PC/104 and small form factors

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FOR THE INDUSTRIAL INTERNET

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PC/104 and Small Form Factors Editorial/Production Staff

John McHale, Group Editorial Director
jmchale@opensystemsmedia.com

Lisa Daigle, Assistant Managing Editor
ldaigle@opensystemsmedia.com

Steph Sweet, Creative Director
ssweet@opensystemsmedia.com

Sales Group

Tom Varcie, Sales Manager
tvarcie@opensystemsmedia.com
(586) 415-6500

Rebecca Barker, Strategic Account Manager
rbarker@opensystemsmedia.com
(281) 724-8021

Eric Henry, Strategic Account Manager
ehenry@opensystemsmedia.com
(541) 760-5361

Twyla Sulesky, Strategic Account Manager
tsulesky@opensystemsmedia.com
(408) 779-0005

Kathleen Wackowski, Strategic Account Manager
kwackowski@opensystemsmedia.com
(978) 888-7367

Asia-Pacific Sales
Elvi Lee, Account Manager
elvi@aceforum.com.tw

Regional Sales Managers
Barbara Quinlan, Southwest
bquinlan@opensystemsmedia.com
(480) 236-8818

Denis Seger, Southern California
dseger@opensystemsmedia.com
(760) 518-5222

Sydele Starr, Northern California
sstarr@opensystemsmedia.com
(775) 299-4148

Europe Sales
James Rhoades-Brown
james.rhoadesbrown@husonmedia.com

Reprints and PDFs

Wyndell Hamilton, Wright's Media
whamilton@wrightsmedia.com, (281) 419-5725

OpenSystems Media Editorial/Creative Staff

John McHale
Group Editorial Director
Military Embedded Systems
PC/104 and Small Form Factors
PICMG Systems & Technology
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Lisa Daigle
Assistant Managing Editor
Military Embedded Systems
PC/104 and Small Form Factors

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

Curt Schwaderer, Editorial Director
Embedded Computing Design
cschwaderer@opensystemsmedia.com

Joe Pavlat, Editorial Director
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jpavlat@opensystemsmedia.com

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Sally Cole, Senior Editor
Military Embedded Systems

Joy Gilmore, E-cast Manager
jgilmore@opensystemsmedia.com

Rich Nass
Embedded Computing Brand Director
Embedded Computing Design
rnass@opensystemsmedia.com

Monique DeVoe, Managing Editor
Embedded Computing Design
mdevoe@opensystemsmedia.com

Brandon Lewis
Assistant Managing Editor
PICMG Systems & Technology
Embedded Computing Design
Industrial Embedded Systems
blewis@opensystemsmedia.com

Mariana Iriarte, Associate Editor
Military Embedded Systems
miriarte@opensystemsmedia.com

Rory Dear, Technical Contributor
Embedded Computing Design
rdear@opensystemsmedia.com

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Corporate

www.opensystemsmedia.com

Patrick Hopper, Publisher
phopper@opensystemsmedia.com

Rosemary Kristoff, President
rkristoff@opensystemsmedia.com

John McHale, Executive Vice President
jmchale@opensystemsmedia.com

Rich Nass, Executive Vice President
rnass@opensystemsmedia.com

Wayne Kristoff, CTO

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Headquarters – ARIZONA:
16626 E. Avenue of the Fountains, Ste. 201
Fountain Hills, AZ 85268
Tel: (480) 967-5581

MICHIGAN:
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small MATTERS

By Mike Southworth, Curtiss-Wright Defense Solutions

Small is the next big thing for COTS

In July of this year, Marvel released "Ant-Man," its latest film blockbuster, proving that superheroes can come in extremely small packages. Meanwhile, the aerospace and defense embedded commercial off-the-shelf (COTS) market are well ahead of the curve. We've already started to see whole new classes of small and ultra-small line-replaceable unit (LRU) offerings that are dramatically redefining the performance, power dissipation envelope, and cost savings that can be achieved with "shoebox" and even "pocket-sized" processors and Gigabit Ethernet switch and router LRUs.

Recently, market demand has intersected with previously unattainable higher levels of integration, enabling these new classes of technology miniaturization. First installed in smaller unmanned aircraft system (UAS) platforms, these new small and ultra-small LRUs are opening up entirely new market opportunities. These LRUs are equally adept at reducing size, weight, power, and cost (SWaP-C) on helicopters and ground vehicles as well. Users can rapidly migrate toward faster and faster sensor interfaces on their manned and unmanned airborne and ground vehicles, for example, from cameras collecting high-resolution data or from radars and other onboard sensors. In cases where 10/100 Ethernet used to suffice, platforms now require Gigabit Ethernet (GbE). At the same time, designers and users are seeking ways to eliminate space and weight in already burdened platforms, leading to efforts like the U.S. Army's VICTORY standard, which aims to reduce hardware redundancy and foster interoperability.

In response, COTS vendors have begun to leverage technology advances to address these two market drivers. One recent approach is the use of multipurpose shoebox-sized stackable LRUs that combine Core i7 processing with Cisco IOS network routing software that runs as an application on Linux or on a VMware Hypervisor. This approach adds the capabilities of a secure Cisco router or virtual machine application without adding any additional weight to the processor system. With this setup, two or more standalone functions can be deployed in a single chassis, slashing required equipment space by 50 percent and cutting weight by four to five pounds.

An even more dramatic development is the emergence of a new class of function-specific ultra-small form factor (USFF) standalone LRU solutions, such as pocket-sized network routers, switches, and computers. These small subsystems take advantage of low-power processors, like ARM and Atom, developed for battery-powered or very power-sensitive applications, such as mobile phones and tablets. The smaller hardware on these diminutive boxes also tells a big story: The latest generation of silicon, from switches to CPUs, is shrinking the size of the die and reducing power consumption. In one great example, new Ethernet switch architectures feature low-power Gigabit Ethernet PHYs capable of turning off unused ports, putting them in a low-power or idle state. They are also intelligent enough to sense the length of the cable connection, limiting power for transmitting data, to say, 10 meters, rather than defaulting to the 100-meter Ethernet specification.

What's more, rather than using traditional connectors like DTL-38999s, USFF boxes often use new "micro-miniature 38999-like" connectors which deliver all of the performance benefits of their larger 38999 cousins but in smaller, lighter, and more dense configurations. On many platforms, just finding available space to add new hardware can be a real challenge. These small, low-power USFF boxes enable system integrators to easily install the solution they require without adding significant SWaP burdens. They are limited, either in processor performance or port count, compared to larger solutions, but for many applications they hit the sweet spot in ways that designers could previously only hope for. These tiny USFF solutions also open up whole new system upgrade architecture possibilities. For example, size-optimized USFF data bridge devices can be used to translate legacy data bus protocols from a platform's traditional data buses (i.e., CAN, RS422, MIL-STD-1553) and convert them to Ethernet for the improved situational awareness offered by an IP network. This approach provides a low-cost alternative to large and expensive one-size-fits-all data concentrator/conversion solutions, for which you'll likely end up paying for much more functionality than you'd ever use or need.

