EXCLUSIVE: Immersion cooling, redefining 'standard,' power management

PC/104 and small form factors

THE JOURNAL of MODULAR EMBEDDED DESIGN

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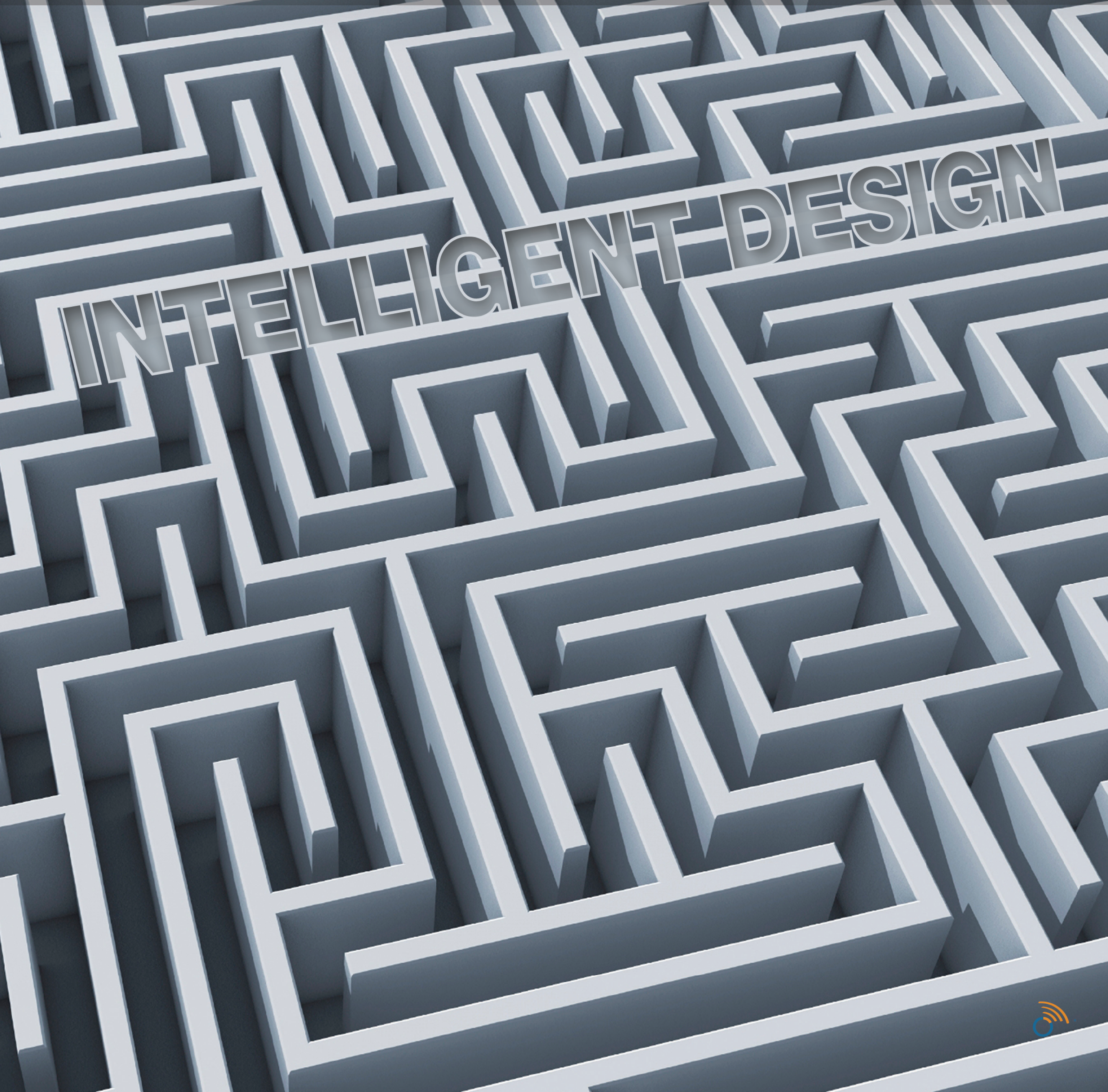

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PC/104 and small form factors

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ON THE COVER:
Embedded designers are dreaming up all kinds of innovative ways to architect small form factor modules and systems. Strategies such as immersion liquid cooling, tightly integrating single-board solutions, and power management via embedded controllers are optimizing SFF designs for smarter, more efficient performance.

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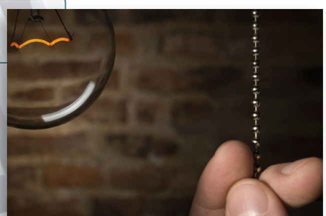

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Small Form Factor SIG

By Paul Rosenfeld,
SFF-SIG President

Whither the system OEM?

