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Global Strategy and
Business Development,
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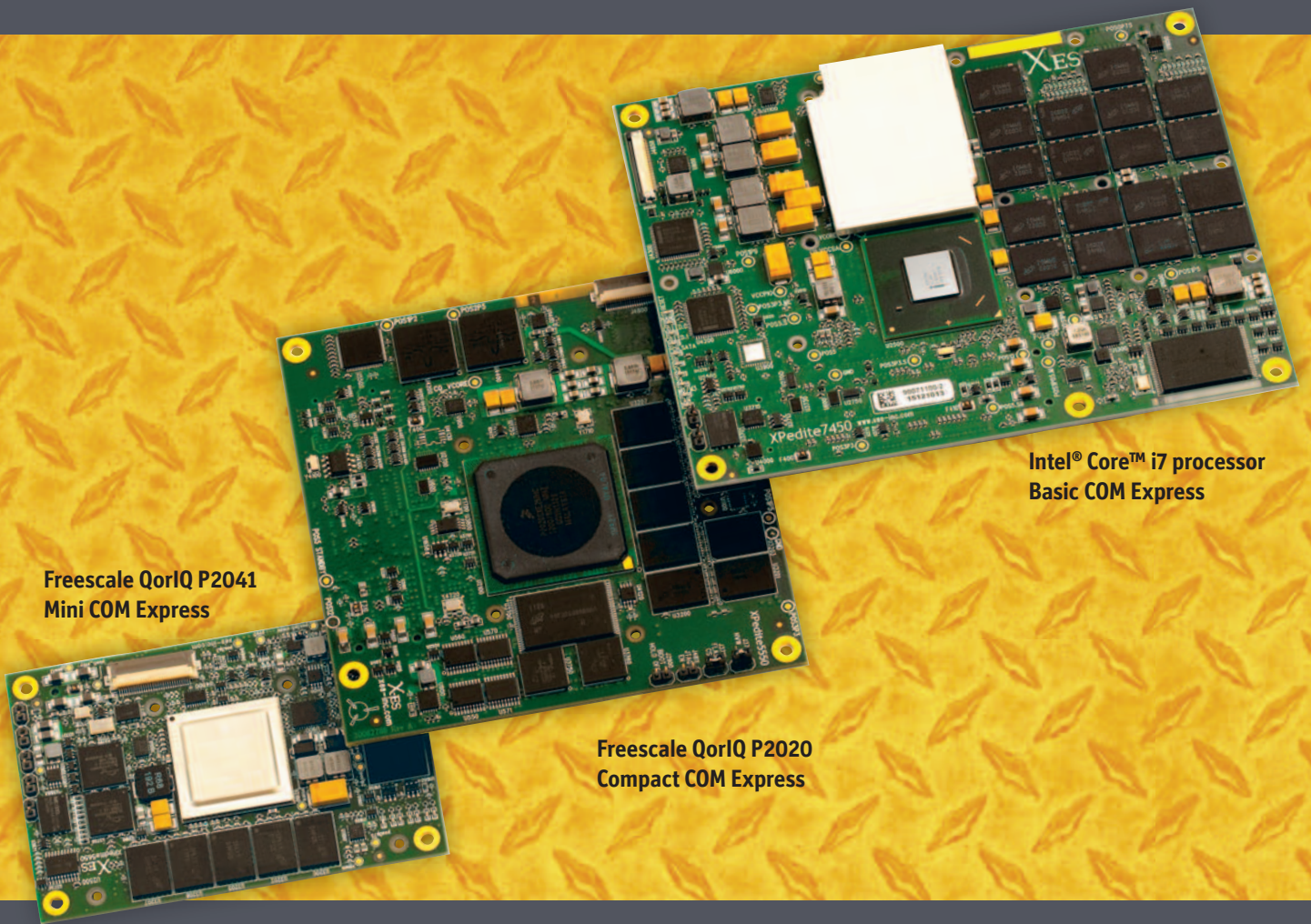
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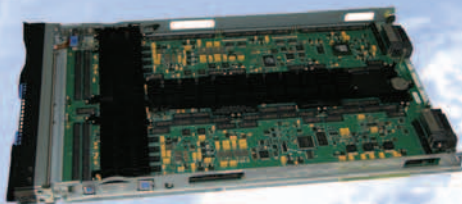
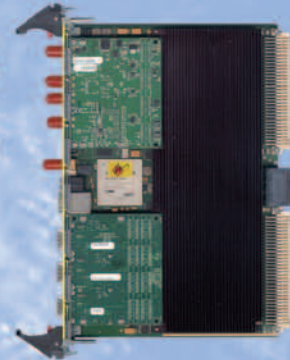
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ON THE COVER

While the telehealth realm continues to gain traction among health-care providers and patients, the Continua Health Alliance tackles the behind-the-scenes challenges to help eliminate obstacles including interoperability and three other top issues (see Q&A, page 20). This edition also explores the latest microcontroller tech trends, with our editors catching up with industry experts from Microchip, Silicon Labs, and Freescale Semiconductor to find out the latest (beginning on page 8). And finally, articles from Seapine Software and GammaTech explore static analysis-enabled program visualization and testing and traceability software that make the designer's job easier (pages 14 and 17).



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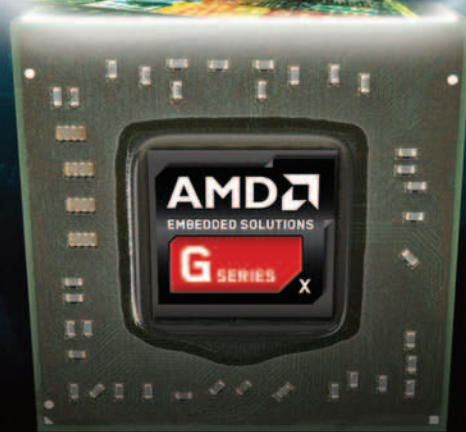
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ECD Editorial/Production Staff

Warren Webb, Editorial Director
wwebb@opensystemsmedia.com

Sharon Hess, Managing Editor
sharon_hess@opensystemsmedia.com

Steph Sweet, Creative Director
ssweet@opensystemsmedia.com

Sales Group

Tom Varcie
Senior Account Manager
tvarcie@opensystemsmedia.com

Rebecca Barker, Strategic Account Manager
rbarker@opensystemsmedia.com

Eric Henry, Strategic Account Manager
ehenry@opensystemsmedia.com

Ann Jesse, Strategic Account Manager
ajesse@opensystemsmedia.com

Christine Long
Vice President, Online Business
clong@opensystemsmedia.com

International Sales

Elvi Lee, Account Manager – Asia
elvi@aceforum.com.tw

Gerry Rhoades-Brown
Account Manager – Europe
gerry.rhoadesbrown@husonmedia.com

Christian Hoelscher
Account Manager – Europe
christian.hoelscher@husonmedia.com

Lauren Palmer
Account Manager – Europe
lauren.palmer@husonmedia.com

Regional Sales Managers

Barbara Quinlan, Southwest
bquinlan@opensystemsmedia.com

Denis Seger, Southern California
dseger@opensystemsmedia.com

Sydele Starr, Northern California
starr@opensystemsmedia.com

Ron Taylor, East Coast/Mid Atlantic
rtaylor@opensystemsmedia.com

Reprints and PDFs

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OpenSystems Media Editorial/Production Staff



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Warren Webb
Editorial Director
Embedded Computing Design
Industrial Embedded Systems
wwebb@opensystemsmedia.com

Sharon Hess
Managing Editor
Embedded Computing Design
Military Embedded Systems
Industrial Embedded Systems
sharon_hess@opensystemsmedia.com

John McHale, Editorial Director
Military Embedded Systems
jmhale@opensystemsmedia.com

Joe Pavlat, Editorial Director
xTCA and CompactPCI Systems
jpavlat@opensystemsmedia.com

Jerry Gipper, Editorial Director
VITA Technologies
jgipper@opensystemsmedia.com

Monique DeVoe
Assistant Managing Editor
VITA Technologies
EDA Digest
DSP-FPGA.com
mdevoe@opensystemsmedia.com

Brandon Lewis
Associate Editor
xTCA and CompactPCI Systems
PC/104 and Small Form Factors
blewis@opensystemsmedia.com

Curt Schwaderer
Technology Editor

Steph Sweet
Creative Director

David Diomede, Art Director

Joann Toth, Senior Designer

Konrad Witte, Senior Web Developer

Matt Jones, Web Developer

Editorial/Business Office

Patrick Hopper, Publisher
Tel: 586-415-6500 ■ Fax: 586-415-4882
phopper@opensystemsmedia.com

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Karen Layman, Business Manager
30233 Jefferson
St. Clair Shores, MI 48082

Rosemary Kristoff, President
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16626 E. Avenue of the Fountains, Ste. 201
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Tracking Trends in Embedded Technology

By Warren Webb



@warrenwebb



wwebb@opensystemsmedia.com

Microcontroller evolution drives embedded development

Microcontroller technology is the centerpiece of billions of intelligent devices that enhance many of our everyday activities. In a typical day, the average consumer interacts with hundreds of embedded microcontrollers in telephones, automobiles, appliances, security systems, toys, environmental controls, point-of-sale terminals, and entertainment electronics. With this enormous base of applications, any change in microcontroller specifications can have a significant impact on embedded development. As microcontroller technology evolves, embedded designers are able to create new innovations and upgrade existing applications with enhanced features such as faster performance, lower power requirements, improved interfaces, and remote management. Universal connectivity and cloud computing are the latest trends permeating the embedded landscape, and microcontroller manufacturers are updating their specifications to match this new level of performance.

In the Silicon section of this issue of *Embedded Computing Design*, several industry experts examine the impact these trends have had on the latest generation of microcontroller technology. For example, Kaivan Karimi, Executive Director for the Microcontroller group at Freescale Semiconductor, discusses new low-power, low-cost devices along with future development strategies related to the Internet of Things. In the same section, Diwakar Vishakhadatta, Vice President and GM of Embedded Systems at Silicon Labs, concentrates on ultra-low-power MCUs, wireless protocols such as ZigBee, and emerging sensor technology. Together with a discussion of Wi-Fi implementation techniques, Mitchell Little, Vice President of Worldwide Sales and Applications at Microchip, outlines the evolution in embedded user interface technology plus Microchip's certified training personnel and facilities.

As consumers demand an interactive interface, ubiquitous connectivity, absolute security, and extreme reliability in new embedded devices, the software development and analysis task grows exponentially. To help with this burden, several embedded vendors have developed tools to analyze and eliminate errors from the complex software. In this month's Software section, Paul Anderson, VP of Engineering at GrammaTech, presents new visualization tools that developers can use to analyze the overall structure and locate

problems of complex embedded software programs. With another approach for embedded software testing and traceability, Peter Varhol, the solutions evangelist at Seapine Software, explains Application Life-cycle Management (ALM) tools.