USFFs are also being deployed right now. In a recent example, a tactical UAS used for reconnaissance, surveillance, and targeting required upgrades for Ethernet switching capabilities for onboard communications and sensor payload equipment. The relatively small physical size of these platforms and the noisy electromagnetic interference (EMI) generated by their communications equipment presented a challenge to the manufacturer, who was seeking a COTS networking solution. Their USFF solution was Curtiss-Wright's "pocket-sized" miniature Parvus DuraNET 20-11 and 20-12 Ethernet switches. These LRUs are 10 percent of the size of a traditional small form factor GbE switch and only 25 percent of the weight of the next lightest Ethernet switch available in the company portfolio. Using microminiature MIL-circular connectors, this type of LRU can feature eight ports of GbE or, when fitted with a miniature rectangular Quadrax connector for enhanced signal integrity, it supports six ports of shielded 10/100 Ethernet.

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PC/104 and Small Form Factors

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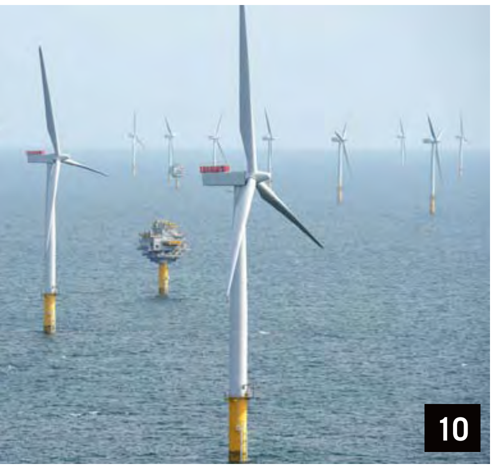
ON THE COVER:
The Industrial Internet, also called the Internet of Things (IoT), is very hungry for sensors. These sensors and their platforms will need to be high-performing, rugged, small, and power-conscious. Ruben Dhillon, Marketing Director, Embedded Systems at GE Intelligent Platforms, tells PC/104 and Small Form Factors how he views the IoT sensor market now and down the road.



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By Alexander Lochinger, SFF-SIG President

SFFs take to the skies

Drones are taking off: Much more than just for recon or warfare missions, much more than about retail giants leveraging consumers to hasten along government agency approvals. Even more than for spying on your neighbor or on Apple's new spaceship-shaped headquarters. Just visit your neighborhood unmanned system trade show to see how strong this market segment's thrust is.

Space is once again the new frontier, this time for small form factor processor modules (SFFs). Design teams are working on airborne unmanned aerial vehicles (UAVs) that deliver packages, UAVs that provide a relay network for Internet access, weather balloons that do the same, and inner-space miniature satellites that collect real-time data and images and send them back to earth. "Earth to SFF, do you read me?"

At the current inflection point, all we know is that we cannot know the breadth and depth of industry applications for drones. From a design standpoint, size, weight, and power (SWaP) are important, of course. The altitude UAVs reach takes design challenges to new heights for processor boards. Additionally, while the reduced temperature aloft is beneficial, lower air density makes it harder to remove heat. The reduced atmosphere, in turn, exposes electronics to cosmic radiation that generally doesn't affect embedded systems that operate on the ground. Fortunately, most drones don't need to fly that high, but some do.

Payload and processing

The particular industry and application also play a big role in scoping the design task. Data bandwidths are somewhat limited out across the radio interface, so where image capture or high-sample-rate sensors are involved, significant computation or preprocessing must be done. That addition drives up the drone's power consumption, forcing heavier processor boards and batteries, reducing the actual payload weight by grabbing a larger chunk of the total weight.

In order to run network stacks for cloud connectivity, we move beyond the 8-bit and 16-bit microcontroller space. There, our attention is immediately drawn toward miniature low-power, low-cost ARM chips and boards with wide operating temperature ranges and TrustZone security. MIPI camera interfaces on some boards allow a quick off-the-shelf development methodology.

Taking the high road

While it's easy to dismiss the x86 processor architecture as having inherently higher power consumption for this space, it's worth a closer look. The 64-bit dual and quad-core processors with large caches and PCI Express Gen 3 bandwidth tend to come to mind when thinking about x86. However, several new headless systems-on-chip (SoCs) are available that draw only several watts and are available on commercial off-the-shelf (COTS) boards. Some manufacturers went to a great deal of trouble to add in low-speed (low-power) interfaces like I2C bus and UART serial port. Development kits come with Linux drivers and APIs for these interfaces, making it easier to attach sensors, A/D converters, and so on. Developers, equipped with the well-established and reliable x86 Linux operating system, can focus their time on complex algorithms and high-level coding, even building and debugging first on PCs and then moving to the embedded target without having to cross-compile for ARM. Yes, even now x86 still has an edge in the tools and software development ease-of-use department.

Rough, tough, and ready

Flight systems are exposed to harsh environments, including dust, moisture, shock, vibration, and rapid temperature changes (thermal shock/gradient). While land systems have moved away from cables due to reliability concerns, the direct attachment of peripherals to a host board may not address the above environmental characteristics. In fact, smaller boards with locking pin-in-socket/header connectors and short lightweight cables appropriately supported may offer a more reliable system-design path. The flashy performance specs of the rugged high-definition MIPI camera module may draw all the attention, but connecting and mounting it poses mechanical problems. Walk through the list of peripherals and look for small and light modules with cabled versus socketed interfaces, and weigh the tradeoffs. Soldered RAM and eMMC boot flash are more rugged than conventional socket-based counterparts. Now the design task no longer resembles "mission impossible."

Commercial and ruggedized drones are all the buzz. We are only beginning to imagine the types of sensors, data collection, communication, control, and intelligence that will be placed in locations that humans cannot or should not reach. While many of the camera and GPS-based systems on the market are limited in their application usage, look for a new wave of general-purpose SFF compute boards on the drone horizon.

Small Form Factor
Special Interest Group
408-480-7900
info@sff-sig.org

PC/104 Consortium

By Stephen St. Amant, PC/104 Consortium President

PC/104: Ready solutions

A dozen people sit around a large conference-room table. A few have visitor's badges. Everyone has a smart device of some sort. Many have engineering notebooks and pens. Business cards have been cordially exchanged, and cups of coffee are still too hot to drink. In the middle of the table sits an assortment of printed circuit board assemblies.

"So, what are they?" asks one engineer, itching to get back to the lab.