When those of us in industry trade groups gather our membership to define new specifications, we seek a mix of participants, including suppliers of CPU boards, I/O boards, memory, flash devices, and occasionally a chip manufacturer or two. And we usually get an eclectic mix of engineering gurus who interpret the latest technologies, as well as marketing types who try to map these technologies into their view of the latest set of requirements from system OEMs – the folks who put this technology into real products.

That said, there is one glaring omission from this team: the system OEMs themselves. Every year, hundreds of thousands of boards, chips, and memory devices are sold into an incredibly diverse set of products ranging from blood analyzers to vehicles. The system OEMs who design and build these products include medical equipment suppliers, military contractors, telecommunications giants, industrial system designers, commercial equipment suppliers, and others who are highly technical in understanding the requirements of their customers, the ultimate end users of these products. Yet these companies essentially abdicate all responsibility when trade groups begin work to define next-generation standards. They leave it to their suppliers – the chip and board manufacturers – to do as they will with new standards. This leaves the system OEMs with no one to complain to but themselves when all their potential suppliers jump on a bandwagon that they might not even subscribe to.

How many test and measurement companies, medical equipment suppliers, or military contractors gave Intel a piece of their mind when the chip company forced them to toss out those perfectly functional ISA-based designs they'd been shipping for 15 years and start over again with new PCI Express designs? How many system OEMs had any input into the definition of new specifications to replace those based solely on ISA and PCI?

"In successful companies large and small, teams consisting of marketing, engineering, and manufacturing personnel define next-generation products *together*."

There's a disease in Silicon Valley that has spread throughout the technical community. It has been around as long as the technology industry itself. The disease enables engineers to define new products that solve a problem they have faced, perhaps for many years. The thinking goes, "I would love to be able to buy this great new product. Of course, my customers are engineers just like me, so they'll love it too." At times, this approach is absolutely wonderful. At other times, it can create a disaster of epic proportions.

The cure for this disease has also been around for many years. In successful companies large and small, teams consisting of marketing, engineering, and manufacturing personnel define next-generation products *together*. It's marketing's job to determine if there are potential customers for the product with the features and price point being proposed. Unfortunately, there are still many companies where engineering runs the show, or marketing is too weak to influence product direction. Some engineers even think that marketing only means promoting their inventions after the fact.

The same thing happens in trade groups, where the customers for products built to new specifications are nowhere to be seen. This isn't a new phenomenon. We've collectively put our heads in the sand on this issue for years. We do our best with information filtered through participating members, but frequently this information isn't very good, or more likely, incomplete.

SFF-SIG recognizes this as a serious issue. We want system OEMs to participate in our activities. That's why SFF-SIG is offering a 50 percent discount on membership to system OEMs who are willing to participate and write about their experiences in an SFF-SIG Working Group. Look for more initiatives in this area from SFF-SIG in the near future.

In the meantime, dear reader, if you are a user of small form factor technology with ideas about where this technology should be going in the future, SFF-SIG wants you. For more information about membership, go to www.sff-sig.org or contact us at info@sff-sig.org. You'd be surprised at how a group of industry leaders will sit up and pay attention and treat every word you say as golden.

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www.sff-sig.org

PC/104 Consortium

By Jim Blazer,
PC/104 Consortium President

New opportunities promise enhanced benefits

Summer is coming to an end, and while some were enjoying their Hawaiian cruises, the PC/104 Consortium was busy moving embedded standards forward. The technical committee has been working on revisions to the PCI/104-Express and PCIe/104 specification that will open new opportunities for Consortium members. I cannot release any details at this early stage, but you can be assured that like all PC/104 Consortium specifications, the revisions will be well researched, technically sound, and consistent with all other Consortium specifications. The specifications will need to be approved by the voting members, and I expect they will be ready for release by early 2011.

The PC/104 Consortium has received an offer from a component manufacturer to post a reference design on our website. This is something the board has discussed several times in the past, but it is the first time that someone actually offered to deliver a design. The board sees this as a chance to enhance member benefits while giving component manufacturers a way to get reference designs in the hands of PC/104 Consortium members.

The technical committee will develop a set of rules for the reference design, and the marketing committee will work out the details of how it will appear on the Consortium website. The board fully endorses having reference designs on our website and hopes other component manufacturers will elect to join the Consortium and provide their reference designs as well. It is a great opportunity for component manufacturers and will provide a benefit for members. This is truly a win-win situation.

In addition to the reference design project, the marketing committee has been working on several white papers and articles, investigating other trade show opportunities, and reviewing our website to continue making incremental progress.