This month's Strategies section targets medical technology such as the latest ventilator innovations, in addition to home health-care devices and telehealth services, which are among the fastest growth areas for embedded systems manufacturers. These home health-care devices plus associated services are rapidly growing in popularity and allow doctors to monitor, diagnose, and often treat select health conditions remotely. To bring us up to date on the challenges in implementing remote health-care devices, three industry experts and members of the Continua Health Alliance answered a series of questions on the subject. Ian Hay, Head of Emerging Ecosystems at Orange, Barry Reinhold, President and Chief Technology Officer at Lamprey Networks, and Frank Wartena, Senior Scientist at Philips Research Europe, revealed the biggest challenges facing the medical/telehealth community and the expected changes to the technology in light of the newly enacted Affordable Care Act. And, alternatively, Barbara Schmitz from MEN Mikro Elektronik sheds light on new adaptive support ventilation technology designed to reduce the length of hospital stays and associated costs while improving the patient experience for the times when patients are on ventilators in ICUs, post-anesthesia care units, and emergency rooms.

I hope you find this edition's interviews and articles on microcontrollers, software testing, and medical/telehealth helpful in your development efforts. Our team will continue to make every effort to bring you the latest design information that is on the cutting edge. If you have ideas for future articles and coverage that would help in your design efforts, please let us know. We are always interested in contributed technical articles or videos that would appeal to other embedded designers. We are also searching for guest bloggers who can deliver real-time educational and informative technical information to the embedded community. If you have a suggestion for a technical article, video, or guest blog topic that would be of interest to you or other designers, please send along an email with a short abstract.



Q&A with Mitchell Little, VP of Worldwide Sales and Applications at Microchip Technology Inc.

Trend watch: MCU-based user interfaces take shape as key differentiator in cloud connected devices

As size and power considerations continue to rule the day in the microcontroller realm, many current MCU trends revolve around the user interface as a key product differentiator, as explained to our editors by Mitchell Little of Microchip Technology Inc. in the following interview. These incarnations include touch buttons/sliders, touch pads for automotive applications, and 3D gesturing controllers, among others.

ECD: *What new microcontroller technologies are available to meet the growing demand for cloud connected embedded devices?*

LITTLE: The most popular technology supporting the cloud connected devices is certainly Wi-Fi, which is being added to embedded applications. Fully certified, surface-mount Wi-Fi modules allow designers to quickly and seamlessly add Internet connectivity to their applications. Such modules' small form factor and ultra-low power make them suited to mobile wireless applications such as asset monitoring, sensors, and portable battery-operated devices, for example. By integrating certified modules into an embedded application, customers can be sure of FCC/CE/ETSI/IC certification. Wi-Fi modules with on-board TCP/IP stacks are also available so no external drivers are required. Such modules might feature an ASCII command interface and over air firmware upgrade capability for easy interface to a standard MCU via UART or SPI. For developers who want more flexibility to modify the TCP/IP stack, services, and source code, Wi-Fi radio transceiver modules work with TCP/IP stacks and can be customized for various protocol layers.

ECD: *As you look ahead for the next few years, what trends do you see in the embedded design area and how will they affect your product development plans?*

LITTLE: During the past few years, the evolution in user interface technology was very rapid from touch keys to touchless interface driven by the consumer market. But it also happened in every type of application and market as the user interface is now a key product differentiator. We were among the first to introduce a microcontroller-based solution for capacitive touch buttons. It is based on standard MCUs, from 8 bits to 32 bits, which provide highly integrated building blocks for the implementation of touch systems. We open up our algorithms and techniques to engineers, so that they can design with our touch implementation on our microcontrollers. From a system level, we are seeing touch buttons/sliders integrated with application in higher-end microcontrollers in addition to the low-cost dedicated touch controllers. The same capacitive solutions can also be used in more than just user interfaces; they can also measure water level or be used for pressure sensing, for instance.

In addition, low-cost and low-power touch pad request are a rapidly growing trend, outside the PC market, for user interface for all kinds of end equipment such as remote controls and automotive. 3D gesturing controllers, such as the one we just introduced, are enabling the next dimension in intuitive, non-contact user interfaces for a broad range of end products.

ECD: *With ubiquitous connectivity dominating embedded designs, what*

security precautions are available to prevent unauthorized access?

LITTLE: Transactions such as those done with smartcards require a very high level of encryption to protect data that is being transferred. Developers also need to consider items such as:

- › **Privacy (AES-128)**, that is, I sent a message but I do not wish for anyone to see it, other than the person to whom I sent it.
- › **Authenticity (HMAC)**, that is, I sent a message to someone but how do they know it is from me?
- › **Integrity (SHA-2)**, that is, I sent a message to someone but how do we know if the data is being tampered with?

Free software libraries are available also, offering the ability to implement flexible security solutions on many microcontrollers. USB-based card reader solutions are also on the market, all capable of providing a high level of security.

ECD: *Software development is a huge portion of each new embedded development project. What development tools and libraries do you offer developers?*

LITTLE: When evaluating any development tool infrastructure, engineers should focus on four areas. First, the IDE, or Integrated Development Environment, must be easy to use,

highly modular, and support a wide range of MCU price and performance points. Second, the C compilers should be as highly optimized as possible for the target architectures to ensure the smallest code footprint. Third, developers should look for a wide range of available development hardware, from simple prototyping boards to highly functional test-and-measurement kits. Lastly, the availability of supporting documentation, code examples, and software libraries is highly important in helping speed time to market.

Our MPLAB X IDE addresses the increasingly complex development cycles our customers find themselves in. It enables a unified development environment that supports all of our silicon products. Our line of MPLAB XC compilers is highly optimized for PIC MCU architectures, enabling our customers to be as efficient as possible with on-chip resources. We offer hundreds of development hardware tools, which give customers the option of selecting the appropriate tool for their development task. Our tool offering is designed to take advantage of the consistent use of similar peripherals across the product line. This allows for maximum reuse of existing code base in future projects.

ECD: Does your company offer any educational events or online classes to help embedded designers get started with microcontroller-centric projects?

LITTLE: Solving technical problems and getting customers' products to market quickly are vitally important, and because training needs are constantly changing, we offer several types of training based on what customers need. We offer face-to-face training at our Regional Training Centers (RTCs) and at customer facilities. Live training over the Web is also available for many of our topics, and we offer hundreds of short training sessions through the Webinar site.

Additionally, now in its 17th year, Microchip's MASTERS Conference technical training conference provides face-to-face, engineer-to-engineer training in seven countries. While the specific class list in each location varies, core classes taught in most locations include topics such as motor control, USB, TCP/IP, power supply design, touch sensing, and RTOS. Both lecture and hands-on lab classes are offered, and classes are taught by application engineers. Classes are available for engineers across any range of experience.


In summary, with a worldwide network of Regional Training Centers, certified third-party trainers, and authorized distributors, we strive to make it easy for developers to enhance technical skills with live instruction. These courses are taught by our staff or by Microchip Certified Technical Training Engineers live at various sites throughout the world, and usually in the local language. In addition to having a Technical Training Engineer on location teaching the course, all required tools and materials are provided for use during the class.

Also, our library of 100+ On-Demand Web Seminar presentations helps developers get the information they need, when they need it. Available in several formats (streaming video, PDF downloads, and so on), most of these presentations take only 20 minutes. **ECD**

Mitchell Little has served as Microchip's Vice President, Worldwide Sales and Applications, since July 2000. Prior to that, he served as Vice President, Americas Sales; Vice President, Standard Microcontroller and ASSP Division; and Vice President, Memory Products and ASSP Division. Mitchell holds a BSET from the United Electronics Institute.

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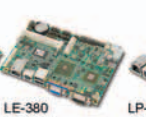

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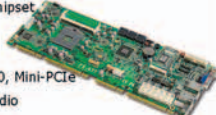
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Q&A with Diwakar Vishakhadatta, Vice President and GM, Embedded Systems, Silicon Labs

Advanced ultra-low-power MCUs help enable the Internet of Things

The ever-expanding Internet of Things (IoT) phenomenon has myriad connected devices in its toy box: tablets, smartphones, security systems, home appliances, smart meters, and much more. At the core of this exploding IoT phenomenon are ultra-low-power MCUs, along with sensor networks, ZigBee SoCs, and sub-GHz transceivers. Meanwhile, semiconductor-embedded AES encryption blocks in MCUs and wireless devices are also critical pieces of the puzzle.

ECD: *What new microcontroller technologies are available to meet the growing demand for cloud connected embedded devices?*

VISHAKHADATTA: For many connected embedded devices such as motion and light sensors in a smart home, the cost of installing new wiring to power these devices can be prohibitive compared to the cost of the device itself. As a result, these connected devices must offer superior power efficiency so they can operate by battery or harvested energy sources. To meet the power efficiency requirements of connected devices, MCUs must support ultra-low power consumption through mixed-signal integration. An on-chip DC/DC buck converter, for example, can enable higher energy efficiency while allowing MCUs to operate all the way down to the lowest usable battery voltage. A 32-bit MCU with an integrated DC/DC buck converter can achieve 40 percent lower active mode power compared to a similar MCU without a buck converter.

MCUs used in connected devices ideally must support multiple power domains, enabling peripherals to operate autonomously at different frequencies with the CPU powered down. For example, a Direct Memory Access (DMA) technique can be used to collect sensor data and wake the CPU when there is a full buffer of data to process. This results in a greater sleep-to-wake ratio and higher power efficiency. A 32-bit MCU with a

dedicated Data Transfer Manager (DTM) hardware block can enable complex tasks to execute autonomously without CPU intervention. In these instances, the MCU core remains in its lowest power state until all tasks have completed. The DTM is useful in wireless data transfers in which raw data is processed through multiple operations before being delivered to the radio for transmission.

Connected embedded devices must be able to use wireless protocols such as ZigBee that are lightweight and offer data rates that reflect their requirements. The ideal RF technology depends on the specific application. For example, Wi-Fi is appropriate when high data rates are required for bandwidth-intensive tasks such as streaming video. For lower-bandwidth applications, 2.4 GHz ZigBee and sub-GHz RF technologies provide a more power-efficient wireless link that is easily integrated into the connected embedded device. For simple applications such as garage door openers or systems requiring long-distance connectivity such as smart meters, sub-GHz transceivers are an optimal choice. For mesh networks with a large number of connected devices, ZigBee technology offers a proven, robust solution.

A mesh topology is ideal for many connected device applications. Consider a home lighting system where the number of nodes can exceed 30 lights and sensors. Connected device applications based on ZigBee technology

provide self-configuring, self-healing mesh connectivity that can interconnect hundreds or even thousands of devices on a single network.