"Well … they're the solution you'd have spent the next six months designing from scratch. But they're ready now."

[clearly interested] "OK. Tell me more."

We spend the next half-hour showcasing the latest in PC/104 to a group representing all levels of design and procurement. The PC/104 form factor is robust. The manufacturers are many, and the ecosystem is strong. PC/104 has been around a long time, and for this group that's a good thing. It's established. It's proven. It has industry support and it continues to innovate.

Some know the form factor's history, but others are eager to learn that PC/104 has grown into more than its namesake. Now, in addition to the stackable 104-pin ISA bus, the format also supports a stackable 120-pin PCI bus and a stackable 156-pin PCI Express bus (also available in a 52-pin variation).

The 30-minute scheduled meeting turns into an exciting hour-and-a-half discussion about system design, single-board CPU capabilities, signal needs, I/O requirements, environmental ruggedization, thermal management, and lifecycle expectations. By the time our coffee cups have been emptied twice, there are a half-dozen system designers with their sights set on robust, off-the-shelf PC/104 building blocks, along with several confident program managers ready to report back to their directors.

This is how it often goes when PC/104 manufacturers and sales reps visit new potential customers across the globe. Those who have been following PC/104 over the last 25 years are not surprised to see the latest and greatest; they've been winning many contracts with 104-based solutions all along. Others, however (those who thought PC/104 innovation had somehow slowed) are thrilled to see the latest technologies incorporated into this small, versatile form factor.

PC/104 has many benefits. If you follow publications that cover PC/104, you're aware of them: inherent rugged architecture, compact size, stackability and upgradability, interoperability across manufacturers, and utilization of mainstream bus architectures. On top of that, PC/104 has a deep off-the-shelf footprint that enables rapid uptime, and low development costs. Ultimately, PC/104 offers advantages for stakeholders at all points of the embedded supply chain.

"ULTIMATELY, PC/104 OFFERS ADVANTAGES FOR STAKEHOLDERS AT ALL POINTS OF THE EMBEDDED SUPPLY CHAIN."

This issue of PC/104 and Small Form Factors touches on the topic of "customization." PC/104 excels here too. There are many times when an off-the-shelf system needs a unique added element; that is, some measure of customization in order to meet a distinctive end-user application requirement. In these instances, PC/104 designers and system integrators are able to create a customized element to fit within the rest of the stackable architecture. The advantage of such a setup is that a custom, compatible peripheral card eliminates the need for a ground-up, one-off, high-cost solution. "COTS (commercial off-the-shelf) plus custom" will likely win out over "custom plus more custom."

Even with custom peripherals in the mix, one can readily see the wide variety of existing peripheral cards in the PC/104 marketplace. Look through pc104.org and you'll find a huge selection of add-in cards that meet a diverse range of application needs. Networking, processing, analog, digital, high-speed, low-speed, storage, power … they're all there. These solutions come from dozens of designers and manufacturers who work continually to bring the latest technologies to the PC/104 architecture, while continuing to support legacy infrastructures.

So whoever you are in that lab or conference room – the hardware engineer, the software engineer, the system integrator, the program manager, the procurement specialist, or the end user – PC/104 has something attractive for you. Learn more about the open specifications and our diverse membership at www.pc104.org. Thinking of spinning your existing technology for compatibility with the PC/104 form factor? We encourage you to do so, and to join the ever-growing PC/104 market.

For more information visit the PC/104 Consortium website at www.pc104.org.

Smaller form factors benefit electronic warfare applications

By Lance Brown and Ching Hu

An MQ-1B Predator unmanned aerial system (UAS) [left] and an MQ-9 Reaper UAS taxi to the runway in preparation for takeoff from Creech Air Force Base in Nevada. U.S. Air Force photo/Airman First Class Christian Clausen.

Small form factor (SFF) requirements continue to drive higher-performance computing platforms in electronic warfare (EW) and other signal-processing intensive applications year after year as there is an insatiable need for intelligence, surveillance, and reconnaissance (ISR). Airborne EW is a critical component of the military's overall EW strategy and almost all approaches desire more computational performance while reducing size, weight, power, and cost (SWaP-C) as more capabilities are added.

Smaller unmanned aerial system (UAS) platforms (for example, the Boeing Insitu ScanEagle or MH-6 Mission Enhanced Little Bird or the Northrop Grumman MQ-8 Fire Scout) are now performing EW missions alongside larger platforms like the General Atomics MQ-9 Reaper, the Northrop Grumman RQ-4 Global Hawk, and manned fixed-wing and rotary aircraft. Some platforms are not able to carry onboard the payloads of current processing technologies, so these smaller craft must download the data for ground-based processing.

Applications such as signals intelligence (SIGINT), digital radio frequency memory (DRFM), and radar processing for all aspects of EW (attack, support, and protection) are requiring more digital signal processing to achieve their goals, especially when they need to be adaptive with increasing bandwidth or are distributed.

This trend is unlikely to change even if the U.S. reduces its military footprint worldwide. Fewer boots on the ground means an even greater dependence on actionable intelligence from persistent ISR and EW systems.

Moore's Law provides a basis for increased processing capabilities, but this does not imply that power consumption drops accordingly or that memory bottlenecks can be opened up. In some sense, a technological leap is necessary to allow the desired processing capabilities to fly on SWaP-constrained platforms.

Smaller boards for EW purposes

Algorithms that traditionally required a large, heavy box or ground-based system can now be performed on a small form factor board. In addition to the EW-centric applications mentioned previously, synthetic aperture radar (SAR), space-time adaptive processing (STAP), real-time spectrum monitoring and SIGINT, multispectral (MSI) and hyperspectral (HSI) image processing, communications link encryption, multiple channels of H.264/H.265 video compression, software-defined radio, and many other defense/intelligence-critical functions can be considered for onboard processing within small SWaP envelopes.

PC/104 answers the call

For meeting the magic sub-one-pound payload SWaP-C requirements of smaller platforms, PC/104 is an attractive and robust commercial off-the-shelf (COTS) standard with a rich assortment of existing I/O modules like Intel Core i7s and analog-to-digital/digital-to-analog converters (ADCs/DACs). The PC/104 form factor is just large enough for an FPGA plus one or two hybrid memory cube (HMC) memory chips, currently two or four GB each, and a variety of I/O interfaces.

FPGAs have become a game changer for signal processing systems such as EW and radar as they handle the front end, where the signals are received by the embedded computing system whether PC/104 or larger systems such as 6U VPX. The components are better connected to I/O than general-purpose processors and handle real-time processing more efficiently as well. In the end FPGAs essentially provide integrators with more control in their systems, enabling them with the flexibility pivot and modify their applications based on mission requirements.