If you have not visited the PC/104 Consortium website at www.pc104.org lately, I encourage you to do so. It is the portal for PC/104 information. You can keep abreast of the latest specifications for free and check out the improved product section, where you can search by specification, member company name, product type, or keyword. The product directory includes a picture, description, hot links, and company contact info for each product. It contains many more products and companies than in the past, and they are easier to find. If your company does not have its products listed here, you are missing a great benefit of Consortium membership.

It is very important that the PC/104 Embedded Consortium present a clear and focused presence of PC/104 technology to avoid confusion in the marketplace. We must protect the Consortium's trademarks, copyrights, and IP for our members' benefit. We will continue to monitor technological advancements for possible inclusion into the PC/104 architecture.

The PC/104 Consortium has maintained open communications with members through its open member forum at every board meeting and by keeping technical and marketing committees open to voting and nonvoting members (as observers). If you are interested in participating in the PC/104 Embedded Consortium or on a committee, contact Jeff Milde at the PC/104 Consortium office.

PC/104 Consortium
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By Hermann Strass

Small 'farm' factors power machinery

SFFs for agricultural equipment

Fire engines, agricultural equipment, and similar machines often involve mobile automation. ISO 11783, also referred to as ISOBUS, is a protocol that specifies a serial data network for control and communications on forestry or agricultural tractors with mounted, semimounted, towed, or self-propelled implements. Based on the CANbus physical layer, ISO 11783 standardizes the method and format of data transfer between sensors, actuators, control elements, information storage, and display units that are mounted on or part of the tractor.

Precision farming is a well-known ISOBUS application (see Figure 1). The international Agricultural Industry Electronics Foundation (AEF) focuses the resources and knowledge of its members, such as AGCO and John Deere, toward enhancing the use of electronics in the farming sector. AEF has addressed important subjects surrounding ISOBUS and control system safety.

The SAE J1939 protocol, a CANbus variant for trucks and buses, has many parts in common with ISO 11783 to provide maximum interoperability. The Competence Center ISOBUS (CCI) is a German organization that promotes this technology (see Figure 2). Jetter, an industrial and mobile automation solutions provider, and Krone, a farming equipment manufacturer, are members of CCI.

Krone makes a large selection of farming machinery such as self-propelled mowers. The Krone Big M features constant power, crop-cutting discs, protection from rocks and foreign objects, and humidity sensing under the control of a Small Form Factor (SFF)-based system. The SFF boards are enclosed in rugged aluminum boxes protected up to IP68 for a temperature range of -40 °C to +85 °C.

This system uses MCUs like the JCM-350 from Jetter. A 32-bit ColdFire microprocessor coordinates two CAN buses (ISOBUS), an SPI master, I2C, optional Ethernet and digital, as well as analog I/O. Jetter also provides matching software such as ISO-Designer, which is a mask editor for ISOBUS applications, the JetViewSoft visualization tool for HMI, and the JetSym STX language. ISOBUS specifies that data for the HMI masks (parameters) should be held in the peripheral (virtual terminal), not in the control computer. At power-up or first contact, the HMI control panel system loads the masks of all attached devices for operation. Preconfiguration and preloading are not required in such an environment. A random selection of peripherals can be used any time without specific configuration.

Figure 2 | The Competence Center ISOBUS promotes the CCI ISOBUS HMI terminal and other technologies for controlling agricultural machinery.