Emerging sensor technologies are also enabling new capabilities for connected devices. For example, CMOS-based humidity sensors can be added to smart thermostats or security systems to provide accurate relative humidity measurements. Many advanced mixed-signal MCUs include integrated temperature sensors that provide exceptional accuracy over an extended temperature range, making them ideal for connected devices that require economical yet high-precision temperature sensing.

ECD: *As you look ahead for the next few years, what trends do you see in the embedded design area and how will they affect your product development plans?*

VISHAKHADATTA: The Internet has made huge leaps in recent years. IPv4 is giving way to IPv6 so that every connected device will have its own IP address. Machine-to-Machine (M2M) communication is enabling connected devices to exchange and act on information without the direct end-user involvement. This growing web of connected devices – the Internet of Things (IoT) – includes smartphones, tablets, TVs, gaming consoles, home appliances, security systems, smart meters, and many other devices.

Ultra-low-power MCUs, sub-GHz transceivers, ZigBee SoCs, and sensor networks will form the backbone of the IoT. Until recent years, these components were not power efficient, robust, or small enough to meet the requirements of connected devices. However, semiconductor technology has advanced rapidly to enable the development of energy-efficient end points that can operate for many years on battery power or even indefinitely on harvested energy.

Despite these advancements, connected embedded devices are not as ubiquitous or intelligent as they could be. By analogy, the car you owned 20 years ago conveyed basic information through simple dashboard indicator lights. Nowadays, cars feature sophisticated infotainment systems that provide detailed information and intelligence. A similar evolution is occurring with connected devices, and the key to this added intelligence is software. While embedded components provide the foundation for connectivity, application layer software enables the underlying M2M interactions that ensure that connected devices operate reliably regardless of operating environments. Developers can implement advanced functionality through software that extends the range of autonomous control to enhance efficiency and convenience. For example, while it's helpful to be able to turn on a light remotely, it's even more useful when the lighting system alerts us that an LED bulb needs replacing. A smart home's sensor network could even determine when no one is around and power down all electronic devices. Such a simple innovation, multiplied over hundreds of millions of households, could save considerable energy.

ECD: *With ubiquitous connectivity dominating embedded designs, what security precautions are available to prevent unauthorized access?*

VISHAKHADATTA: Security for cloud-connected devices is a system-level challenge that must be addressed holistically through hardware and software. Semiconductor suppliers can help meet this challenge by embedding

AES encryption blocks in MCUs and wireless devices. The end application generally determines the type of security technology required for an embedded product. For wireless products based on ZigBee or Bluetooth, security is built into the wireless protocol.

For most simple embedded applications, AES provides a secure, cost-effective solution that's easy to implement in firmware or hardware. For low-bandwidth systems, such as a USB dongle, a simple firmware implementation of AES that uses a few kilobytes of code and minimal RAM can be effective. For higher-bandwidth systems, a hardware implementation of AES makes more sense, and there are many MCU products available with AES encryption peripherals. The benefit of choosing a flexible, commonly available encryption protocol like AES is that it does not define the hardware platform and lets engineers choose the right MCU for their embedded application.

Beyond AES, it is important for connected device developers to collaborate with software vendors and system integrators to tackle embedded security at the application layer.

ECD: *Software development is a huge portion of each new embedded development project. What development tools and libraries do you offer developers?*

VISHAKHADATTA: To streamline the development of embedded applications based on our 32-bit and 8-bit MCUs, Silicon Labs offers development platforms featuring interchangeable MCU and radio components and other subsystems.

Our complimentary Eclipse-based Precision32 IDE for 32-bit designs includes a compiler, debugger, and an online dashboard for application-critical information. A centerpiece of the IDE is our GUI-based AppBuilder software, which enables developers to graphically select their peripheral mix, optimize designs for ultra-low power, customize pinouts, and generate source code – all without having to write a line of code.

Our GUI-based Wireless Development Suite (WDS) software for EZRadioPRO transceivers enables developers to design and deploy sub-GHz wireless applications with little or no specific RF design experience.

For mesh networking applications based on ZigBee technology, we offer the EmberZNet PRO protocol stack, a comprehensive ZigBee development environment featuring visualization and debugging tools, and application templates for ZigBee Smart Energy, Home Automation, and Light Link profiles.

ECD: *Does your company offer any educational events or online classes to help embedded designers get started with microcontroller-centric projects?*

VISHAKHADATTA: We offer online video demonstrations and tutorials through our YouTube channel, <http://youtube.com/viralsilabs>. We also offer two-day ZigBee training classes in our Boston office each month. For in-depth customer education and training, we and our distributor partners offer training classes at classroom sites around the world. **ECD**

Diwakar Vishakhadatta is the Vice President and GM of Silicon Labs' Embedded System products group. He joined Silicon Labs in 1999 as the Wireless Director of Engineering prior to the divestiture of the company's cellular business to ST-Ericsson (then NXP) in 2007, at which point he became Vice President of Entry Cellular Products for ST-Ericsson. Diwakar rejoined Silicon Labs in 2009 as the Director of Isolation and Power Products, and then became the General Manager of Broadcast Audio products in 2011. Prior to Silicon Labs, he served as a Design Manager at Cirrus Logic. Diwakar holds an MSEE from Oregon State University and a BS from the Indian Institute of Technology.





Q&A with Kaivan Karimi, Executive Director of Global Strategy and Business Development for the Microcontroller group at Freescale Semiconductor

When implementing Internet of Things tech, remember: One size does not fit all

As the Internet of Things (IoT) continues to accelerate the need for cloud connected embedded devices, IoT use cases will all entail processing, sensing, software, wireless or wired communication, and security. But because IoT use cases are all different, one-size solutions won't fit all computing scenarios, as explained to our editors by Kaivan Karimi of Freescale Semiconductor.

ECD: *What new microcontroller technologies are available to meet the growing demand for cloud connected embedded devices?*

KARIMI: The focus on the Internet of Things (IoT) is driving the growing demand for cloud connected embedded devices. Embedded processing is at the heart of the IoT. However, there are layers of embedded processing that will be happening all the way from the sensing nodes on the edge of the network, through the cloud processing. Requirements common to all types of IoT-related use cases include sensing, processing, wired or wireless communication, software, and security – most of which involve microcontrollers or microprocessors in some fashion. Use cases vary significantly, as one size will not fit all.

Specific technologies include extremely low power 32-bit MCUs with a CoreMark score of 15.9 CM/mA, which means power consumption running CM is 6.684 mA. Such MCUs perform at almost $40\mu\text{A}/\text{MHz}$. Additionally, other technologies and strategies suited for IoT-related embedded processing include cost effectiveness for end sensor nodes and advancements in larger memory integration (both RAM and ROM), very low-power NVM technologies for read-intensive applications, seamless integration of HMI and haptics technologies, wired and wireless MCUs, and using robust tools and system software as

building blocks to get to market faster. All of these include an emphasis on ease of use and system solutions. A thorough and comprehensive security and tamper-protection strategy is also a must-have at all layers of embedded processing, and this is an area that is subject to a lot of innovation.

ECD: *As you look ahead for the next few years, what trends do you see in the embedded design area and how will they affect your product development plans?*

KARIMI: Embedded processing is being proliferated into new applications every day and the IoT trends have added new dimensions to these trends. I expect this will continue and will impact our development plans and have implications on product size, cost, power efficiency, and ease of use. Integrated precision analog, a robust set of peripherals across a wide portfolio, differentiating flash, a wide set of tools and enablement, and quality and reliability are all requirements needed for success in the embedded space. As an example, adding embedded processing to smart pills for digestible devices or adding embedded processing for smart shoes – versus the traditional MCU and MPU markets segments such as home automation or white goods such as washers, dryers, and so on – will require changes to how we build and package our devices to meet the constraints of the applications.

Wireless MCUs, for the most part, need a 32-bit architecture, yet the expectation is that the cost, size, and power specs will be less than the 8-bit products of a couple of years ago. Add the need for an ecosystem of software providers and you can see why ARM is becoming the architecture of choice for MCU designers.

ECD: *With ubiquitous connectivity dominating embedded designs, what security precautions are available to prevent unauthorized access?*

KARIMI: Security technology must be coordinated across the continuum of IoT embedded processing layers. For us, this means a system-level approach to security from the sensing nodes at the edge of the network, through various layers of embedded processing, all the way through the data centers and cloud processing. It also encompasses what is needed for a safe and secure automobile. Specifically, this system-level approach requires a wide range of peripherals and hardware and software technologies to support a secure design and protect against various forms of attack, depending on the use cases as well as the security needs of that segment application. There's no such a thing as "one size fits all" here, and some system-level techniques include use of crypto engines and secure memories that can automatically be erased upon the detection of tamper; other techniques include embedded flash

locking, debug security, and boot-up checks that ensure application software integrity. Use of security protocol accelerators and processors that integrate seamlessly with ARM TrustZone – which separates and protects secured keys and environments from the application space – is also becoming popular.

On the hardware front, the addition of cryptographic engines, embedded security modules, and protocol accelerators is important. On the software front, symmetric and asymmetric crypto middleware to support the hardware cores and architectures are required. Then for the application software, HDCP and DTCP-IP are examples of the software needed for DRM and content protection. Finally, wireless MCUs and MPUs and the implementation of networking security protocols such as IPsec, SSL/TLS/DTLS, SRTP, MACsec, and so on are a must-have for that part of the portfolio, above and beyond what we just talked about.

ECD: Software development is a huge portion of each new embedded development project. What development tools and libraries do you offer developers?

KARIMI: Today software is at least as important, if not more so, as the hardware it commands, and over time, we believe software will become a key differentiator when our customers choose our devices. As a semiconductor company, it's been our experience that it's important to not only offer your own software tools but also leverage the third-party ecosystem built around various cores, such as the ubiquitous ARM cores.

Besides development tools there are RTOS solutions, DSP libraries, encryption libraries, connectivity libraries, and Processor Expert software generation tools. We have our own development platforms – the Tower system and Freedom Development Platform.

We also have application-specific code for a variety of end segments. For

example, our wireless MCUs not only support the protocol stack and security software needed, but for select segments we support application layer profile software.

ECD: Does your company offer any educational events or online classes to help embedded designers get started with microcontroller-centric projects?

