V power supplies and outputs. They have a low output skew of 50 ps with only 14 mA core current consumption. All the devices in the family are characterized at an extended temperature of -40°C to 105°C enabling the buffers to meet the requirements of automotive infotainment applications as well.

www.idt.com/go/timing

Tiny mobile brain-computer interface for smartphones

Mind Solutions has announced that pre-orders of its mobile BCI (Brain-Computer-Interface) will begin April 28th, 2015. The company has completed development of what they believe to be the smallest BCI on the market, which interacts with smart phones and computers through the power of your mind.

Mind Solutions has developed a wireless headset that detects and processes real time brain activity patterns (small voltage changes in the brain caused by the firing of neurons), software then translates these brainwaves into action on a user's computer and or smart phone. By using non-invasive electroencephalography (EEG), it is possible to observe each person's individual electrical brain activity, and then translate this into actions powered by thought.

The BCI takes the form of the common Bluetooth ear piece. The EEG signal is obtained via a small ear piece that is uses the ear canal to pick up the brain's electrical activity. Programmes have been developed to operate electric wheel chairs, control a computer by opening and controlling web browsers, a well as compose and send e-mails. Users can use software applications either on their PC or on the go on a smartphone with just thought control.

www.MindSolutionsCorp.com

PAM-4 analysis capability for real-time oscilloscopes

Keysight Technologies has introduced measurement software designed to help engineers quickly and accurately characterize PAM-4 (pulse amplitude modulation with four amplitude levels) signals using the the company's V-Series, Z-Series, and S-Series real-time oscilloscope platforms.

The N8827A PAM-4 analysis software (for V- and Z-Series oscilloscopes) and N8827B PAM-4 analysis software (for S-Series oscilloscopes) provides comprehensive analysis of electrical PAM-4 signals.

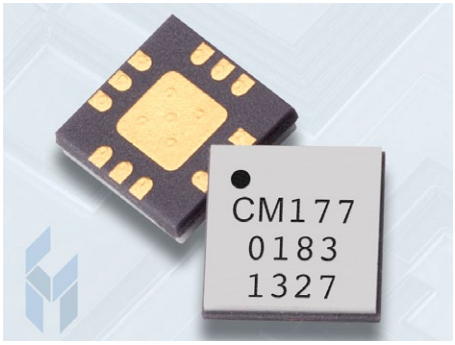
N8827A/B PAM-4 analysis software offers measurements such as: eye width, eye height and eye skew; level amplitude, level noise and level skew; as well as amplitude level linearity.

Engineers can combine the N8827A/B PAM-4 option with existing Infiniium real-time oscilloscope software tools to provide even more powerful analysis capability, including: PAM-4 equalizers (LFE, CTLE) using the N5461A InfiniiSim serial data equalization software; embedding/de-embedding of PAM-4 channels using the N5465A InfiniiSim waveform transformation toolset; as well as jitter and amplitude analysis on IEEE JP03 patterns using the N8813A EZJIT Complete software tool.

www.keysight.com

Fundamental mixer

covers 6-14 GHz with high isolation



Custom MMIC has added the CMD177C3, a packaged 6 to 14 GHz double-balanced mixer, to their growing standard product library. The CMD177C3 has a low conversion loss of 6.5 dB, high LO to RF isolation of 45 dBc, and a high input IP3 of +18 dBm across the 6 to 14 GHz bandwidth. The minimum LO drive requirement is +9 dBm, with saturation reached at levels above +13 dBm.

Housed in a leadless, 3 mm ceramic surface mount package, the CMD177C3 can be used in both up- and down-converting systems.

Additionally, a pair of CMD177C3 components can be configured as an image reject mixer or single sideband modulator with external hybrids and power splitters. The wide IF bandwidth of DC to 5 GHz allows for the support of numerous frequency conversion plans.

Ideal applications for this new mixer are point-to-point and point-to-multi-point radios, test equipment and sensors, and military end-use.

www.CustomMMIC.com

5-bit attenuator

for applications up to 31 GHz

RFMW has announced design and sales support for a 5-bit digital attenuator spanning 1 to 31 GHz.