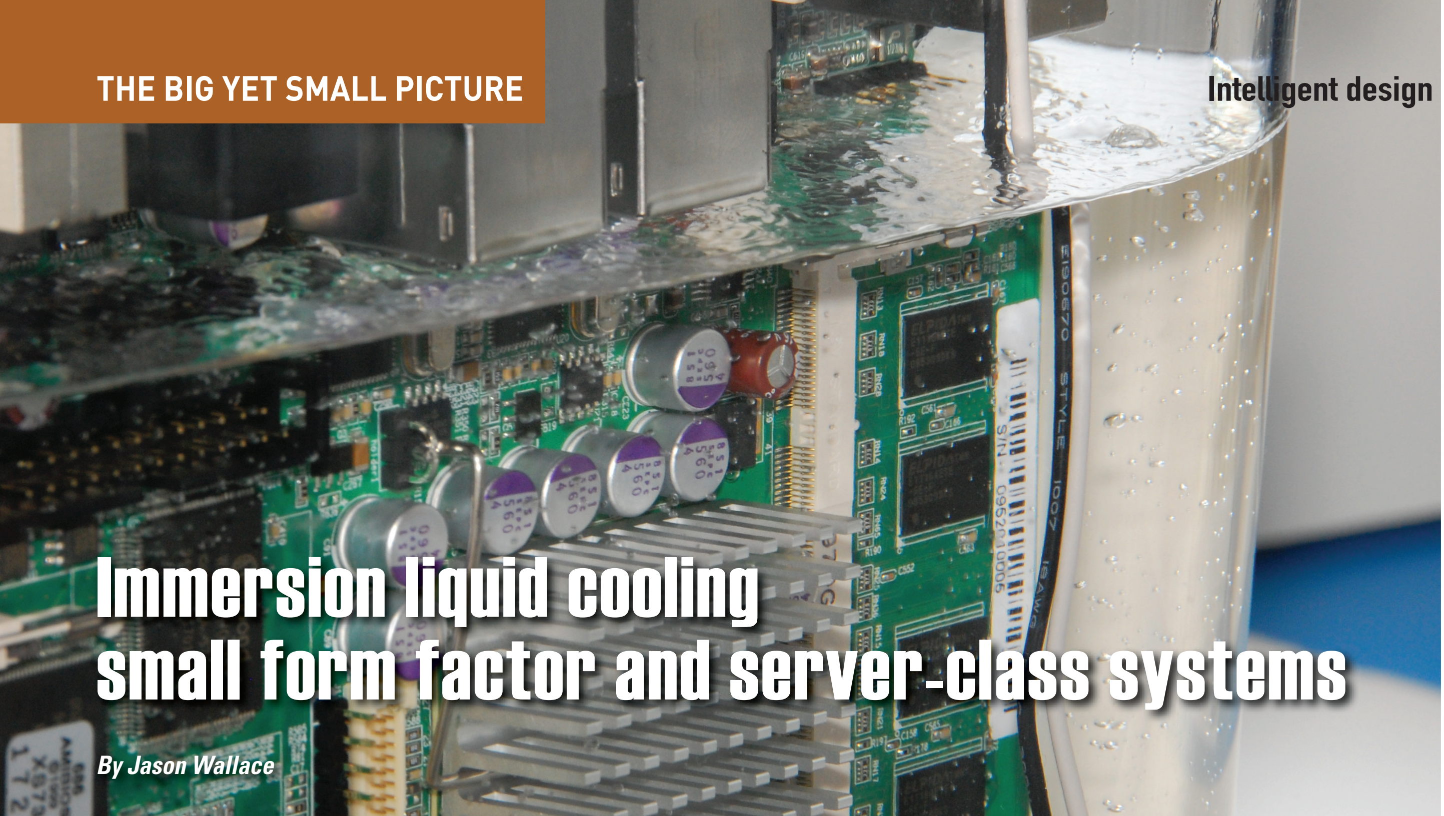
Figure 1 | SFF-controlled farming equipment uses ISOBUS electronics to automate system functions and standardize system communications.

Summer events

The Boards & Solutions Conference on July 15 in Munich provided technology sessions on open standards and SFF boards. I presented the SFF overview and moderated the SFF technical trends forum. The afternoon session was divided into three tracks: industrial automation, medical electronics, and transportation electronics. Another major topic of discussion was how to ensure safe, reliable SFF performance for several years of continuous operation.

The Automatica conference and exhibition is held biannually in Munich, this year from June 8-11. It is considered to be the world's largest trade show for robotics and automation technologies. About 31,000 visitors from 114 countries came to see products from more than 700 exhibitors.

For more information, contact Hermann at hstrass@opensystemsmedia.com.



Immersion liquid cooling small form factor and server-class systems

By Jason Wallace

As long as computers have been in existence, engineers have struggled to cool their creations, partly because the methods of cooling have remained relatively unchanged. Recent advances have prompted some to explore a new spin on a very old method of computer system cooling: total liquid immersion.

Standing in our development and engineering lab during a recent experiment, I nervously watched while a computer system, powered on and lights blinking, slowly submerged into a clear, watery liquid. Technology professionals are conditioned at almost a primal level to believe that liquid + electronics = bad, so it was quite a novelty to observe a computer functioning perfectly, completely submerged in what appeared to be nothing more than water.

Immersion cooling, formerly reserved for only the most expensive and exotic supercomputers, can be effectively downsized and applied both to small form factor embedded applications and server-rack systems. The following discussion analyzes various forms of liquid cooling and explores how small embedded systems can be cooled through submersion in new dielectric cooling fluids.

Drawbacks of traditional cooling methods

First, let's examine the shortcomings of air cooling and why designers might consider alternative methods of cooling their computer systems:

- Comparatively, air is an extremely inefficient heat conductor.
- Air cooling requires large open channels of space to direct airflow on the boards (increasing signal path lengths), inside the chassis, and between server racks.
- Fans consume a lot of energy, are noisy, and relentlessly pull dust and other contaminants into computer housings.
- Fans only cool the areas the airflow can effectively move across.
- Air cooling requires large heat sinks that add cost and weight to a system and waste a tremendous amount of space.
- Fans and air cooling move the heat to the surrounding atmosphere around the computer, where it is recycled into the system (further reducing efficiency) and dealt with via energy-consuming, oversized HVAC systems.