KARIMI: Yes. There are several hours of webinars and presentation materials on our website: www.freescale.com. In addition, we have domestic and regional "Designing with Freescale" events that focus on topics that are important to the embedded designer of particular geographies and regions and with specific sets of applications in mind. Lastly, on a biannual basis, we have our Freescale Technology Forum, which brings thousands of customers to meet with the Freescale engineering community and attend comprehensive classes of their choice. **ECD**

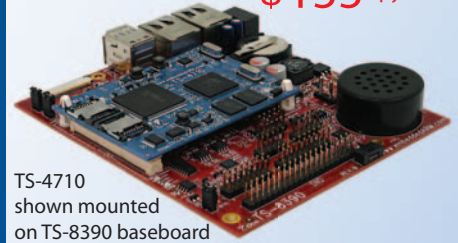
Kaivan Karimi is the Executive Director of Global Strategy and Business Development for the Microcontroller group at Freescale Semiconductor. In this role, he is responsible for defining and driving the technology, product, and business strategies related to the Internet of Things. Kaivan has been with Freescale for more than nine years serving in a variety of roles, including leading the wireless product management and networking baseband processing groups and serving as Director of Global Strategy and Corporate Development. Kaivan has more than 19 years of experience in the semiconductor industry. He has a Master of Sciences in Electrical Engineering from Florida Atlantic University and a Master of Business Administration from Baylor University.

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Application Life-cycle Management (ALM) software boosts testing and traceability for embedded product development

By Peter Varhol

Testing and traceability play a vital role in embedded product development. Traceability rendered via Application Life-cycle Management (ALM) software enables the team to automatically generate test cases that link back to requirements, and report defects that link back to test cases. By knowing that defects are addressed and test cases run successfully, the team can have an immediate and accurate accounting of the state of product requirements.

Fifteen or 20 years ago, many embedded systems consisted of an 8-bit processor with a few KB of memory and perhaps a couple hundred lines of code. Today, the explosion of embedded systems in automobiles, ATMs, cell phones, and other devices has dramatically changed that dynamic. It's not uncommon to see multiple 32- and 64-bit multicore processors on an Ethernet network, running multiple applications totaling hundreds of thousands of lines of code in these systems.

As these devices grow in complexity, it has become a significant burden for project teams to confirm that software requirements have been tested and tests can be traced back to requirements. In many cases, even with extensive testing, teams might not know whether they have successfully met all of the product requirements.

A high level of complexity and the need for greater system reliability also bring

quality to the forefront. Older embedded systems were either simple enough or not important enough to spend time finding, tracking, and fixing software defects. Today, defects in embedded systems can be just as common and even more important than those in enterprise applications. And because of the greater complexity, it becomes more important to be able to trace defects back through test cases and to requirements so that teams have increased transparency into issues and the features they affect.

Today's complex embedded systems can have hundreds or thousands of requirements, with as many or more test cases. Tracking and executing these test cases, and using that information to make sure requirements have been satisfied, becomes a real concern for teams that have to gain better control over their processes. To address this challenge, teams need an automated way to link artifacts so that data about one

artifact becomes information for others. Application Life-cycle Management (ALM) software can help.

The value of traceability

Traceability is the practice of linking requirements to downstream artifacts like risk, test cases, defects, and even source code. Links enable two-way communication of change and progress between related artifacts.

For example, once a product has requirements, those validating it need to write test cases that ensure the product under development is meeting the design requirements. If test cases fail, the resulting defects are recorded in an issue tracking system.

Traceability enables product teams and stakeholders to understand and derive valuable information from the relationship between product development artifacts. By looking at defects, it is



Source code can be traced to defects and back to requirements, closing the loop between design, development, and testing.



possible to determine which requirements haven't yet been satisfied. Teams can use this information as an important guide to determine whether a product is ready to ship, and also to triage defects to satisfy the most important requirements first.

But effective traceability can do a whole lot more for a project. If safety risks are identified as a part the product, these can be linked to nonfunctional requirements that can then be traced to downstream artifacts. Source code can be traced to defects and back to requirements, closing the loop between design, development, and testing. In the same vein, when defect fixes are checked back in to source control, and tests run to confirm the fixes, the team and other product stakeholders know very clearly that the corresponding requirements have been satisfied.

Traceability also provides essential project information that often can't be obtained in any other way. It provides testers with an easily understandable and reportable measure of product quality. By knowing which requirements remain unsatisfied, and whether they have issues logged against them, testers can estimate the time remaining to product completion. Last, traceability enables teams to better understand the work remaining, and in which functional areas of the product that work remains.

Managing requirements, test cases, and defects using Microsoft Word or Excel is challenging enough. But tracing requirements through test cases to defects and back to requirements is impossible without a real tracking system.

Building traceability into an embedded project

How does a product team go about building traceability? It starts with

requirements. Once functional requirements are defined, risk analysis and mitigation begins, and testers generate test cases that will enable them to determine if the product under development meets those requirements.

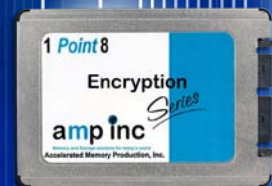
As testers run test cases, the cases that pass indicate that the related requirements have been satisfied. If test cases fail, testers record defects that are associated with those test cases and, by linkage, to the requirement under test. The defects are associated with the related test cases and test runs, providing a link back to the testing stage.

Ideally, this linking is done automatically. While it is possible to manually create and maintain links between project artifacts, the work involved is detailed and constant. Whenever a requirement or

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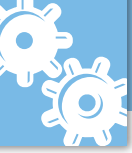
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test case changes, links have to be manually reestablished. The effort needed to manually create and maintain links between requirements, test cases, and defects is excessive, especially if those links have to be examined and updated almost daily.

In most projects, testers execute test cases multiple times, in different test runs. Tests are rerun when an initial run fails, and the fix needs to be verified. Tests are also run additional times for regression purposes, as the embedded software product scope grows to meet more requirements.

Tests may also be performed manually, or in an automated fashion using a testing harness. In practice, most teams do some of both. Manual testing is typically done the first time, and recorded using an automated tool. Subsequent tests are often run automatically, unless the functionality changes significantly. Test results provide the basis for traceability information, through either defects or successful test results. Both can trace back to requirements and other artifacts.

With automated testing and traceability, testing teams have the opportunity to perform at a high level, accomplishing testing within the product schedule and providing valuable information on quality and requirements fulfillment to product stakeholders. This makes testing more relevant to all stakeholders, especially in the latter stages of product development.

Ideally, this starts with requirements, but must also incorporate test management, defect tracking, and source code management. For products with safety implications, it should also incorporate risk management and mitigation. ALM software, such as TestTrack from Seapine Software, offers the ability to create, manage, and link artifacts from the beginning through the end of a design and development project. Figure 1 illustrates how a traceability matrix can help teams easily determine how defects or requirement changes can affect other parts of a project.

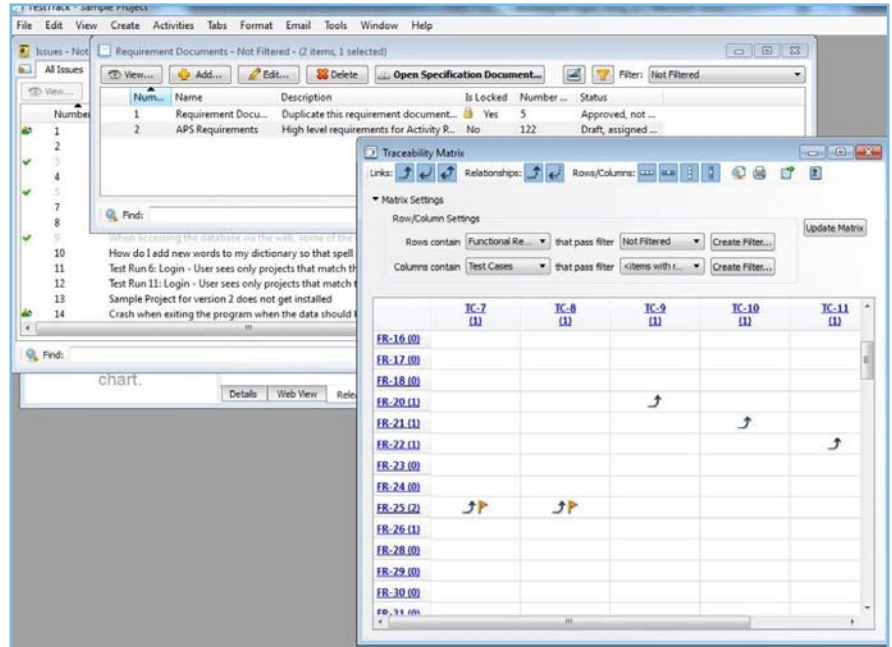


Figure 1 | Traceability in application life-cycle management solutions such as Seapine TestTrack provides embedded project teams the ability to quickly and easily understand how defects and other changes affect the project.

Traceability and safety-critical projects

Traceability has traditionally been used for large development projects with hundreds of engineers and testers, and thousands of requirements. This has been primarily the realm of commercial and military aviation and space systems, where the need for information to combat complexity overcame the cost of that information. These systems can take years to develop and bring to market, making the information gained through traceability especially valuable as team members leave and new ones arrive.

But with automation, such as that provided by ALM software, the cost and effort of traceability can be driven down to the point where it makes sense for smaller projects, and with shorter schedules. Automatic traceability between requirements and downstream artifacts, and back upstream from defects to requirements, makes identifying and communicating development hurdles and issues faster and more transparent.

Projects, such as smartphones, automotive systems, and smart industrial control equipment, benefit from better traceability. As more testing teams incorporate automated ALM methods to collect and disseminate traceability information, product quality will continue to improve, even as systems become more complex. **ECD**



Peter Varhol is the solutions evangelist at Seapine Software and has authored dozens of articles and spoken during many industry conferences and webcasts. His past roles include technology journalist, software product manager, software developer, and university professor. He has advanced degrees in computer science, applied mathematics, and psychology. Contact Peter at varholp@seapine.com.

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Static analysis-enabled advanced program visualization eases the development process

By Paul Anderson

Advances in static analysis and graphics technology have enabled new software visualization tools that can yield insights into the structure of complex programs, making the development process easier.

It has long been evident that pictures are often better than text in helping developers understand complex programs and review code, so the use of program visualization in software development is widespread. UML and other primarily graphical formal design notations are now widely accepted as the best standard mechanisms for communicating various aspects of software design. Some model-based design tools can generate code directly from graphical representations. At the informal end of the spectrum, developers often sketch out flowcharts or call graphs to inform themselves or others of important aspects of the software.

UML diagrams are all very well for designs, but suffer from two important drawbacks when used later in the development process to help developers understand existing code. First, as design abstractions they (correctly) omit some implementation details, but those details

are often important if the goal is to understand the finished software. Second, design diagrams are very often stale with respect to the implementation, leading to an inaccurate or incomplete portrayal of the system as it actually exists.

Informal visualizations tend to be ephemeral and rarely make it into the official record of documentation for the program.