The Qorvo TGL2223-SM offers a 0.5 dB least significant bit (LSB) providing 15.5 dB of overall attenuation range. The digital attenuator is packaged in a ceramic, air-cavity QFN measuring 3 x 3 x 1.45 mm.

Useful in applications such as point-to-point radio, SatCom, EW and radar, the Qorvo TGL2223-SM has measurably low step and attenuation errors. RMS step attenuation error is <0.5 dB while RMS attenuation error is <0.9 dB.

www.rfmw.com

5G millimeter-wave channel sounding test system targets research

Rohde & Schwarz is offering a novel 5G channel sounding system in cooperation with Fraunhofer Heinrich Hertz Institute (HHI). It supports the research activities aimed at exploiting the microwave and millimeter-wave spectrum within 5G networks.

Although a significant amount of channel sounding campaigns have been conducted and many results published, new spectrum in the discussed range from 6 GHz to 100 GHz requires much more measurement data. Multiple research projects as well as the upcoming 3GPP standardization need comprehensive measurement data in order to derive suitable channel models for efficient testing in future.

The test system from Rohde & Schwarz comprises the SMW200A vector signal generator and the AFQ100B I/Q baseband generator on the transmitter end and the FSW signal analyzer on the receiver end. The transmitter and receiver are synchronized and triggered by high-precision clocking units from Fraunhofer HHI, which also serve as absolute time bases with an accuracy of 2 ns.

The SMW200 and AFQ100B provide a wideband sounding signal with up to 500 MHz signal bandwidth and up to 40 GHz carrier frequency. The sounding signal is based on an optimized correlation sequence. The FSW receives this signal up to a carrier frequency of 67 GHz, and demodulates and samples it using its built-in 500 MHz demodulator.

www.rohde-schwarz.com
www.hhi.fraunhofer.de

Home gateway network processor

delivers carrier class connectivity

Claiming to be the industry's most integrated home gateway network processor, the GRX350 from Lantiq combines unsurpassed routing performance and bi-directional packet classification to provide True Quality of Service (TrueQoS™), along with a dedicated Trusted Execution Processor (TrustWorld™) and hardware-enforced virtualization (TrueVirtualization™).

This virtualization isolates concurrent applications so that networking functionality executes separately from non-networking applications, such as smart home services. One benefit of this architecture is shortened test time and time to market of new applications — without endangering the stability and integrity of the core networking software.

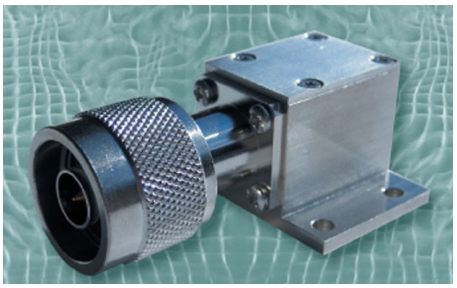
The MIPS based GRX350 network processor integrates carrier grade edge router features into its advanced home gateway architecture, which includes multiple CPUs, Gigabit switch with integrated GPHYs, 3x3 Wi-Fi, Voice and DECT telephony. Following Lantiq's AnyWAN™ concept, the chipset effortlessly handles any kind of wide-area-network (WAN) connectivity including the new G.fast standard.

Next generation multi-service gateways based on the Lantiq processor will concurrently manage multiple Gigabits of incoming data streams from interfaces, like G.fast, GPON, Gigabit Ethernet WAN, VDSL2 or hybrid access network approaches such as DSLTE™ (DSL + LTE).

With GRX350 the home gateway supports virtual provisioning of network functions in SDN (Software Defined Network) and NFV (Network Function Virtualization) scenarios by linking the standard OpenFlow™ protocol to its embedded TrueQoS and Packet Acceleration engines.

www.lantiq.com/GRX

50-W conduction cooled termination



The model series 552-308-050 from BroadWave Technologies is a conduction cooled termination that delivers 50-W of RF power (average) and has been deployed in commercial and military applications.