What about fanless small form factor machines? Such systems generally conduct heat directly to the surrounding atmosphere via the computer housing. The problem with this method is that the actual heat to transfer originates from only a very small surface area, greatly limiting efficiency. Dissipating that heat effectively requires careful engineering and thermally conductive materials to spread the heat over a larger area where it can radiate to the surrounding air. These conditions typically dictate that only lower-power, lower-heat processors can be used in such systems.

The answer to the shortcomings of air cooling high-performance systems has largely come in the form of liquid cooling. Active liquid cooling (pumped fluid) has gained more mainstream popularity in recent years, particularly in the high-performance computer gaming community. This generally involves a hybrid of air cooling, with liquid coolant applied via hoses to specific locations within a computer system.

However, liquid cooling for large-scale, hot-swappable server deployments has proven impractical and risky. Even when using expensive hose quick connects, engineers must deal with the potential for catastrophic leaks and the complexities of piping coolant around the insides of multiple computer housings in a rack. Thus, it's understandable that IT professionals have not given this technology much thought.

Where small form factor systems are concerned, there simply isn't room to contain liquids, radiators, hoses, and pumps in such confined spaces. Therefore, liquid cooling is ruled out almost immediately.

New fluids for immersive cooling

The concept of cooling circuitry via submersion has existed for years. However, this traditionally is limited to the most high-end supercomputing equipment. Immersion cooling has recently gained niche popularity as something to experiment with for high-performance video gaming systems, using mineral oil as the cooling fluid. While an interesting novelty, these mineral oil submerged systems still demand spot cooling for specific chips, thus requiring pumped fluid via hoses directly connected to the board. Removing components from the oil bath is an ungainly process, not only when dealing with the hoses and pumps, but also considering the sheer mess associated with dunking and withdrawing motherboards and computer systems in and out of tanks filled with slippery oil.

Back in the lab with the "drowning" computer (see Figure 1), engineers have found a solution to the oily mess using new dielectric cooling fluids. With these fluids, immersion cooling is not only a possibility, but also highly practical. Imagine a liquid that a designer can specify to a variety of boiling points. It looks just like water, but in actuality is nothing of the sort. Nonconductive and noncorrosive, the liquid allows a computer board to be submerged indefinitely without heat sinks or fans and cools it far more effectively than air. To hot-swap a system, simply withdraw the board from the liquid, and it dries almost instantly upon removal, with no residue or aftereffects.

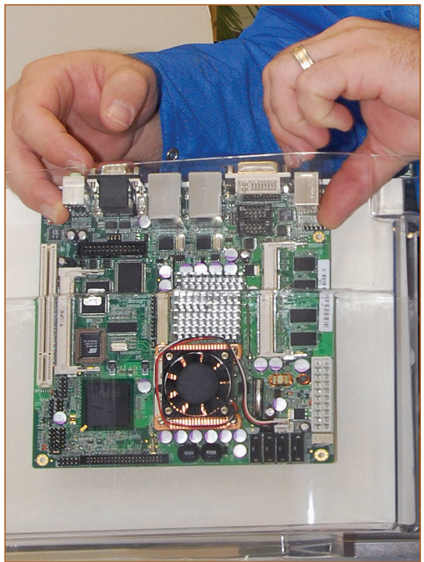


Figure 1 I A Corvalent G45IX motherboard equipped with an Intel Core 2 Duo processor is lowered into the cooling fluid. The hot components in this liquid boil starting at 34 °C, thus effectively limiting and removing the heat.

Small form factor systems such as body-worn computers, vehicle computers, or computers in hazardous environments might use a passive single-phase system where the liquid stays in liquid form. Buoyancy-driven flows cause the fluid to circulate due to the differences between the device and the housing temperatures. The fluid touches every surface of the interior housing, so the heat transfer process can be very efficient. This also allows more powerful processors to be utilized than what was previously possible with traditional passive-cooling solutions.

For server-class systems, a two-phase system can be highly efficient, permitting a significant amount of heat to be dissipated by allowing naked chips to boil the fluid around them and thus carry heat away. Because the boiling point can be low, the onboard chips remain well within operating parameters and form nontoxic, completely inert bubbles around the hot-test components. Those gases rise up, condense, and recirculate back into the liquid bath. A nonrefrigerated system of water or other heat-conductive fluid can be pumped through a radiator system over the bath to condense the gases. Alternatively, it could flow around the outside of the tank holding the computers, thus carrying the excess heat to be vented into the atmosphere outside the facility.

Measuring immersion cooling efficiency

So how efficient is this cooling method? Research suggests that power densities are limited more by the electrical bus than by the capabilities of the cooling fluids.