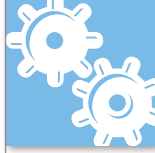
Very often, the only artifact that a developer has to work with is the code itself. Unfortunately, code visualization tools have historically been subject to problems such as confusing diagrams and difficulty in scaling to large programs. However, new tools are emerging that are beginning to solve these problems. The key advantage of these tools is their ability to generate useful visualizations directly from the code itself. As such they are guaranteed to be accurate and up to date.

Program structures

Programs are made up of a large and complex web of dependences between lots of different kinds of components. A visualization that attempted to show all of these simultaneously would be too unwieldy to be useful. Indeed, there is no single ideal visualization. Instead, the most useful visualization for a particular task is the one that corresponds to the mental model used by the engineer undertaking that task. Some of the more useful program structures are the following:

Type hierarchy

Developers usually find it very useful to see the various ways in which data types can relate to each other. The standard UML class diagram represents the class hierarchy in a form that is very easy to understand, with the association and containment relations at a higher level of abstraction than the code. While this is good from a design



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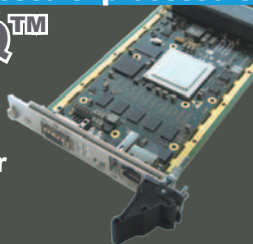


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The graph model

Most common program visualizations use the same graph-based paradigm: Shapes – or nodes – represent items such as files, variables, functions, and so on, and lines – or edges – represent relationships such as dependence or inclusion. Nodes may be nested inside other nodes to indicate hierarchical relationships such as containment, while node size, shape, and color can be used to express other properties of interest. Nodes and edges may be labeled with text. The layout of the nodes in two dimensions can be used to communicate important information too.

A graph with a few dozen nodes and a few hundred edges is pushing the limits of human cognition. Good tools can scale to very large graphs because they offer features to help the user pick out important features.

Sidebar 1 | It is possible to generate layouts for quite large graphs, though their usefulness is limited by the capacity of the human brain.

perspective, programmers often find it more helpful to see the concrete relations between types.

Include tree

C and C++ programs often can make heavy use of the preprocessor. If done well, this can make programs easy to understand, but very often it interposes a layer that gets in the way of understanding. Undisciplined use of the preprocessor can lead to dependence tangles that cause build problems and hurt reusability potential. Consequently, being able to see which files are included where can help engineers unravel complex dependences.

Call graph

The call graph, in which each node represents a subprogram and each edge indicates one or more calls to another subprogram, is often considered the most helpful program structure to visualize. Subprograms are convenient units for developers to reason about, and the calling relation captures data and control flow nicely. A call graph for even a small program can have hundreds of nodes and thousands of edges (see Sidebar 1), so it has long been recognized that it is essentially useless to visualize the entire call graph all at once. Instead, researchers have focused on ways to visualize the call graph in smaller, easily digestible parts.

New call graph techniques and tools

Because of the importance of call graphs in program understanding and the challenges involved in visualizing them, they have been the subject of much research. In particular, new techniques have been developed to help tame call graph complexity. This section describes some of the mechanisms that have been implemented in static analysis tools delivering advanced visualization capabilities.

Top-down views

A top-down view of a call graph helps answer user questions such as “What are the high-level components of this program, and what are their properties and relationships?”

To solve this problem in the context of program understanding, tool designers take inspiration from geographic mapping programs such as Google Maps. As the user zooms in, more detail starts to resolve: first cities, then towns, villages, and ultimately, individual buildings. The level of detail shown is coupled to the zoom level.

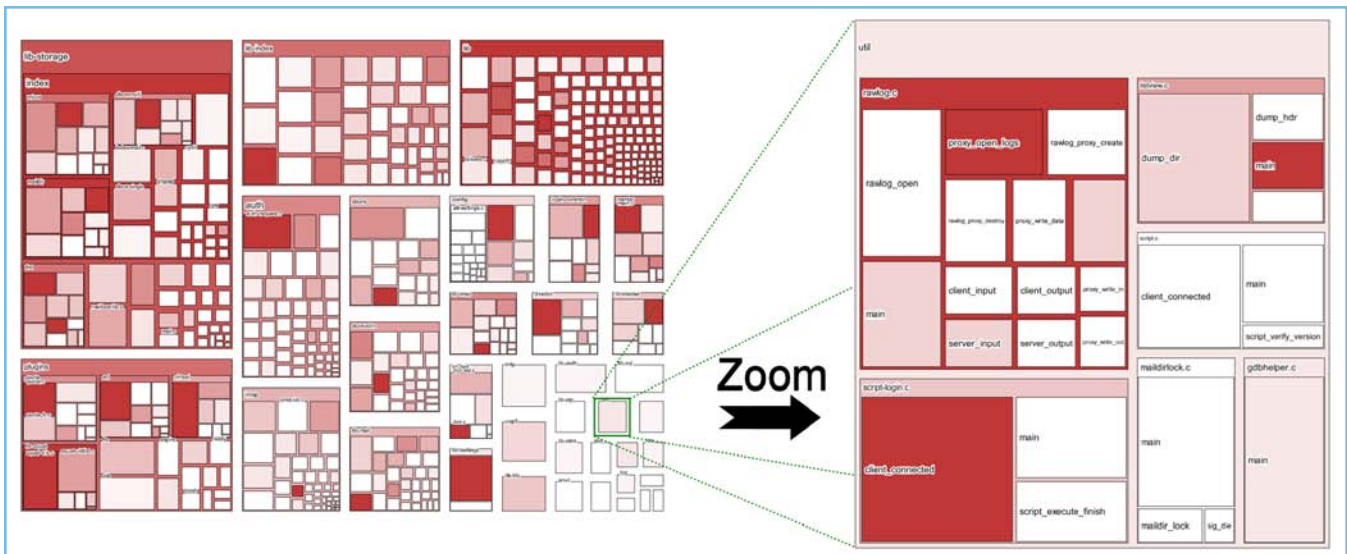


Figure 1 | A treemap for a medium-sized program (approx 200 KLOC). The strength of the color indicates the number of static-analysis warnings detected within each part.

Programs are made up of components that are themselves made up of smaller components, and so on, forming a hierarchy; although the direct calling relationship is between low-level sub-programs, it can be projected up to higher-level components that contain those subprograms. In the top-down view of a call graph, the highest level items are directories. These can contain some combination of subdirectories and files, and the files will then contain sub-programs. Thus, an edge from one box to another simply indicates that a sub-program contained in the first box calls a subprogram contained in the second.

This approach turns out to be very effective at helping developers gain a deeper understanding of a program.

In the left window, the user has selected the edge from component *find* to component *gnulib*. The function calls summarized by this aggregate edge are shown in the pane to the right. The right window illustrates that more detail is shown when the user zooms in to see a single function. This zoom level further illustrates an important feature: It is important for the developer to be able to relate the view to the code itself. Consequently, selecting one of those functions causes the source code of that function to be shown.

Bottom-up views

Often a developer will want to take a bottom-up approach. This helps users answer questions such as “What does this procedure do, how does it fit into the structure of the program, and how is it invoked?”

For example, say a program has crashed in a particular function. To find the cause of the crash and to plan a fix, the developer is likely to begin by focusing on that single function, then explore its immediate neighborhood to see what other functions it calls and is called by. Previously done manually on a whiteboard, a tool can handle the drudgery of drawing and layout automatically.

Metrics layers

The utility of a visualization can be increased by adding layers to show the value of various metrics. An example is shown in Figure 1. This shows a particularly useful visualization – the treemap. In a treemap, the area of a node is proportional to a metric – usually a metric that encodes the size of the item. Subnodes are then tiled inside the top level node. Edges are usually not displayed. In this example, the color intensity of each item encodes the number of code vulnerability warnings issued by the static analysis tool.

From this view, it is easy to pick out the components of the program that are the most risky. Treemaps are very effective for showing deeply nested structure, and are also very amenable to the zooming paradigm discussed earlier, where more detail is shown at higher magnifications.

These visualizations are most useful when developers use them interactively to pan around and zoom in and out, or even add and remove nodes and edges. Interacting with such an interface can be extremely frustrating if it is not sufficiently responsive. Showing hundreds of nodes and thousands of edges can be a challenge. **ECD**



Paul Anderson is VP of Engineering at GrammaTech. He received his B.Sc. from Kings College, University of London and his Ph.D. in Computer Science from City University London. Contact him at paul@grammatech.com.

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Q & A



Continua Health Alliance aims to cure top telehealth industry challenges

Q&A with Continua Health Alliance members Ian Hay, Barry Reinhold, and Frank Wartena

By Sharon Hess, Managing Editor

Striving to cure telehealth challenges – including connected health equipment ease-of-deployment, integration of telehealth data into care providers' normal workflow, and meeting changing patient needs – is all in a day's work for the nonprofit Continua Health Alliance. A primary technical focal point for the organization is to enable personal connected health devices' interoperability/plug-and-play connectivity. And, as the Affordable Care Act (aka "Obamacare") takes hold, the need for personal connected health device connectivity will only increase, as mentioned by Alliance members Ian Hay (Orange), Barry Reinhold (Lamprey Networks), and Frank Wartena (Philips Research Europe) in the following interview.

ECD: Briefly describe the Continua Health Alliance – when formed and by whom, how many members, technology focus.

CONTINUA: Continua Health Alliance, established in 2006, is an international not-for-profit industry organization enabling end-to-end, plug-and-play connectivity of personal health devices and services. Continua convenes industry standards that enable personal connected health technologies, to move health and wellness into the day-to-day lives of consumers and improve health management, quality of life, and clinical outcomes, while reducing costs.

The Alliance's activities include publication of interoperability Design Guidelines, a certification and brand support program, events, and collaborations to support technology and clinical innovation, as well as promotion of the end-to-end ecosystem. Continua is working with a number of countries and national health ministries around the world to support the development and implementation of groundbreaking national connected health initiatives.

The Alliance is the industry voice with employers, payers, regulatory bodies,

government agencies, and care providers, and its policy initiatives influence advocacy and legislative and regulatory agencies on the state, regional, and national government levels. With approximately 220 member organizations reaching across the globe, Continua comprises technology, medical device, and health-care industry leaders and service providers dedicated to making personal connected health a reality.

ECD: What is the Alliance's mission, and how does it aim to achieve it? Also briefly describe a couple of the design guidelines/specifications the Alliance has passed, and when.

CONTINUA: As mentioned, Continua's mission is to convene global technology standards as the basis for its interoperability Design Guidelines that promote end-to-end, plug-and-play connectivity for devices, systems, and services in personal connected health. Continua also works to foster independence and empower people and organizations to better manage health and wellness. Continua implements partnerships with international standards bodies – with a total of 13 now represented within the guidelines, including IEEE, IHE, HL7, and W3C – to establish Continua as the

global framework for connected health systems.