For smaller form factors they are ideal. Add to that support for IEEE 754 Floating Point Unit (FPU) via Hard IP blocks and for OpenCL integration into the tool chain and the value of such a solution increases. The FPU is also a key enabler for OpenCL, which enables scientists, engineers, and researchers to program using the C language to massively parallelize their applications.

In addition to the standard PC/104 connector, a similar type of connector with custom I/O can be located on the opposite side to provide more I/O bandwidth if connecting to boards with mating connectors. Adding two peripheral boards containing high-speed ADCs and DACs can realize a full DRFM or general active sensor back end enclosed in a low-volume box.

Interface	Connector	Max. data rate
DisplayPort Source	Mini-DisplayPort	17.28 Gbps (effective)
DisplayPort Sink	Mini-DisplayPort	17.28 Gbps (effective)
Ethernet	RJ45	1 Gbps (raw)
USB 2.0 Host	USB-A	480 Mbps (raw)
USB 2.0 Device	µUSB-B	480 Mbps (raw)
PCI-Express (top)	PC/104 (top)	126 Gbps (effective, in each direction)
PCI-Express (bottom)	PC/104 (bottom)	126 Gbps (effective, in each direction)
LVDS (top)	Custom I/O	17 Gbps (raw)
LVDS (bottom)	Custom I/O	17 Gbps (raw)
XCVR (top)	Custom I/O	128 Gbps (raw, both directions)
XCVR (bottom)	Custom I/O	128 Gbps (raw, both directions)
HMC Interface	N/A	1280 Gbps (effective, both directions)

Table 1 | ACE-PCIE-104 interface data rates

Given the effective x16 PCIe Gen 3 bandwidth of 15.754 GBps in each direction, the data converter modules can transfer over 120 Gbps (e.g., 12-bit resolution at 10 GSamples/s [Gsps] or 16-bit resolution at 7.8 Gsps) and even more if a custom module can utilize the connector.

One recent example of a small form factor board comes from Colorado Engineering, the Arria Common Element PCI/104 (ACE-PCIE-104). The ACE-PCIE-104 features the 10AX066 with two to eight GB of HMC memory.

With the introduction of the some of the new powerful high-end field programmable gate arrays (FPGAs), such as the Altera Arria 10 and Arria 10 system-on-chip (SoC), many of these missions can be executed within smaller and lighter payloads. In case of this particular FPGA, it can provide as much as 1.5 TFLOPS and as much as a 65 percent drop in power consumption compared to a previous generation Stratix V, even with the embedded dual ARM cores of the SoC variant. When this increased performance per watt is married with HMC technology that provides 1.2 Tbps or 160 GB/s data rate, the possibilities expand. (See Table 1.)

Other applications that could benefit from the ACE PCIE-104-CL SBC are scalable distributed aperture systems (DAS), situational-awareness 360 (SA360) systems, scalable ultra-wide band receivers, and small form factor EW threat generators. **SFF**

Lance Brown *is the director of High Performance Computing (HPC) at Colorado Engineering Inc. (CEI). Lance's current work focuses on HPC for radar, electronic warfare, and cybersecurity systems along with smaller platform using FPGAs and GPUs for smart cities.*

Ching Hu *is a senior strategic and technical marketing manager in the Military, Aerospace, and Government Business Unit at Altera. Hu has been employed in the military and aerospace industry for more than ten years with roles in software and firmware engineering, program and engineering management, and military marketing. Hu earned his bachelor's degree in optics at the University of Rochester, Rochester, New York.*

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Sensor processing platforms add performance, cut SWaP for the Industrial Internet

Interview with Rubin Dhillon, GE Intelligent Platforms

Powering the Industrial Internet demands top performance from data acquisition systems. Increased processing power must be built into sensor networks that balance SWaP (size, weight, and power) and the ability to withstand harsh operating environments. Image of Sheringham Shoal Offshore Wind Farm courtesy Harald Pettersen/Statoil.

As the Industrial Internet demands more out of resource-constrained industrial data acquisition systems, sensor processing platforms are required to add performance while reducing size, weight, and power (SWaP). Rubin Dhillon, Marketing Director of the Embedded Systems division at GE Intelligent Platforms discusses his company's approach to developing "brilliant machines," and how off-the-shelf hardware is enabling these sensor platforms for the Industrial Internet.

For GE, where do sensors fit into the Industrial Internet?

DHILLON: The fundamental building block of the Internet of Things (IoT)/ Industrial Internet is, of course, the communications infrastructure. Attached to that are increasingly smart, brilliant machines with substantial data acquisition, processing, and storage capability built into them. For the Industrial Internet and for the Connected Battlefield, those very smart machines need to be incredibly rugged, able to operate in the harshest, most challenging environments.

Sensors are a critical element within the IoT, Industrial Internet, and Connected Battlefield because they acquire the data necessary to effect huge improvements in efficiency and reliability – with minimal human intervention. GE has a long history of dealing with sensor-acquired data through our work with the military – radar, sonar, video, and so on. We're now finding that that expertise and experience plays out well in the Industrial Internet space.

Given the resource constraints of industrial devices, what innovation is occurring at the sensor level to realize the full potential of the Industrial Internet?

DHILLON: The key here is that the proliferation of sensors is producing a fire hose of data, and that situation is exacerbated by the resolution of the data that is being captured. Video sensors, for example, now commonly acquire and transmit high-definition data rather than standard definition, with huge implications for the numbers of pixels being captured, processed, transmitted, and stored. That in turn has huge implications for both processing power and network bandwidth. The trick, of course, is to be able to process that data in real time and extract only the meaningful data to deliver to the network.

Here, GE believes that one answer is GPGPU technology – using the graphics processors designed for high-end video gaming and so on, and leveraging their hugely parallel architectures to process vast amounts of data at incredible speeds. We're working closely with NVIDIA, and an outcome of that relationship has been products like the recently announced rugged mCOM10-K1, which is based on NVIDIA's Tegra K1 technology (Figure 1). That's an incredibly appropriate solution for Industrial Internet applications. First, it's based on the COM Express architecture, which means that it is very small and can be deployed in very tight spaces. Second, it delivers 326 GFLOPS of processing power. And third, it consumes less than 10 watts of power, meaning that it can be used in environments where power availability is at a premium.

We're also working very closely with AMD, as a result of which we've just announced the bCOM6-L1700 (Figure 2). That also is a COM Express architecture product, featuring AMD's latest SoC technology, and, like the mCOM10-K1, it is small, rugged, and consumes minimal power.

It's going to be devices of that level of processing performance, ruggedness, size, and power consumption that we'll see increasingly drive the Industrial Internet because of their ability to help make sense of the huge amounts of data that sensors are capable of collecting.