This 50 Ohm device has an operating frequency range of DC to 4-GHz and features maximum VSWR of 1.35:1. The RF connector is N male. Additional heat sinking is required for safe operation of the device at 50 W (case temperature must be maintained at +100ºC or less).

The nickel plated copper enclosure provides excellent thermal conductivity at an affordable price. Conduction cooled terminations are appropriate where space is limited and heat dissipating metal is available.

www.broadwavetech.com

Small, high-efficiency TWT amplifiers

target the 2-kW Ku-band and 1.5-kW DBS-band

Comtech Xicom Technology has introduced highly efficient, very high power Ku-band and DBS-band SuperPower™ traveling wave tube amplifiers (TWTAs) that can double available TWTA output power and provide direct replacement for Klystron power amplifiers (KPAs) in satellite communications uplink applications.

These breakthrough TWTAs were made possible with Xicom's advanced development of its SuperPower technology that brings proven space designs down to the ground and takes established millimeter-wave designs and scales them for use at Ku- and DBS-band frequencies.

The SuperPower TWTAs at both frequency bands are available as rugged outdoor antenna-mount units that can withstand -40 to +60 C operating temperatures or as indoor rack-mount configurations that incorporate Xicom's LCD TouchScreen front panels.

The Model XTD-2000KHE Ku-band TWTA provides the user with 750 W of linear power in a compact, rugged package weighing only 92 lbs (42 kg). and drawing less than 3200 W of prime power. The Model XTD-1500DBSHE DBS-band TWTA provides the user with 560 W of linear power for Direct-to-Home (DTH) applications in the same rugged 42 kg package and draws only 2500 W of prime power.

www.xicomtech.com

GaN SiC HEMT pulsed power transistor

covers 960-1215 MHz bandwidth

M/A-COM Technology Solutions has announced the MAGX-000912-650L00 and MAGX-000912-650L0S, a 650 W gallium nitride (GaN) on silicon carbide (SiC) HEMT pulsed power transistor for L-band pulsed avionics applications. This transistor is available in standard flange or earless flange packaging.

The MAGX-000912-650L00/MAGX-000912-650L0S is a gold metalized, internally matched, GaN on SiC depletion mode RF power transistor. Operating in the 960 to 1215 MHz frequency range, the MAGX-000912-650L0x is a rugged and robust transistor, boasting a mean time to failure (MTTF) of 600 years.

The internally matched MAGX-000912-650L0x features 650 W of peak output power with 20 dB typical gain and 62% drain efficiency. The semiconductor structure is designed to achieve a high drain breakdown voltage (BVdss), which enables reliable and stable operation at 50 V in extreme mismatched load conditions unparalleled with older semiconductor technologies.

www.macom.com

Tiny microwave vector signal generator

with 40 GHz frequency option

Rohde & Schwarz has released a 40 GHz version of the SGU100A RF upconverter. This version expands the frequency range of the SGS100A vector signal generator from 12.75 GHz to 40 GHz, making it the smallest microwave device of its kind on the market for continuous signals between 80 MHz and 40 GHz.

Though compact (two height units and ½ 19" rack width or one height unit and full 19" rack width), the combination of the SGS100A and the SGU100A offers outstanding performance. The setup is perfectly suited for ultrawideband aerospace and defense applications, as starting from 12 GHz the SGU100A can be used with a 2 GHz I/Q modulation bandwidth.

Together with the SMW200A high-end vector signal generator with a frequency range up to 40 GHz, a compact system with a maximum of three phase coherent outputs up to 40 GHz can be set up — ideal for testing phased array antenna systems.

The SGU100A is now available as a pure CW upconverter and as a version for I/Q-modulated signals.

www.rohde-schwarz.com

Compact directional coupler

with 6 dB coupling over 4.0 to 12.4 GHz

KRYTAR has announced the continued expansion of its growing line of directional couplers with a model offering 6 dB of coupling over the frequency range of 4.0 to 12.4 GHz, in a single, compact and lightweight package.