Continua Design Guidelines make the collection and sharing of personal health data convenient and secure for consumers and health-care providers, and are proven to decrease time to market and reduce development costs. For example, in Japan, Continua-certified devices used in a disaster relief effort for cardiac patients following the 2011 tsunami decreased time to market from three months to just three weeks, and reduced development costs by as much as \$80,000 per device. Continua's 2012 Guidelines, which are now publicly available, include products that incorporate Bluetooth Smart, the low-energy technology at the heart of the Bluetooth v4.0 specification. Continua first issued Design Guidelines in 2009, and provides updated versions of its guidelines each year to further provide enhancements and new technologies.

Certifying a device with Continua guarantees that mandatory and optional functions implemented in a device will work with any other peer device that passed the Continua certification program. It also means guaranteed access to tools and resources throughout

the process, including the Continua Enabling Software Library (CESL), test tools, Continua certification experts, premarket interoperability testing, technical operations leads, and brand support for certified products.

ECD: *What are the top 3 biggest technical challenges faced by the medical/telehealth community? How will/should those challenges be mitigated?*

CONTINUA: The top three are:

1. Integrating data from personal connected health devices or systems into the normal workflow of care providers: Currently, personal connected health tools are separate from the regular EHR [Electronic Health Record] and IT tools that care providers are using for their normal work. There will often be dedicated staff that reviews the data transmitted from devices in patients' homes and takes action based on that data. However, in many cases, that data never makes it into the normal health record of the patient. To make connected health part of normal clinical practice, the relevant data from these systems needs to be integrated into EHRs. Continua has developed an interface for this data, in close collaboration with HL7 and IHE, which we call the *Health Reporting Network* interface. We believe that EHR vendors should implement this interface such that they could receive relevant information from personal connected health devices and systems. Meaningful Use stage 3 would be an excellent mechanism to drive the adoption of this interface in EHRs.

2. Achieving easy deployment of connected health equipment:

The ease of setup and teardown of devices in patients' homes is a critical factor to a cost-effective deployment of this equipment. Today, this might require putting an Internet subscription in place in case the patient doesn't have that yet, sending an installer to

the patient's home to connect the devices to the local Internet gateway, and sometimes pairing the sensors to the connected health hub. Cellular technology is an excellent way to simplify the deployment of personal connected health devices, as no extra steps are needed to hook the devices to the Internet and, in many cases, sending an installer is not required. The duration of the deployment

of the equipment in the patient's home determines if it is cost-effective to spend money on a cellular connection and to remove the need for sending an installer.

3. Accommodating the changing needs and preferences of patients:

Patients with a chronic condition often develop additional chronic conditions over time. When such patients are using personal

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connected health technologies, monitoring systems would need to accommodate those changes in the patient's health status by adding extra measurement devices and providing additional services. Also, a patient might already be using some measurement devices (for example, a glucose meter or a weight scale) when they enroll in a connected health program. Ideally patients would be able to use existing measurement devices, and add additional measurement devices as needed, within the limitations of the regulatory framework.

Enabling such plug-and-play of measurement devices requires the implementation of solid interoperability standards, which Continua facilitates through its Design Guidelines and certification program. Wider adoption of these standards by medical device and connected health hub manufacturers will enable more flexibility in the setup of personal connected health devices and systems and cater to the needs of patients and providers. In parallel, more discussion with the U.S. Food and Drug Administration (FDA) is required to ensure the safety and efficacy of such flexible personal connected health solutions.

ECD: *Which historical or nascent technologies have revolutionized telehealth/medical technology the most? Why/how?*

CONTINUA: Mobility represents, arguably, the biggest revolution in personal connected health. More specifically, mobile broadband technology enabled by WiFi and cellular has enabled connected health to gain mobility by removing reliance on POTS [Plain Old Telephone System] in a fixed location to provide service. Broadband provides a step in the right direction, but still requires some level of setup in the home. Even using WiFi to allow sensors and devices to move within the home can raise issues resulting from interference and pairing/security of devices to the home access point. Mobile broadband

removes the setup issues but can also suffer from coverage issues depending on the location, so it is not always the most suitable choice.

However, the benefits of enabling mobility both within and outside the home have allowed for a new range of services to be created. An example of this is geofencing, which uses mobile technology to define boundaries that the device must stay within or it will immediately set off an alert to care providers. Using location-based services, the patient can be located and aided. This type of monitoring can be especially beneficial for Alzheimer's or elderly patients. Being able to free the provision of care from a specific location by using certified devices with interoperable interfaces is enabling the creation of a new range of services.

ECD: *What is the best path to achieving the connectivity so vital in telehealth/home health technology today? Where do Android- and iOS-based devices fit in – now and in the future?*

CONTINUA: As mentioned earlier, cellular connectivity provides a great way to simplify the deployment of personal connected health equipment in patients' homes. In addition, off-the-shelf mobile devices such as smartphones and tablets will play an increasingly important role in connected health setups. Managing chronic conditions, which often requires FDA approval, will likely continue to require "locked down" devices. Over time, dedicated versions of off-the-shelf smartphones and tablets will replace the current proprietary connected health hubs; a number of examples exist in the market where specific versions of Android phones and tablets are used as a hub. In the fitness and wellness domain, people will be able to use their own mobile devices with health-related apps and connected health sensors. The app stores of Google and Apple are full of health-related apps and measurement devices such as weight scales and blood pressure cuffs, which can increasingly be

connected to phones and tablets. The Continua interoperability guidelines play a key role in leveling the playing field and creating a healthy ecosystem where apps, phones, and medical devices can easily be combined.

ECD: *Which technologies are needed most in the telehealth/medical realm but not yet available?*

CONTINUA: Actually, the technologies needed most for personal connected health are broadly available today. There are many connectivity options across a variety of technology types, each with specific benefits depending on the need, whether it is out-of-the-box connectivity via Machine to Machine (M2M) cellular connectivity, a smartphone, or a home gateway connected to a consumer's broadband connection. There are also many medical devices that can connect to a wide range of devices over a number of short-range radio technologies that are required to enable remotely provided care.

ECD: *How is the telehealth/medical technology industry landscape changing now, in light of "Obamacare," and how will it change in the next 5 to 10 years?*

CONTINUA: The health-care industry is facing a number of challenges, including payment reform and accountable care, at a time when we have fewer health-care providers available to care for a growing number of patients. That creates demand for personal connected health. Providers are going to have to care for the current patient base, plus the millions of new patients who will be seeking care under the new access reform policies. As a result, providers will have to expand their tool set beyond the office or emergency room visit. Personal connected health devices and systems that are easy for consumers and health-care providers to use are becoming vital in the new health-care delivery paradigm. End-to-end, plug-and-play connectivity for personal connected health devices will enable remote monitoring of

chronic conditions such as hypertension and diabetes, and will empower patients to better self-manage their health and wellness.

With new models of care delivery, and as the Affordable Care Act takes effect, we are seeing the need to manage care at the individual level more closely. This allows us to keep individuals out of the expensive modes of care – emergency rooms and hospital beds – and enables patients to stay healthy at home. Also, the need to provide a pathway for those already in hospitals to return home sooner will require follow-up and monitoring, which can be provided through personal connected health. Using this technology, we have already seen a drop in six days for in-hospital stays, thereby allowing more critical needs to be addressed while reducing costs. This is the future of health-care delivery. **ECD**

Ian Hay is Head of Emerging Ecosystems at Orange and has more than 23 years of experience in telecommunications. He was unanimously elected as the Chair of the Technical Working Group at Continua in 2012, managing the expert group to deliver the Design Guidelines.

Barry Reinhold is the President and Chief Technology Officer of Lamprey Networks. He founded LNI in 1999 and has more than 20 years of leadership experience developing Internet technologies with different standards organizations. He chairs the Service Task Force for the Continua Health Alliance.

Frank Wartena, M.Sc. is Senior Scientist, Care Management Solutions, at Philips Research Europe, and has fulfilled Secretary of the Use Case Working Group and Vice Chair of the Technical Working Group roles in the Continua Health Alliance. He has been recognized for his contributions with two Continua Key Contributor Awards in 2007 and 2010.

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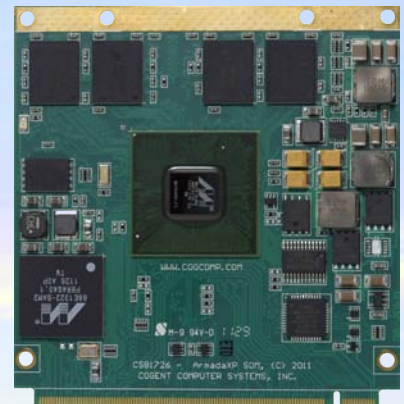
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Breathing a sigh of relief: Increased patient safety through advanced ventilator electronics

By Barbara Schmitz

Compact, rugged computing modules lay the framework for lifesaving advancements in today's ventilator technologies. Increased ventilator control is paving the way for optimum patient health as well as reduced hospital stays and associated costs.

Achieving optimum respiration and precise diagnostics of lung function via a ventilator are crucial to instituting safety precautions for patients in ICUs as well as in post-anesthesia care units and emergency rooms.

While ventilators are critical, lifesaving devices for patients unable to breathe on their own, as with any medical process, there are certain risk factors, particularly to those patients hooked up to a ventilator for an extended period of time.

Ventilator-Associated Pneumonia (VAP), an airway infection that can develop more than 48 hours after a patient has been intubated, is the leading cause of death amongst hospital-acquired infections. It exceeds even the rate of death resulting from central line infections, severe sepsis, and respiratory tract infections in nonintubated patients.

While preventing pneumonia of any variety is a goal of all medical care professionals, there are some reasons to be particularly concerned about the impact of pneumonia associated with ventilator use.

Perhaps the most concerning aspect is the high level of death associated with VAP's onset. Hospital mortality of ventilated patients who develop VAP is 46 percent compared to only 32 percent for ventilated patients who do not develop VAP.

VAP prolongs time spent on the ventilator as well as the length of a patient's time in the ICU and overall hospital stay after discharge from the ICU, adding an estimated \$40,000 to a typical hospital admission.

Overall, the best defense is a good offense – reducing the amount of time a patient is intubated decreases the risks of VAP and associated complications. Better ventilator control will reduce the amount of time a patient spends intubated, and therefore decreases the risk of VAP (Figure 1).

Intuitive monitoring, enhanced operation

Ventilator control including patient monitoring for invasive or noninvasive ventilation (with or without an artificial



Figure 1 | Patient safety is greatly increased by avoiding VAP-related incidents.

airway access) is integral to reduced patient risk, proper operation, and optimum cost management. The quicker a patient comes off a ventilator, the less chance there is for VAP to occur.

The ventilator is an important piece of equipment as it must provide a user interface that improves safety through intuitive operation and monitoring, while offering superior performance in complex environments that improves patient outcomes without breaking the bank.