Estimates reflect that a full server rack assembly using 80 W of fans per kW of server power amounts to $2,800 a year in energy costs just to operate the server fans. Fluid cooling would reduce that cost $123 per year, not taking into account the savings from reduced HVAC energy usage.

Furthermore, by eliminating heat sinks, fans, and the airspace normally required for air cooling, a server can become very compact and dense, packed into a confined space along with many more identical servers. Under normal to nearly ideal conditions using traditional air cooling, one would expect the temperature of a processor to be 20 °C to 30 °C higher than ambient temperature. Using submerged fluid cooling with reasonable surface area for heat dissipation, this delta drops to a consistent 10 °C over ambient temperature. This efficiency gain is also significant for small form factor applications.

Engineers in the lab performed one test that involved the thermal equivalent of cooling 30 full-speed Intel i7 940 processors (120 cores) in a less than 8 x 8 square-inch area. To simulate this, engineers mounted an array of twenty 19 mm x 19 mm heater assemblies on a circuit board, each generating 200 W of heat. This 4,000 W (4 kW) assembly was submerged in 200 cc of fluid with a 49 °C boiling point. Water circulated around the outside of the closed tank, entering circulation at 37 °C and leaving at 47.1 °C, and dissipated the heat to the air outside the building.

The water was only capable of air cooling to 37 °C, yet it maintained a consistent temperature of 58 °C on all the chips. This was accomplished at just a fraction of the energy usage that would otherwise be spent on an array of fans and HVAC climate control systems to manage the heat generation. While this example is on the extreme end with unrealistic heat densities, it illustrates the cooling capacity of the fluid in a submerged server or small embedded system.

This idea of submerging computer systems for cooling may eventually catch on with the commercial masses. The technology and its substantial benefits are available and ready to be implemented. Engineers with special cooling needs are encouraged to participate in this evaluation and exploration project, and perhaps in time we can determine if the cost and environmental savings can outweigh the primal urge to keep liquids away from technology.

In addition to the efficiency benefits, these new dielectric fluids provide some degree of entertainment value. Besides the potential for practical jokes ("accidently" dumping a glass of "water" on a laptop or iPhone), it's somewhat relaxing, in a geeky zen sort of way, to see fans turning and lights blinking on a computer as it bubbles away, blissfully unaware of its strange, new liquid environment. ➤

For more information on immersion cooling and a video demonstrating how it works, see www.corvalent.com/martinscorner.

Jason Wallace *is the product marketing manager at Corvalent. He has more than 10 years of experience with product marketing, public relations, and x86 computer technologies.*

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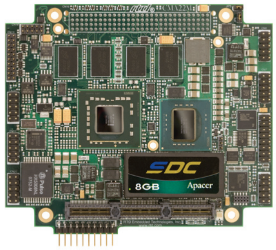

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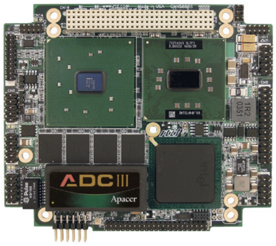

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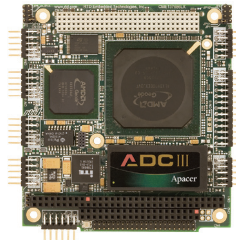

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Expansion Bus	PC/104 ISA Bus			✓						✓	✓	✓	✓	✓	✓
	PCI-104 PCI Bus	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
	PCIe/104 Express Bus	✓	✓												
CPU and BIOS	CPU Max Clock Rate (MHz)	1860	1200	1400	1400	1400	1400	1400	1400	650	650	650	650	500	500
	Intel SpeedStep Technology	✓	✓	✓	✓	✓	✓	✓	✓						
	ACPI Power Management	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0
	Max Onboard DRAM (MB)	2GB	2GB	512	1GB	512	1GB	1GB	1GB	512	512	512	512	512	512
	RTD Enhanced Flash BIOS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Nonvolatile Configuration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	RTD Quick Boot	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	USB Legacy (Keyboard & Boot)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Peripherals	Watchdog Timer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Solid State Hard Drive Disk Chip	8GB	8GB	8GB	8GB	8GB	8GB	8GB	8GB	8GB	8GB	8GB	8GB	8GB	8GB
	Audio	HD	HD		✓	✓	✓	✓	✓		✓	✓	✓		
	Analog Video	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA	SVGA
	Digital Video	LVDS	LVDS	LVDS	LVDS	LVDS	LVDS	LVDS	LVDS			TTL	LVDS	LVDS	
	PS2 Mouse/Keyboard/Utility Port	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	USB Mouse/Keyboard	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
I/O	RS-232/422/485 Ports	4	4	4	4	4	2	4	2	2	2	2	2	2	2
	SATA	2	2												
	USB 2.0	6	6	4	2	2	4	2	4	2	2	2	2	2	2
	Gigabit Ethernet	1	1												
	10/100Base-T Ethernet			1	1	1	1	1	1	1	1	1	1	2	1
	Parallel Port				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	aDIO (Advanced Digital I/O)	14	14	14	18	18	18	36	36	18	18	18	18	18	18
	aAIO (12-bit Advanced Analog I/O)	8	8												
	multiPort (aDIO, ECP, FDC)				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SW	ROM-DOS Installed	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	DOS, Windows, Linux	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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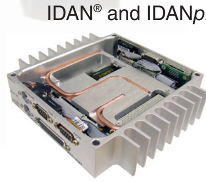