The latest directional coupler adds to the family of superior performance narrowband products covering the frequency range of 0.3 to 50 GHz. This coupler enhances the selection of multi-purpose, stripline designs that exhibit excellent coupling. Model 120406 covers the 4.0 to 12.4 GHz frequency band.

This latest coupler is uniquely designed for systems applications where external leveling, precise monitoring, signal mixing or swept transmission and reflection measurements are required. Applications include electronic warfare (EW), commercial wireless, SATCOM, radar, signal monitoring and measurement, antenna beam forming, and EMC testing environments.

Model 120406 enhances the product line with performance ratings including nominal coupling (with respect to output) of 6 dB, ±0.5 dB, and frequency sensitivity of ±0.30 dB. The directional coupler exhibits insertion loss (including coupled power) of less than 1.8 dB, directivity of greater than 15 dB, maximum VSWR (any port) of 1.35, input power rating of 20 W average and 3 kW peak. The directional couplers come with industry-standard 2.4-mm SMA female connectors.

www.krytar.com

Wide-band biased mixer

covers the V-Band

Spacek Labs model MV-1B is a wide-band biased mixer with full V-Band coverage in the RF and LO ports.

The RF and LO ports span 50 to 75 GHz in WR-15. The local oscillator

power is reduced to only 0 to +5 dBm by applying a DC bias. The IF port covers 10 MHz to 3 GHz and is supplied with a DC block on the SMA (female) connector. Conversion loss is 6 dB typical and 9 dB maximum.

Lower conversion loss is available on units with reduced bandwidths. The input 1dB compression point is 7 dB below the LO input power. The DC bias requirement is +12 V at 10 mA.

www.spaceklabs.com

Three stage Wi-Fi 5-GHz power amplifier

The RFPA5522 from Qorvo is a three-stage power amplifier (PA) designed for 802.11a/n/ac applications. The integrated input and output 50Ω match greatly reduces the layout area, bill of materials and cost of manufacturing in the customer application.

The RFPA5522 is manufactured on an advanced InGaP heterojunction bipolar transistor (HBT) process and is capable of achieving linear powers up to 23 dBm with an EVM <1.8% while maintaining excellent power added efficiency. The device is provided in a 4.0- x 4.0- x 0.9-mm laminate package that meets or exceeds the power requirements of IEEE802.11a/n/ac WiFi RF systems.

The device features an output power of 23 dBm at 5 V, 11ac, 80 MHz MCS9 at 1.8% EVM. Typical transmitter gain is 33 dB. Other features include high PAE, integrated regulator, and integrated power detector, harmonic filter, and notch filter.

www.rfmd.com

Broadband coaxial limiters

suit hard limiting conditions

Pasternack has introduced their latest broadband, high power coaxial limiters, which help protect sensitive low power RF receivers and other microwave circuits in

close proximity to high power signals.

This latest release of high power limiters consists of seven unique designs that provide low leakage power to sensitive control components in the receiver chain while offering good suppression of even-order harmonics under hard limiting. These RF limiters operate over a very broad frequency range in bands from 0.5 GHz to 40 GHz and also provide low leakage power circuit protection of 10 to 15 dBm. This latest selection of coaxial limiters exhibits high CW power handling up to 100 W peak power and fast recovery time of 10 to 100 nanoseconds.

The high power, broadband limiters help stabilize generator outputs, provide constant amplitude signals in phase sensitive systems and reduce amplitude variation in frequency modulation (FM) systems. The 50 Ohm hybrid designs incorporate complete limiting diode circuitry and do not require any external matching components. These microwave limiters offer a guaranteed operating temperature range of -54° C to +85° C and are constructed with high-rel, ruggedized packages that are designed to meet MIL-STD-202 environmental conditions for humidity, shock, vibration, altitude and temperature cycle.

www.pasternack.com

LoRa wireless module

targets long-range, low-power IoT

Microchip Technology has announced the first in a series of modules for the LoRa™ technology low-data-rate wireless networking standard, which enables Internet of Things (IoT) and Machine-to-Machine (M2M) wireless communication with a range of more than 10 miles (suburban), a battery life of greater than 10 years, and the ability to connect millions of wireless sensor nodes to LoRa technology gateways.