Thus, companies such as Hamilton Medical are developing innovative respiratory equipment such as the HAMILTON-S1 with its INTELLiVENT-ASV technology, providing automated adjustment of oxygenation and ventilation to meet the individual needs of the patient. The Adaptive Support Ventilation (ASV) technology features closed-loop control technology to reduce the patient's ventilation time significantly.

Weaning time with such a ventilator can, under certain circumstances, be reduced by more than 50 percent in comparison to conventional ventilation, significantly reducing the risk of infections and lung damage (Figure 2). The integrated electronics within the unit help facilitate this important aspect of patient safety, and are described in the next section.



Figure 2 | Adaptive support ventilation technology significantly reduces the time a patient spends on a ventilator.

Adapting to patient needs with fewer preset parameters

Unlike conventional modes that require health-care providers to set many of the unit's parameters, such as Tidal volume (Vt), positive inspiratory airway pressure (Pinsp), inspiration (Ti), and expiration (Te), closed-loop ventilation with ASV requires attention to fewer main settings: Minute Volume, PEEP, and FiO2. This approach helps medical staff easily guide the patient into a favorable breathing pattern and promotes early weaning. Studies show that adaptive support ventilation:

- › Can ventilate all types of intubated patients – whether active or passive and regardless of lung disease.
- › Reduces health-care provider interaction by adapting to patient's breathing activity more frequently, causing fewer alarms and better patient management. Because the unit adapts to the needs of the patient, hospital staff intervene less, optimizing workflow and maintaining safe levels for the patient.
- › Adapts to changes in the patient's lung mechanics over time. Changes in measured respiratory mechanics contribute to the automatic modification of the ventilator. When the machine recognizes an air intake effort by the patient, the algorithm switches automatically from Pressure Controlled Ventilation (PCV) to Pressure Support (PS) mode, placing respiratory rate under the control of the patient. The ventilator reverts to PCV if the respiratory rate dips below the optimal value set for that patient. The PS level is continuously adapted to deliver the desired volume minimum.

Sidebar 1 | Adaptive support ventilation technology requires health-care provider attention to fewer main settings and promotes early ventilator weaning.

Additionally, user setup requires much less health-care provider attention to main settings (see Sidebar 1).

Sophisticated embedded electronics go mobile

As medical equipment becomes mobile, meeting the requirements of volume and weight as well as temperature, drop, and humidity can be a challenge. The embedded electronics within these systems need to be robust, compact, and lightweight to keep pace with product developments.

Advanced computing performance and networking features are necessary to build up the backbone for the communication between medical devices and management systems as well as to increase patient safety.

Compact Computers-On-Module (COMs) have proven to be an ideal method for integrating the ventilator's hardware with the electronics to provide seamless operation, improved monitoring, and ultimately, better patient safety. Because they are complete computers on a small

module that can be placed inside a rugged housing, COMs offer tremendous technology and design benefits in medical equipment development.

These all-in-one modules comprise hardware (CPU, chip set, memory, I/O) that is not fixed to any application-specific function, and an FPGA programmed in VHDL code for user-defined I/O.

The modules are based on the Embedded Systems Module (ESM) specification developed by MEN Mikro that defines one 71 x 149 mm form factor very close to the PMC format. In fact, this allows the use of up to three ESMs on one 6U carrier card (for example, CompactPCI or VME) or one ESM and two PMCs. And support of an FPGA directly on the CPU module allows flexible user-defined I/O extension.

The versatile ESM modules incorporate a robust PCI-104-type connector and soldered components to withstand shock of 15 g for 11 ms and vibration of 2 g from 10 Hz to 150 Hz (sinusoidal) as well as bump of 10 g for 16 ms.



They have been designed to operate in temperatures from -40 °C to +85 °C and can be conformally coated for extra protection when used in harsh medical environments. This includes imaging equipment and patient monitoring devices that are becoming increasingly more portable, making volume, weight, temperature, drop, and humidity increasingly important considerations.

Many ventilators are relying on this ESM COM concept, utilizing standard components based on a reliable PowerPC CPU with a 32-bit processor operating at up to 400 MHz and 700 MIPS. The FPGA for these devices is flexible and, depending on the version, up to 32 standard and custom IP cores can be loaded into the FPGA (Table 1). Through the FPGA, the necessary flexibility and adaptability to the application are achieved. Connection to the device and the application-specific I/O (sensors, ventilators, and so on) is

made possible through carrier boards optimized for this purpose.

Processing requirements are high to ensure accurate patient monitoring. Two 8-channel ADCs polled via two Serial Peripheral Interfaces (SPIs) are located on the carrier board. The safety-critical SPI cores control and monitor ventilation pressure and flow.

For the control aspect of the ventilator, all eight channels of the ADC must be read at once and the corresponding pulse width modulators must be written once every millisecond, constituting the final act of the control cycle. The monitoring portion requires reading the eight ADC channels once every 10 milliseconds.

Without participation of the PowerPC CPU, the data is preprocessed, leaving system capacity remaining on the PowerPC as a reserve for other tasks.

Therefore, even if the ventilation is working on highest load level, additional functions like interactions with the control panel will not cause ventilation interruption.

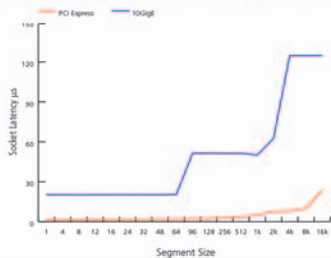
System communication is at the forefront of the ventilator's design. In fact, the safe alarm feature operates via redundant monitoring of the COM through the processor and the carrier via the programmable logic.

Because the ventilators need to be more sophisticated and easier to use to combat errors while maintaining transportability, the described COM concept that reliably controls the devices offers the complete functionality of a standard computer in a much smaller space.

Big benefits from compact computing
Because they incorporate a complete computing system on a single board,

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Input type	Function
Up to 8 UARTs	Communication with data logger, microcontroller on carrier, or different CO ₂ and O ₂ sensors
Up to 6 PWMs	Valve control; speed control of ventilators
Up to 60 GPIOs	General-purpose inputs for system flexibility
2 SPI interfaces	Time-synchronous polling of A/D converters

UARTs: Universal Asynchronous Receiver/Transmitters
 PWMs: Pulse Width Modulators
 GPIOs: General Purpose I/Os
 SPI: Serial Peripheral Interface
 A/D: Analog-to-Digital

Table 1 | Typical functions implemented on the FPGA

these modules bring more processing power into a smaller space. The flexibility of using a carrier card to adapt to specific applications, coupled with the ruggedization and standardized form factor, further enhance the use of this embedded computing concept in advanced medical electronics. Intelligent ventilation can utilize this technology to help deliver superior performance in complex environments while reducing costs and saving lives. **ECD**

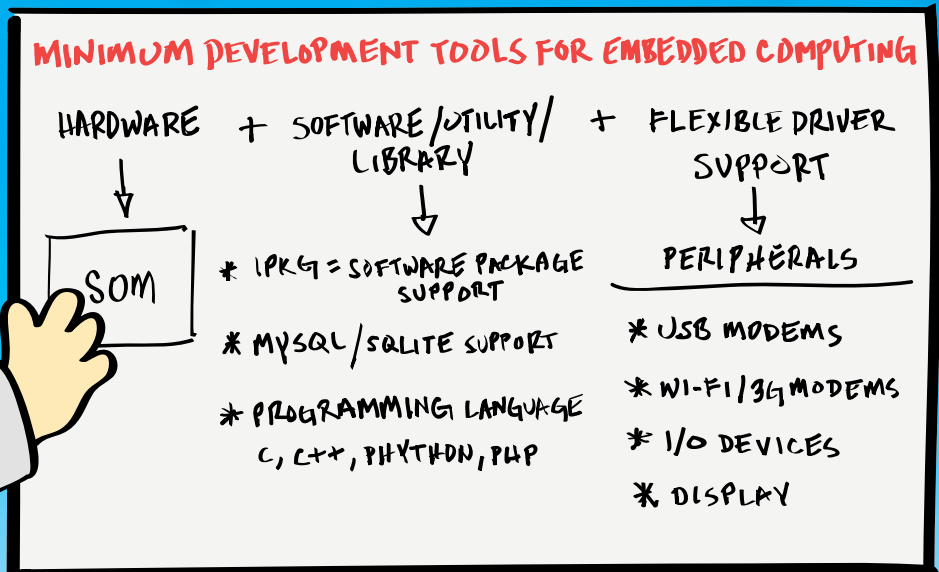


Barbara Schmitz is Chief Marketing Officer at MEN Mikro Elektronik. She graduated from the University of Erlangen-Nürnberg and completed a marketing and communications apprenticeship in Nürnberg.

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Gumstix SBC targets the embedded market

Known for small, low-priced processor boards, Gumstix recently announced Pepper, its first single board computer for the embedded systems market. The module is designed around the Sitara AM3359 ARM Cortex-A8 processor from Texas Instruments and features 512 MB of DDR2 memory, 802.11 b/g/n wireless networking, Bluetooth 3.0, a microSD card slot, audio connectivity, a console port, and two USB on-the-go ports.

Pepper also offers a 4.3" LCD touch screen, expansion headers for interface applications, and GPIO-controlled push buttons/LEDs. The module also supports the open source software Yocto Project with tools and templates to help designers create custom Linux-based systems for embedded products.

Gumstix | www.gumstix.com | www.embedded-computing.com/p371455

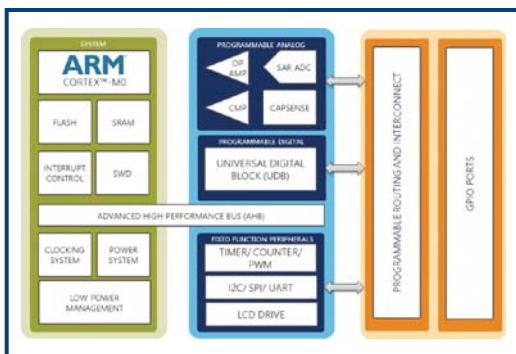
Development kit simplifies Qseven system startup

Allowing designers to evaluate the most popular interfaces for embedded applications, MSC Embedded offers ready-to-run starter kits based on Qseven modules featuring the AMD Embedded G-Series Accelerated Processing Units (APUs). The MSC Q7-SK-A50M-EP4 Starter Kit consists of a 3.5" Qseven baseboard Q7-MB-EP4 with a heat spreader, heat sink, and an integrated power supply with cable kit. The kit comes with a ready-to-run Linux installation in flash disk to enable an out-of-the-box functional experience.

Along with the starter kit, the user can separately select the Qseven module with the most suitable processor and clock speed from the MSC range of Q7-A50M modules. All processors come with the built-in AMD Radeon HD6250 Graphics Processing Unit (GPU), which delivers very high graphics performance, enables dual independent high-resolution displays up to Full-HD, and supports OpenGL 4.0, DirectX 11, and OpenCL 1.1.