What other trends do you see arising in Industrial Internet sensor networks, and how is GE addressing them?

DHILLON: As I noted previously, if we're to avoid dragging the communications

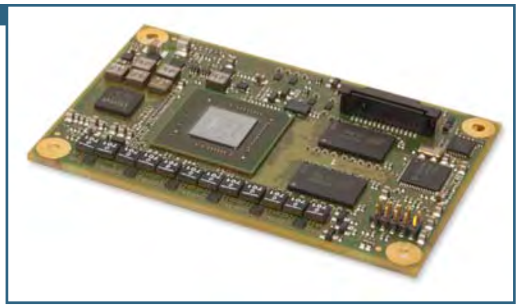

Figure 1 | The mCOM10-K1 is a COM Express-based sensor processing platform that leverages the NVIDIA Tegra K1 SoC to deliver 326 GFLOPS of processing performance.

Figure 2 | The bCOM6L1700 is another rugged COM Express module, and is based on AMD R-series APUs for power-efficient sensor processing.

network to a halt with the sheer burden of sensor-acquired data, that data needs to be processed locally in the machine attached to the network. That has important implications not just for processing power, but for size, weight, and power – so-called SWaP. That processing power has to be built into small spaces in harsh environments that are subject to extremes of temperature, shock, vibration, contaminant ingress, and so on. That means it also has to be rugged. That's a real strength for GE. It's what our customers know and value us for.

The other key area where the Industrial Internet can make a real, valuable difference is in improving efficiency, asset utilization, reliability, and availability. It's one thing to have all those machines generating huge amounts of sensor-derived data about themselves – but what to do with all that data?

GE is investing hugely in software, especially the software that will drive the Industrial Internet by making everything hang together in a way that will deliver benefits to businesses. An example of that, and a rapidly growing business for GE, is our predictive analytics business. We at GE believe that the basis for real transformation here lies in the shift from reacting to equipment failures or current condition indicators to becoming truly predictive and proactive. Answers about the future health of equipment or locomotives or whatever are already there in data that is being collected from sensors onboard those platforms today. It's a matter of leveraging an analytics solution with the proven ability to find the signal in the noise. SmartSignal from GE is that proven solution, with over ten years of proven experience across a broad range of asset-intensive industries.

What predictions do you have for the IoT?

DHILLON: For many companies and organizations, the Industrial Internet is already a functioning reality – it's real, it's here, it's today. Many people don't realize how much progress it's already made. There's no doubt in our minds at GE that the Industrial Internet will become pervasive across all industries, and the day is not too far in the future when we'll wonder how industry ever managed without it. **SFF**

Rubin Dhillon *is Marketing Director, Embedded Systems at GE Intelligent Platforms.*

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www.geautomation.com

Mic check 1, 2, 1, 2: MEMS microphones add reliability for a symphony of IoT apps

By Brandon Lewis, Assistant Managing Editor

Vesper's VM101 piezoeletric MEMS microphone is pin compatible with capacitive MEMS mics to ease engineering design cycles.

Acoustics is one of those sciences most of us take for granted on a regular basis, not because we overlook the importance of sound in our daily lives, but because we underestimate its possibilities beyond speech, music, and as an environmental indicator. Ultrasound, sonar, and noise cancellation are just a few applications that leverage sound waves in capacities that transcend the lay perception of audio.

A prime example of how many of us undervalue sound is probably in your pocket right now. Today, smartphones include arrays of microelectrical mechanical systems (MEMS) microphones that are used not only to capture and amplify voice during calls, but also to eliminate ambient noise and enable far-field audio zoom using beamforming techniques. Delivering these features requires high-quality microphones with a signal-to-noise ratio (SNR) that typically meets or exceeds 64 dB, as even the most sophisticated audio processing algorithms are restricted by the capabilities of the microphones that are capturing sound. Combined with the large quantities of the smartphone space (billions of MEMS microphones are shipped annually), the demand for quality microphones has resulted in a curious phenomenon in the MEMS market in which the majority of growth and production is occurring at the high end. While the correlation between the smartphone mic market and embedded may not be immediately clear, please – keep reading.

Why mics matter

At this point you may be asking, "What the heck do smartphone mics have to do with the Internet of Things?" The reason is that, although speech recognition technology still leaves a lot to be desired, voice will continue to grow as one of the preferred user interfaces for the Internet of Things. Despite the frustratingly low success rate of Siri, "Ok Google," and Dragon (just ask any reporter who has struggled with ways to transcribe interviews), verbal interaction is simply the most effortless form of communication in many scenarios, particularly as everyday objects become Internet-enabled. Think of the possibilities in a smart home that allows you to verbally command your TV, thermostat, and lights (see Amazon Echo), and then think further into the future where microphones could be leveraged in a vehicle to record and transmit engine noises known to be associated with problems or failures, or in a variety of other scenarios for identity management.

Fortunately, that curious fact about the smartphone market driving better-quality microphones should catalyze the performance gains needed for some of the advanced applications mentioned previously, but there is also room for growth in other areas of MEMS microphones, notably reliability. As many of us have experienced over the day-to-day grind with our smartphone sidekicks, the microphones they equip are highly susceptible to water, dust, and other environmental particulates, and once they've been damaged there's little to no hope of them ever again operating at an acceptable level. In part, this has to do with the fact that most MEMS