The 433/868 MHz RN2483 is a European R&TTE Directive assessed radio module, accelerating development time while reducing development costs. Additionally, it combines a small module form factor of 17.8 x 26.3 x 3 mm with 14 GPIOs, providing the flexibility to connect and control a large number of sensors and actuators while taking up very little space.

The RN2483 comes with the LoRaWAN™ protocol stack, so it can easily connect with the established and rapidly expanding LoRa Alliance infrastructure — including both privately managed local area networks (LANs) and telecom-operated public networks — to create low power wide area networks (LPWANs) with nationwide coverage. This stack integration also enables the module to be used with any microcontroller that has a UART interface, including hundreds of Microchip's PIC® MCUs. Additionally, the RN2483 features the company's simple ASCII command interface for easy configuration and control.

www.microchip.com

Miniature signal generator

outputs 25 to 6000 MHz in 1-kHz steps

AtlanTecRF's ASG series of miniature signal generators cover an ultra-wide frequency range of 25 to 6000 MHz, tuneable in 1-kHz steps, with a very good spectral purity.

Phase noise at an output frequency of 1 GHz is better than -106 dBc/Hz at an offset of 100 kHz from the carrier. Spurious are typically lower than -70 dBc and harmonics less than -25 dBc.

The clean output signal combined with power levels to +13 dBm, controllable on 0.1 dB steps, make the ASG series of miniature signal generators suitable for use in most RF theatres of application including test and measurement, communications systems and covert interception and countermeasures.

The versatile ASG digital interface provides control options, which include direct USB with convenient and clearly functional GUI plus input power derivation but each unit also has the capability of being driven by RS232. Additionally, for both the 6 GHz version of the ASG miniature signal generator and its 3 GHz sibling there is an option of Ethernet control thereby allowing totally remote and unattended operation in the field and picking up all the logistics and cost advantages.

www.atlanticmicrowave.co.uk

Bluetooth Smart development kits

from Digi-Key

Dialog Semiconductor has announced a global distribution agreement with Digi-Key Corporation for its SmartBond Basic and Pro development kits — now in stock for immediate delivery.

The kits offer engineers the fastest and easiest route to developing intelligent connected devices, particularly where small size and low power consumption are critical, such as in battery-powered wearables and other IoT applications.

The kits are based on Dialog's DA14580 and DA14581 System-on-Chip (SoC) ICs. These highly integrated devices combine a Bluetooth low energy radio with an ARM® Cortex®-M0 application processor and intelligent power management. Processor resources are accessible via 32 GPIOs to enable development of fully hosted applications. The SoCs measure 2.5 mm x 2.5 mm and need just five external components to create complete solutions that consume less than half the power of alternatives.

SmartBond Basic is a single-board kit with integral flash memory for software development. The Pro version of the kit includes mother and daughter boards and a power profiler to enable power-optimised coding. Both kits are supported by the SmartSnippets™ software development environment, which includes Bluetooth Smart SIG-qualified profiles ranging from proximity to health and fitness, medical, smart home, and security. Software Upgrade Over The Air (SUOTA) is supported.

www.digikey.com

3000 MHz VCO delivers high linearity

The CVCO55CC-3000-3000 voltage controlled oscillator (VCO) from Crystek operates at 3000 MHz with a control voltage range of 0.5 V to 4.5 V.

This VCO features a typical phase noise of -110 dBc/Hz at 10 kHz offset and has excellent linearity. Typical output power is +7.0 dBm. Engineered and manufactured in the USA, the model CVCO55CC-3000-3000 is packaged in the industry-standard 0.5-i x 0.5-inch (1.27- x 1.27-cm) SMD package.