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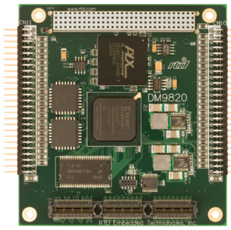

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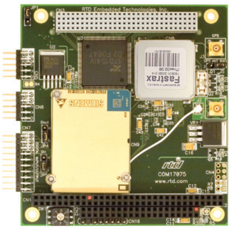

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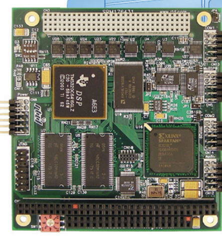

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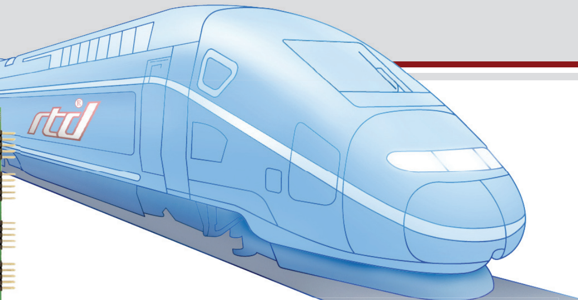

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Bus		Active Bus	PCI	PCI	ISA	ISA	ISA	PCI	ISA	ISA	ISA	PCI	PCI	PCIe	PCI
Bus		Passthrough Bus	ISA					ISA				ISA		PCI	ISA†
Bus		DMA or PCI Bus Master	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓
Bus		McBSP Serial Ports	✓	✓				✓							
ANALOG	Analog Input	Single-Ended Inputs	16	16	16	32	16	16							
ANALOG	Analog Input	Differential Inputs	8	8	8	16	8	8							
ANALOG	Analog Input	Max Throughput (KHz)	1250	1250	500		100	1250							
ANALOG	Analog Input	Resolution (bits)	12	12	12	12	16	12							
ANALOG	Analog Input	Input Ranges/Gains	3/7	3/7	3/4	3/4	1/4	3/6							
ANALOG	Analog Input	Autonomous Calibration	✓	✓											
ANALOG	Analog Input	Data Marker Inputs	3	3	3			3							
ANALOG	Analog Out	Analog Outputs	2	2	2	4	2	2							
ANALOG	Analog Out	Max Throughput (KHz)	200	200	200	200	100	200							
ANALOG	Analog Out	Resolution (bits)	12	12	12	12	16	12							
ANALOG	Analog Out	Output Ranges	4	4	3	3	1	4							
ANALOG	Analog Out	D/A FIFO Buffer	8K	8K				8K							
ANALOG	Advanced Features	Channel-Gain Table	1K	1K	1K	1K	1K	1K							
ANALOG	Advanced Features	Scan/Burst/Multi-Burst	✓	✓	✓	✓	✓	✓							
ANALOG	Advanced Features	A/D FIFO Buffer	8K	8K	8K	8K	8K	8K							
ANALOG	Advanced Features	Sample Counter	✓	✓	✓	✓	✓	✓							
ANALOG	Advanced Features	SyncBus	✓	✓				✓							
DIGITAL	Digital I/O	Total Digital I/O	16	16	16	16	16	16	48	18/9	64	48	48	48	48
DIGITAL	Digital I/O	Bit Programmable I/O	8	8	8	8	8	8	24	6/0		48	48	48	✓†
DIGITAL	Digital I/O	Input FIFO Buffer	8K	8K	8K	8K	8K	8K							
DIGITAL	Digital I/O	Opto-Isolated Inputs									48				
DIGITAL	Digital I/O	Opto-Isolated Outputs									16				
DIGITAL	Digital I/O	User Timer/Counters	3	3	2	2	2	3	3	3		10	10	10	6
DIGITAL	Advanced Features	Advanced Interrupts	2	2	2	2	2	2	2			2	2	2	✓†
DIGITAL	Advanced Features	Versatile Memory Buffer										4M	4M	4M	8MB
DIGITAL	Advanced Features	External Trigger	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓†
DIGITAL	Advanced Features	Incr. Encoders/PWMs								3/9		4/8	4/8	4/8	✓†