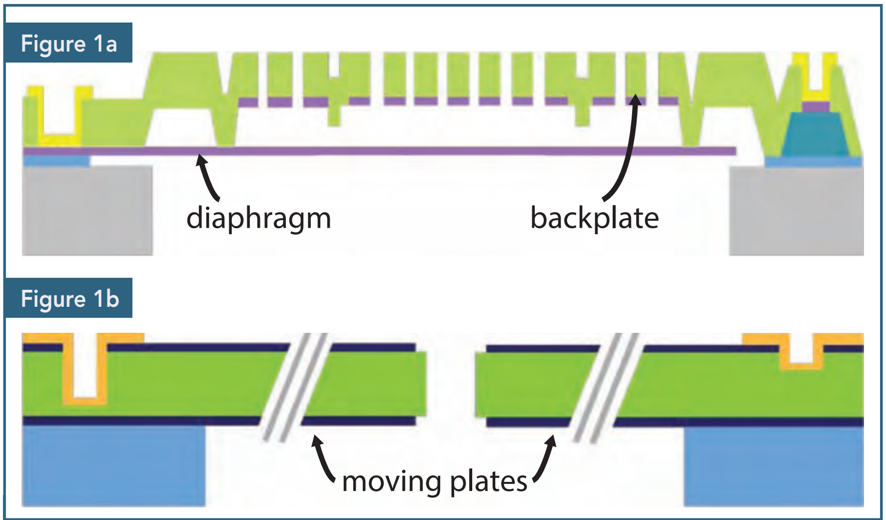
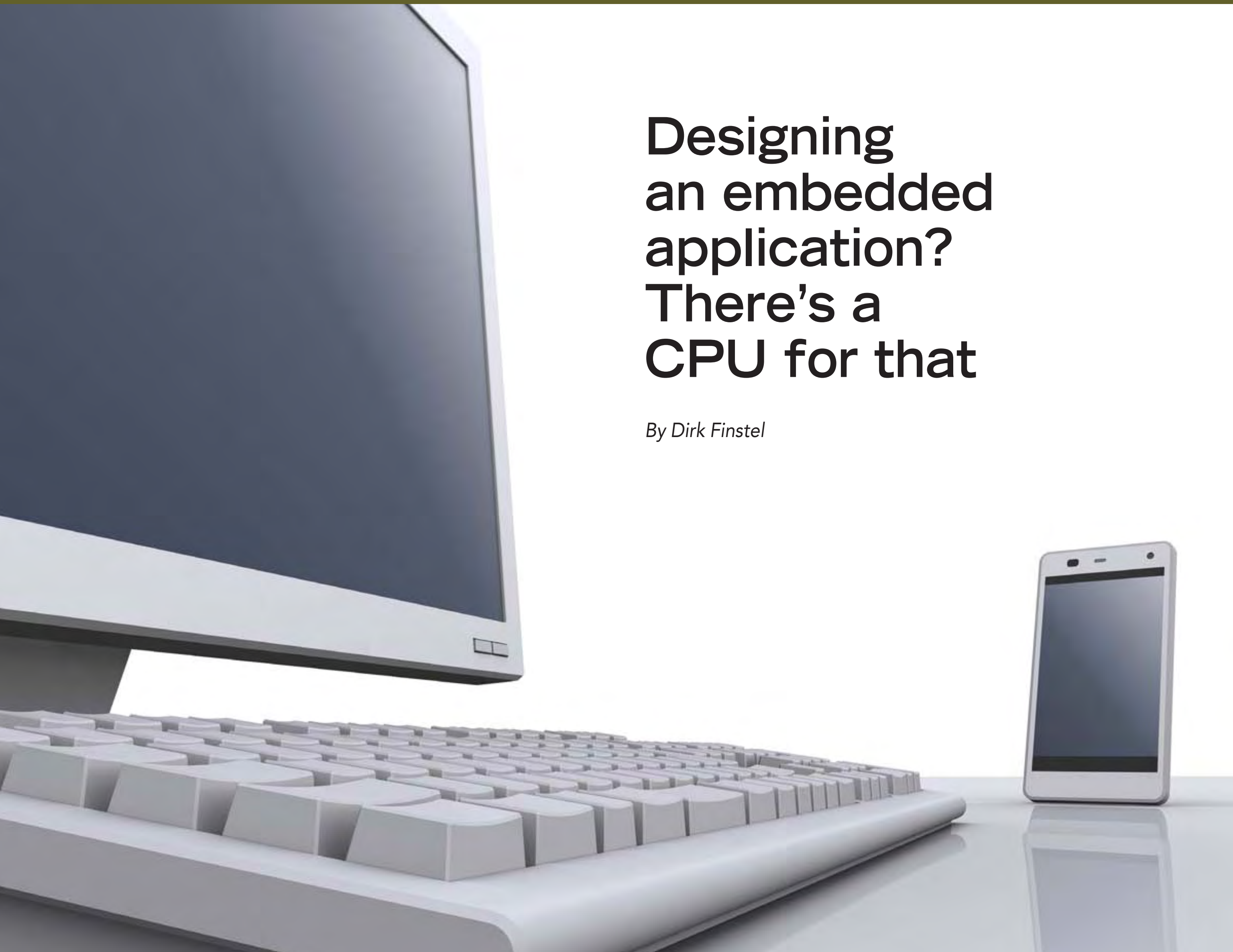


Figure 1a | Capacitive MEMS microphones include an air gap in which water and debris can become lodged and limit performance.
Figure 1b | Vesper's piezoelectric MEMS microphones employ a cantilever design that makes them waterproof, shockproof, and dust- and particle resistant.

microphones today are based on capacitive, two-plate architectures that include a diaphragm and backplate (Figure 1a). What often happens when these microphones lose quality is that debris gets caught between these two plates, preventing air/sound waves from passing through the diaphragm freely, or, in some cases, puncturing the diaphragm itself.

Recently however, Vesper (www.vespermems.com), a startup out of the University of Michigan, introduced a piezoelectric MEMS microphone that relies on four triangular cantilevers (Figure 1b). The advantages of this are twofold. First, the piezoelectric material used converts sound energy directly to electrical voltage, which helps provide a higher quality signal (68 dB typical SNR). Furthermore, the use of cantilevers eliminates the air gap where particles or residue can get trapped. According to Vesper CEO Matt Crowley, the result is a waterproof, shockproof, and dust- and particle-resistant design. Their latest part, the VM101, is also pin compatible with capacitive MEMS products, helping ease technology transitions and reduce design cycles (see large image, top p.12).

In the wild of the IoT, reliability and cost are precursors for most any hardware. Given the long lifecycles, designers must be able to depend on system components for years or decades, and in order to reach projected numbers of connected devices, price points for advanced silicon must be in line with those of a high-volume market. These are the precursors for an IoT app enabler. Piezoelectric MEMS mics are on the right track. **SFF**



Designing an embedded application? There's a CPU for that

By Dirk Finstel

In the debate over ARM vs. x86, the question should be: Which architecture is better for a particular application? Both architectures have their own special place in the embedded industry: ARM-based processors currently rule the smartphone/tablet market; the low-power ARM-based processors are generally a better choice for the smaller, fanless mechanical structure of mobile devices that require low heat output and long battery life. On the other hand, Intel rules the desktop and server market and is the usual choice for PC-based embedded applications and those requiring high computing performance.

The question isn't whether ARM or x86 is the better architecture, but rather: Which architecture is better for your application? The answer depends on how you prioritize requirements, including power, speed, longevity, compatibility, and more.

ARM and x86 architectures both have sweet spots in the embedded industry. It's no secret that ARM-based processors currently rule the smartphone/tablet market. As the low-power leader, ARM-based processors are generally a better choice for the smaller, fanless mechanical structure of mobile devices that require low heat output and long battery life. Intel rules the desktop and server market and is the go-to CPU choice for PC-based embedded applications and those requiring high levels of computing performance.

There's more to this story, however. Power consumption at the device level is driven by multiple components, not just the CPU. Moreover, smartphones are purpose-built devices that are designed to be upgraded every two years, so less emphasis is placed on long product life cycles or compatibility with existing software environments. Smartphones are basically designed to do one thing, and do it very well.