The device has an input voltage of 8.0 V, with a typical current consumption of 35 mA. Pulling and Pushing are minimized to 1.0 MHz and 0.2 MHz/V, respectively, while second harmonic suppression is -15 dBc typical.two

www.crystek.com

All-in-one trackside access point

for reliable train-to-ground communications

Moxa has released the TAP-6226, an all-in-one wireless unit that integrates two access points, a managed fiber switch, and a wide-range AC/DC power supply, to enable reliable train-to-ground communications. Featuring IP68 housing and shock- and vibration-proof M12 connectors, the TAP-6226 is specially designed for the railway environment.

The TAP-6226 features the company's advanced controller-based Turbo Roaming technology for applications like Communication-Based Train Control (CBTC). In addition, the TAP-6226 can supply power to up to four PoE devices while providing reliable LAN connectivity with the Turbo Chain technology.

The TAP-6226 series features two dual-band, IEEE 802.11a/b/g compliant radios, IP68-rated housing, controller-based Turbo Roaming, two fiber ports with Turbo Chain technology, four PoE ports with M12 connectors, high transmission power for extended reach, -40 to 75°C operating temperature range, and compliance with the relevant sections of the EN 50155 standard

www.moxa.com

Autonomous mobile beacon

secures and tracks property and objects

French telematics specialist, TRAQUEUR has introduced NANO, which claims to be the first autonomous mobile beacon for the protection of property and objects, designed to optimize the potential of the SIGFOX network.

Nano offers key advantages for installation and concealment, and uses multiple location technologies (radio and GPS) to ensure foolproof tracking, indoor as well as outdoor. With this combination of location techniques and a battery life of several years, NANO offers a different way for securing and tracking property and objects. NANO features UHF direction finding, providing the ability to locate buried and hidden objects (indoor underground geo-location). It also has a high-sensitivity GPS module and an integrated antenna to transmit its position via the SIGFOX network when the beacon moves (outdoor geo-location).

After several years of development, NANO represents a breakthrough and opens up new Track and Trace (not electronically connected) markets. TRAQUEUR with expertise in UHF, VHF, GSM and GPS formed a strategic partnership with SIGFOX to develop NANO.

NANO is smaller than a pack of cigarettes and has a battery life of three to five years (internal battery without any external connection), depending on how it is configured and used. It has also been designed to be extremely easy to install.

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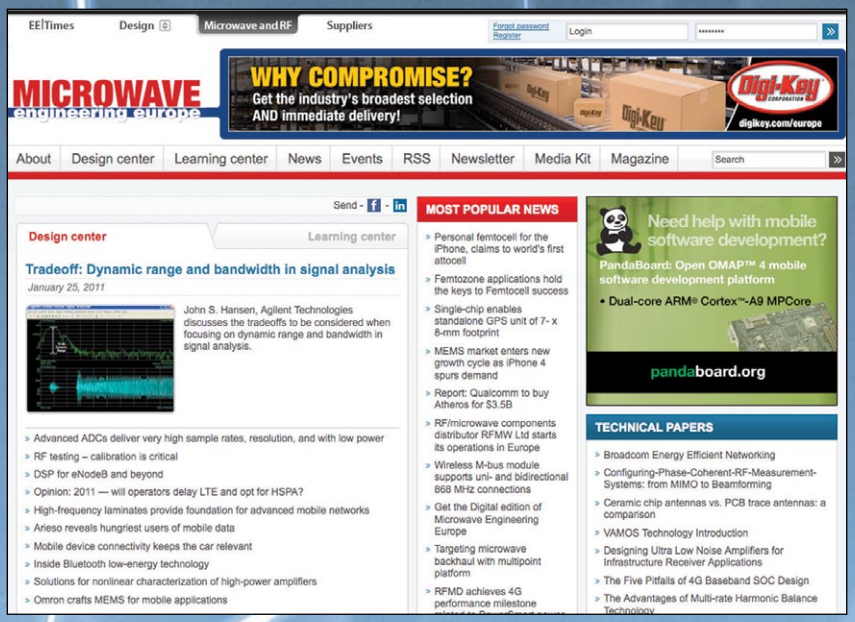