MSC Embedded | www.msembedded.com | www.embedded-computing.com/p371456



Reconfigurable architecture challenges stand-alone microcontrollers

A new Programmable System-on-Chip (PSoC) architecture from Cypress Semiconductor combines analog and digital fabric with CapSense capacitive touch technology and the 32-bit ARM Cortex-M0 core. The PSoC 4 is a custom mixed-signal SoC with programmable analog and digital blocks combined with flexible routing and interconnects. Cypress suggests that designers can replace an entire portfolio of proprietary MCU-based solutions and migrate legacy 8- and 16-bit designs to a single 32-bit platform with PSoC 4.

For analog input, the chip features a high-performance successive-approximation analog-to-digital converter with 12-bit resolution sampling at 1 Msps. Low-power modes include a full stop feature that consumes only 20 nA while still retaining its ability to wake up and a retention sleep mode that draws only 150 nA without disturbing SRAM data. PSoC 4 leverages a graphical system design-based integrated development environment, PSoC Creator, enabling designers to drag and drop precharacterized, production-ready analog and digital IP blocks into a single PSoC device to create customized products.

Cypress Semiconductor | www.cypress.com | www.embedded-computing.com/p371474



Analog input boards support multiple monitoring applications

United Electronic Industries (UEI) offers four new analog input boards featuring 8 analog input channels, 24-bit A/D resolution, and 120 kilosample/second maximum sampling rates. The DNx-AI-218 offers a ± 10 VDC input range suitable for most general-purpose data acquisition measurements while the DNx-AI-228-300's ± 300 VDC input range targets high-voltage applications such as battery testing, power plant monitoring, and aircraft power monitoring.

The boards all offer complete, 350 Vrms channel-to-channel and channel-to-chassis isolation, and provide simultaneous sampling with each channel being based on its own oversampled SAR converter. Input gains of 1, 2, 4, 8, 16, 32, and 64 are software programmable, and the boards go into high impedance mode when power is removed, for use in high-reliability, redundant monitoring applications. Additionally, UEI provides factory written software drivers for all popular operating systems including Windows, QNX, VxWorks, RTX, InTime, and more.

United Electronic Industries | www.ueidaq.com | www.embedded-computing.com/p371458

Mini PCI Express card captures eight concurrent video channels

Specializing in embedded products for video capture, annotation, recording, and streaming, Advanced Micro Peripherals (AMP) has launched the AVC8000nano, a new eight-channel video capture card in a mini PCI Express form factor. The card is designed for high-pressure or extreme environments including UAV-based video capture, real-time situational awareness, law enforcement, crime scene recording, and asset or traffic monitoring. Captured video can be scaled, cropped, and positioned with built-in software controls and streamed continuously to system memory for immediate processing or local display.

The low-power AVC8000nano features eight live NTSC/PAL/RS170 video inputs, supports eight D1-sized image captures at full frame rate, and allows arbitrary video window sizing, cropping, and scaling. The module is supported by drivers for Windows XP Embedded and Linux.

Advanced Micro Peripherals | www.ampltd.com | www.embedded-computing.com/p371473



New transceiver extends ZigBee feature set

GreenPeak Technologies recently introduced the GP501, a new generation of ZigBee transceivers with a coexistence scheme that allows Wi-Fi, Bluetooth, and ZigBee chips to work side by side in the same device. ZigBee shares the 2.4 GHz frequency band with other Wi-Fi equipment, resulting in potential RF interference when operating simultaneously. The GP501 has a coexistence interface that enables arbitration over the shared radio frequency medium to prevent contention, signal degradation, and data loss.

A new feature of the GP501 ZigBee transceiver chip is the Deep Packet Inspection (DPI) for ZigBee applications allowing the host processor to go into a deep-sleep mode to conserve power. The DPI feature can be used for Wake-on-LAN functionality, where the ultra-low power ZigBee chip is used to wake up the main processor from sleep mode to enable Wi-Fi networking. Another advantage of the GP501 is the 32-pin, 5 mm x 5 mm footprint, allowing integration into smaller product form factors.

GreenPeak Technologies | www.greenpeak.com | www.embedded-computing.com/p371457



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Joining the embedded conversation

By Sharon Hess

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HTML5 SDK connects automakers, app developers

Now In-Vehicle Infotainment (IVI) mobile-app-savvy software developers and automakers can

be more connected, thanks to a new HTML5 SDK from QNX that utilizes the trending HTML5 to enable developers to write, emulate, test, and debug IVI code remotely with only a web browser. The HTML5 SDK for the QNX Car has a BlackBerry WebWorks open source framework, and emulation is executed by the BlackBerry Ripple emulator that mobile developers already know. The SDK also aids in developing IVI apps that are JavaScript- or CSS3-based.

Watch the video: <http://opsy.st/YU4LZP>

More videos: video.opensystemsmedia.com



Roving Reporter blog: Remote industrial systems integrate predictive maintenance

By Warren Webb

With fully interconnected embedded devices now the norm in many factory settings, industrial design teams are

implementing predictive maintenance strategies to reduce downtime, lower personnel costs, and increase production. The goal of predictive maintenance is to pinpoint when a failure is going to occur so that repairs can be made at a convenient time before the breakdown actually happens. Successful predictive maintenance requires real-time monitoring and analysis of important equipment parameters via remote sensors, management tools, and diagnostics along with universal connectivity.

Read more: <http://opsy.st/102LaHC>

Could silicon be a thing of the past?

It's a foregone conclusion that computing will always be powered by a silicon backbone ... but, is that true? Believing that silicon transistors' improvement limits have nearly been reached, University of Nebraska-Lincoln (UNL) physicists and researchers have been developing a silicon alternative – a mere-atoms-thick ferroelectric oxide layer, touted to result in more storage capability for digital data than silicon, while utilizing less energy as compared to memory based on silicon. The goal is to make significantly more powerful, smaller electronics a reality.

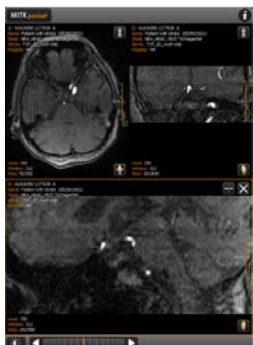
The ferroelectric oxide layer research is based partly on the quantum tunneling phenomenon, where particles penetrate a barrier solely at the atomic or quantum level. Two electrodes have an ultra-thin barrier inserted between them, then electrons – stimulated by applied voltage – produce a current with resistance as they tunnel through the barrier. The ferroelectric oxide provides polarization directions, negative and positive, enabling polarization charge reversal that alters tunnel junction resistance by 100x. These capabilities are in contrast to present-day silicon, which demands more current and more real estate between regions in order to accommodate generated heat.

But don't look for ferroelectric oxide technology at your local Radio Shack just yet. The potentially silicon-replacing technology is only effective when temperatures are a chilly -100 °F or less.



In the meantime, catch the latest updates on silicon-based technologies in each edition of *Embedded Computing Design*.

Access the digital edition: embedded-computing.com/emag



Handy free embedded app for doctors on the go

Physicians on the go can now view patients' medical images including MRI and CT scans on their iPad, iPhone, iPod touch, or Android-based mobile device – if it's loaded with the "MITK pocket" app created by Steinbeis GmbH & Co. KG fuer Technologietransfer. MITK pocket renders high-performance image processing including capabilities for window/level adjustments and multiplanar reconstruction, and provides annotation and measurement tools, allowing doctors to interact remotely with colleagues for patient care.

The latest version of the app (1.1.0) boasts expanded high-res 2D X-ray image viewing, 3D view capability, window-level transformations that are GPU based (read: fast), and is optimized for iPhone 5.

Find the free MITK pocket app at the iTunes app store or on Google play.

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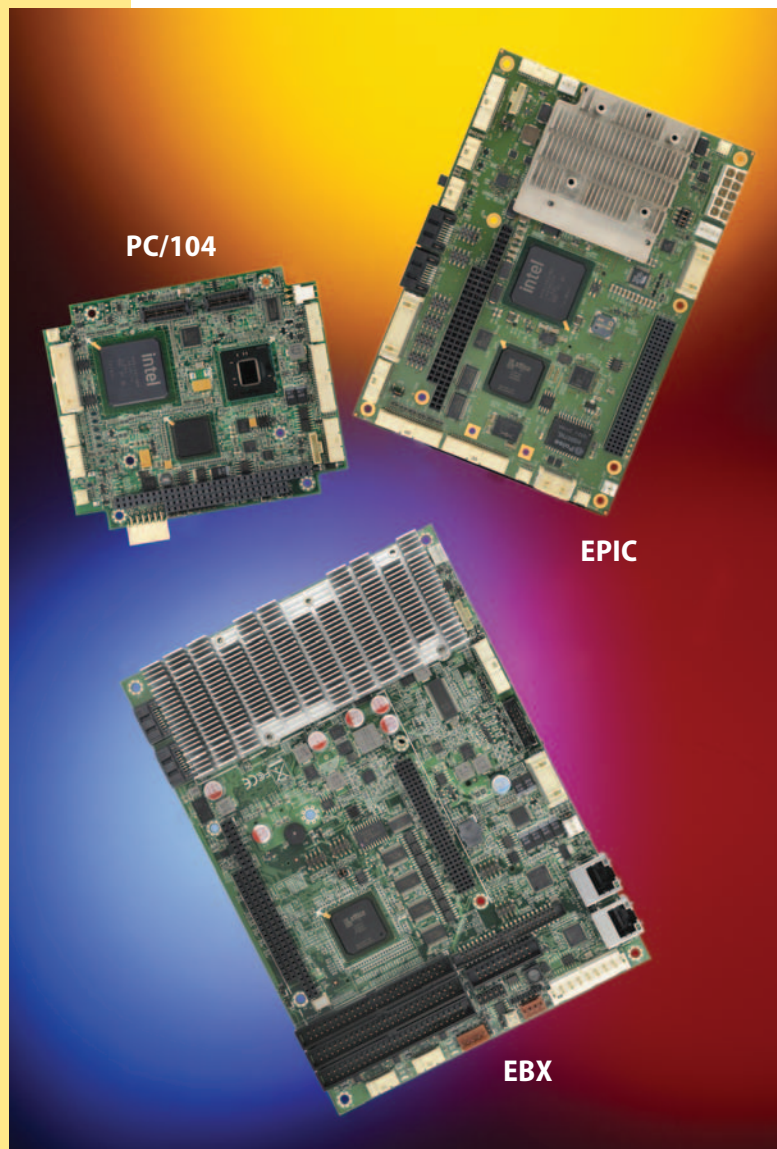
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