In contrast, embedded PC form factors have enabled integrators to implement a wide variety of systems, tackling many different applications. Most successful PC platforms were designed for power envelopes that run from tens of watts to more than a hundred, which can put some portable and low-energy applications out of reach for an off-the-shelf solution.

The rise of the top CPU contenders

Both x86 and ARM have well-developed roles in the embedded marketplace – each ideally suited for a particular set of applications, and each essentially defined by the differences in how they communicate with I/Os. ARM's three-step communication keeps processes streamlined but reduces power, while x86's 10-step process is more detailed but also requires more time, power, and memory to complete.

In x86, this communication process relies on CISC, or complex instruction set computing. CISC is a mature technology, with core architecture choices that include instructions to work directly with I/O, as well as memory. ARM's communication protocol – known as RISC, or reduced instruction set computing – does not include the instructions to work directly with I/O. RISC processes operate only on registers with a few instructions for loading and saving data to and from memory.

ARM's simpler, native 32-bit architecture leads to a small area for silicon and significant power savings features. Optimized for the mobile phone and tablet markets, the ARM architecture provides an effective alternative that extends the power envelope into low-energy applications that have previously found it difficult to adopt standard form factors, and so had to absorb the high upfront costs of custom board and module design.

There are strong historical contrasts between the Intel x86 and ARM market environments. Intel has been instrumental in defining not just the core microprocessor and instruction-set architecture, but also the architecture of peripherals. Companies that provide embedded-computing products based on the x86 architecture have been able to leverage that (chip-level) expertise by providing either proprietary or open-standard products that use a common I/O interface. Through the use of common connector pinouts, it is possible for customers to select from a wide range of hardware- and software-compatible peripherals with which they can customize their end products.

The ARM environment is more complex and differentiated. In contrast to the PC environment – in which the core module is comprised of a processor, Northbridge, and Southbridge device – the focus in the ARM market is on system-on-chip (SoC) products, each usually optimized for a particular application. Historically, there has been far less focus on building standard I/O definitions; each SoC would be used on a custom board design. ARM also gives the user a wider range of I/O options, depending on their target market, with less emphasis on standard buses such as PCI Express.

The result has been the introduction of a number of proprietary form factors and connector definitions in the ARM arena that lock the customer into a vendor's offerings and which may not have support for more than a generation of silicon as they move to different SoCs. Some vendors claim the use of a standard form factor – sometimes piggybacking ARM support on an existing x86-focused specification – but with additional custom connectors to provide support for I/O lines that cannot be supported by the primary connectors.

Considering form factor

COM Express is an example of a successful standards-based embedded computing I/O standard. It is a computer-on-module (COM) form factor that offers high integration to the degree that a complete, compact PC can be used in an end application as though it were a discrete integrated circuit component (Figure 1a). The COM Express module itself typically comprises the core processor and memory together with the standard I/O of a typical PC, including USB ports, audio, graphics, and Ethernet networking. The PCI Express lanes and all other I/O signals that provide support for custom I/O expansion are mapped to two high-density, low-profile connectors on the bottom side of the COM.

With COM Express, the emphasis is on high-speed I/O expansion. A pair of high-density connectors provide as many as 32 PCI Express lanes or multiple storage, networking, and graphics channels. In addition to providing a connector with a high degree of signal integrity and robustness, COM Express provides standardization, which is instrumental in building up a large portfolio of CPU modules and carrier boards from many different vendors. The road to a standard I/O pinout was assisted by the manner in which the PC form factor is itself built; that is, on a commonly accepted set of standard I/O functions.

An alternate COM form factor known as Smart Mobility ARChitecture (SMARC) started as an open-standard definition for ARM-based embedded computing solutions, optimized for low power, cost efficiency, and high performance. (Figure 1b). SMARC also provides support for systems that need more compact solutions than those offered by the PC-oriented form factors. As the ARM SoCs do not need the support chips of a PC platform and draw less power, the amount of board space that needs to be reserved for power converters and power supply lines is greatly reduced. This enables the use of a smaller form factor, facilitating use of SMARC-based modules in low-power portable equipment.

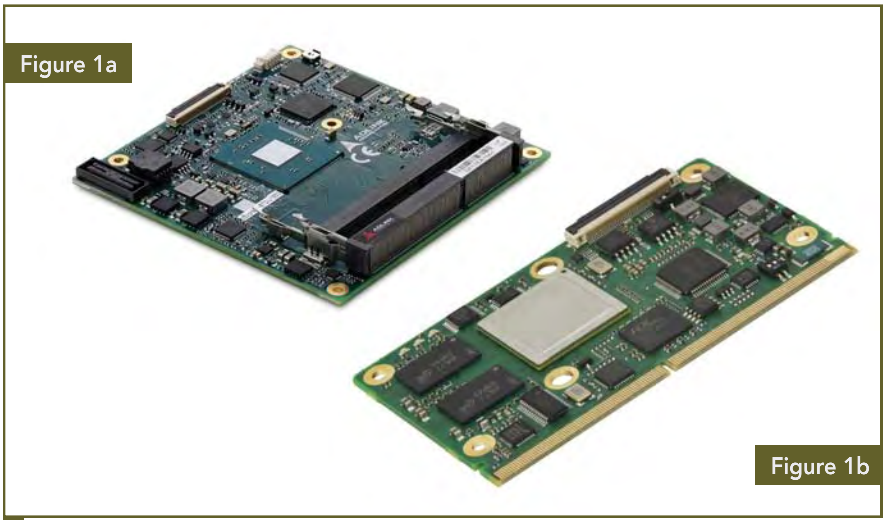


Figure 1a & 1b | Examples of Intel Atom-based COM Express x86 board and Freescale i.MX6 SMARC ARM board.

SMARC CPU modules are expected to have an actual power intake between two and six watts, enabling passive cooling and thus further reducing subsequent design effort and overall cost. The standard allows for as much as a nine-watt continuous power draw for more demanding scenarios, which also open the door for low-power x86-based CPUs like the latest Intel Atom family of SoCs.

If an application requires an x86 interface set, developers would find the ideal fit in a COM Express Mini sized module, providing low power and all the commonly required interfaces. When ARM interfaces are required – or perhaps a mix of both ARM and x86, for example in direct camera support or Integrated Interchip Sound (I^2S) systems – then SMARC modules become the clear choice. Both COM Express and SMARC are good for mobile solutions because both have the option to design in battery-powered usage.

The differentiators

ARM's big.LITTLE architecture is a recent heterogeneous computing innovation that enables the placement of two different types of cores in a single CPU, so a dual-core or quad-core processor can offer two or four cores that differ in performance and power usage. This architecture is a key advancement in power savings for mobile devices, allowing a low-energy core to be used when a device is not busy and a high-performance core to be used when undertaking more complex tasks, such as gaming.