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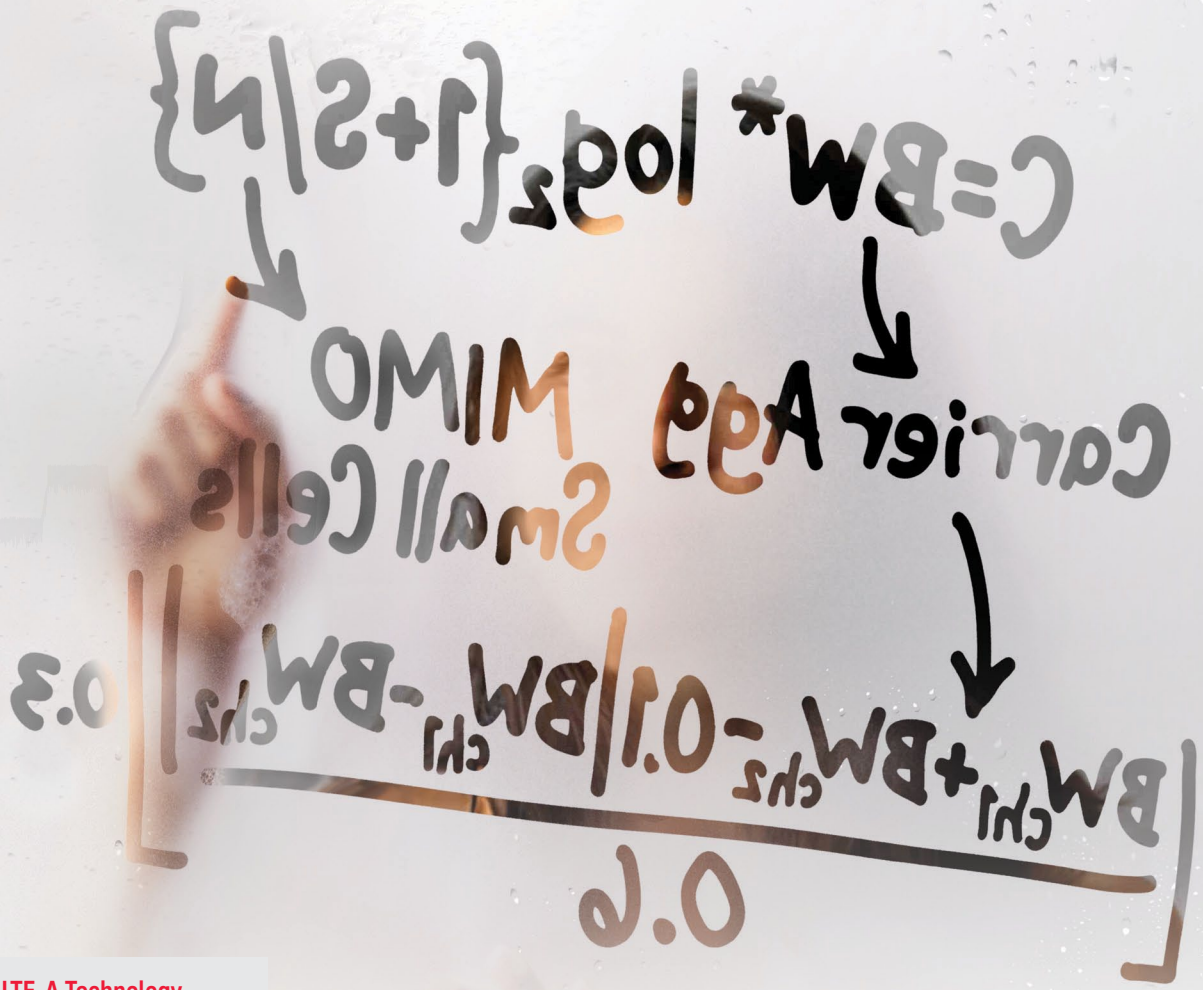

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