It must be noted, however, that ARM's performance cannot compare to the computing power of the Intel Xeon processor family, serving industries such as telecommunications that depend on extremely reliable, well-tested, proven performance in their carrier-grade applications. In addition, the Intel AES New Instructions (Intel AES NI) encryption instruction set improves on the Advanced Encryption Standard (AES) algorithm and accelerates the encryption of data in the Intel Xeon processor family and the Intel Core processor family to enhance speed and security. On the flip side, the latest Intel Atom and Intel Celeron processor families bridge a performance-power-cost gap in the x86 arena and open a range of new embedded design strategies for sub-10-watt power requirements.

> "It's clear that both ARM and Intel believe in the future of the Internet of Things (IoT) and are dedicated to developing standards and reference platforms to simplify IoT deployments."

ARM and Intel in the Internet of Things

It's clear that both ARM and Intel believe in the future of the Internet of Things (IoT) and are dedicated to developing standards and reference platforms to simplify IoT deployments. ARM has developed the ARM mbed IoT Device Platform to promote quick time to market for commercial and interoperable connected IoT devices based on ARM microcontrollers. For its part, Intel offers its Intel IoT Platform as an end-to-end reference model and family of Intel and partner products to provide a foundation for connecting devices and delivering data to the cloud for business analytics.

In addition, both companies have jumped into the pool of vendors working to define connectivity requirements for the billions of "things" soon to make up our connected world. ARM is active in The Thread Group, which focuses on smart-home applications, while Intel is involved in the Open Interconnect Consortium (OIC) and is a founding member of the Industrial Internet Consortium (IIC), which is focused on accelerating growth of the industrial Internet by identifying, assembling, and promoting best practices. Regardless of which CPU is the better choice for a given embedded application, this commitment by both organizations to making the IoT more accessible to industries and consumers alike is good news for the advancement of connected systems now and in the future. **SFF**

Dirk Finstel *is EVP for the Module Computer Product Segment at ADLINK Technology. He has 20-plus years of in-depth experience in embedded computer technology, with a proven track record in embedded modules. He has held executive-level positions at embedded computing companies since he founded Dr. Berghaus GmbH & Co. KG in 1991, and has been responsible for global technology, research and development, and setting technological strategy. Finstel holds a BS in Computer Engineering and Science.*

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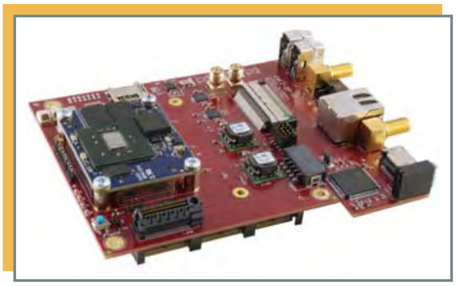

ARM host controller for the PC/104 ecosystem

The EMC²-Z7015 single-board computer (SBC) from Sundance Multiprocessor Technology – aimed at embedded multicore and critical applications – uses the current generation of the Xilinx Zynq system-on-chip (SoC), integrating dual-core ARM A9 CPUs, four lanes of PCI Express, and reprogrammable logic with Artix-7 FPGA technology. The SBC resides on the "OneBank" PC/104 form factor.

The ARM-9 is clocked at as fast as 1 GHz and is supported by 1 Gb of DDR3, SD card for standalone booting/local storage, USB2.0, HDMI, SATA, and 1 Gb Ethernet interface. The board will run standard Linux application and is supported by the free web edition of the Xilinx Vivado 2015.2 tools.

The EMC²-Z7015, although a single-board-computer (SBC) by default, takes advantage of the stackable PC/104 concept that enables multiple SBCs to be integrated into a multiprocessing ARM system, using PCI Express for inter-connection between each Zynq SoC.

The Sundance SBC takes the idea of PC/104 modularity even further with its so-called "cable-less breakout," which removes the requirement for cabling from the PC/104 board to the external world. The EMC²-Z7015 uses a self-mating connector solution that breaks out the I/O to a low-cost connector board.

Sundance Multiprocessor Technology | www.sundance.com | www.smallformfactors.com/p372964

SBC for high-performance, low-power uses

The Aries PC/104-*Plus* single board computer (SBC) from Diamond Systems uses the Intel "Bay Trail" E3800-series processor – a choice of the quad-core E3845 @ 1.91 GHz or the dual-core E3826 1.46 GHz processor – for applications needing high performance and low power consumption. The fully-rectangular Aries board, says the company, gives designers more PCB area and "coastline" to support the multiple I/O options. The SBC is designed to support a broad range of system I/O, including four multiprotocol serial ports, three USB ports, two 10/100/1000 Ethernet ports, and one SATA port.

The SBC also supports the installation of a SATA disk-on-module (DOM) with a mounting hole for increased ruggedness. A jumper provides power directly to the module through the single SATA connector, with no separate power cable required. Both the SATA DOM and PCIe MiniCard sockets can be used simultaneously, which gives users a compact embedded computing solution only a "single board" high.

The LVDS connection is dual-channel 24-bit, with the maximum resolution of VGA, LVDS, and DisplayPort at 2,560 by 1,600; maximum resolution for HDMI is 1,920 by 1,080. The board's LCD power is jumper-selectable between 3.3 V and 5 V, with backlight power jumper-selectable between 5 V and 12 V.

Diamond Systems | www.diamondsystems.com | www.smallformfactors.com/p372965

COM Express module aimed at reliability in harsh environments

GE Intelligent Platforms has aimed the mCOM10K1 Type 10 Mini COM Express module at applications needing to combine very high performance in data-intensive applications, rugged reliability in harsh environments, and very compact size. The module, based on the NVIDIA Tegra K1 system-on-chip (SOC), is designed to deliver 326 GFLOPS of performance. The mCOM10K1 also brings GE's GPGPU (general-purpose processing on a graphics processor) capability within reach of the significant number of applications in which power consumption needs to be 10 W or less.

In the commercial environment, says GE, devices with the capabilities of the mCOM10K1 will be key enablers for the Industrial Internet and the Internet of Things, and will be able to be deployed in such environments as industrial process automation, automotive and transportation applications, medical imaging, along with such military/aerospace applications as image and video processing, sensor processing, and electronic warfare.

The mCOM10K1's processor and memory are soldered to the board, intended to provide resistance to shock and vibration. Users can also opt for a conformal coating to provide additional resistance to moisture, dust, chemicals, and temperature extremes.

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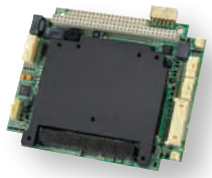

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