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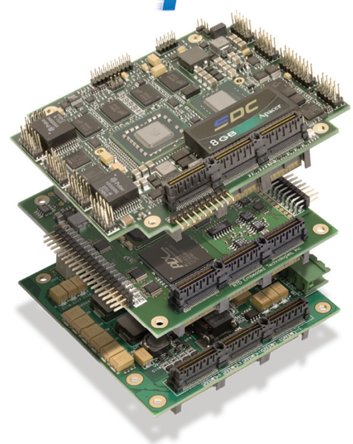

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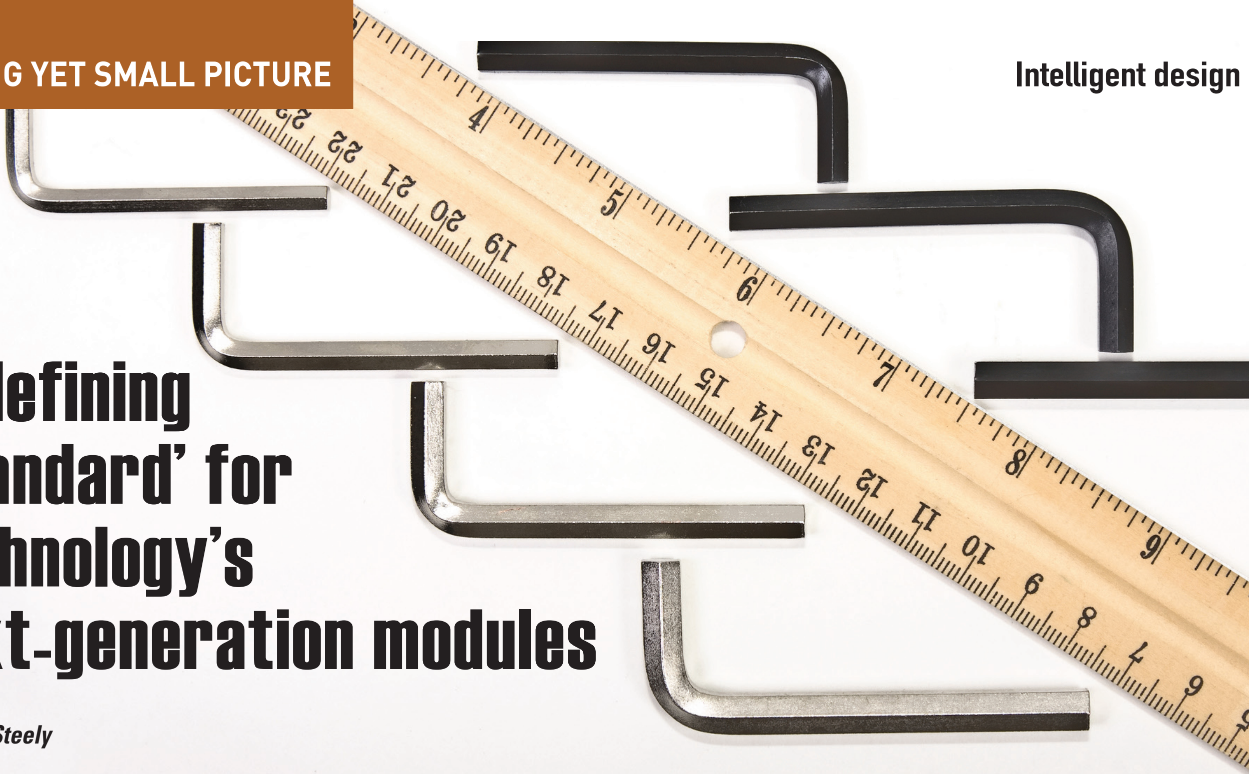

Redefining 'standard' for technology's next-generation modules

By Ryan Steely

As market demand for small size and big performance explodes, designers are challenged to engineer a whole new kind of computing system. A team of designers in California found a way to realize a single-board solution while cutting system-level costs in half.

The latest advancements in silicon technology have created major opportunities, not only for the suppliers of small form factor processing systems, but also for the industry as a whole. We now have the ability to provide extremely high-performance systems on very small platforms. Although the driving factor for this silicon revolution is the consumer market, many of these advancements are finding their way into the embedded market space, most notably in the military, medical, transportation, and portable markets.

One of the common drivers for these applications is Size, Weight, and Power (SWaP), and the other is the demand for ever-increasing performance. The ability for an individual or system to carry a high-performance processing tool that will operate autonomously for many hours or as a remote terminal has become an industry focus resulting from the personal communication revolution. Unfortunately, the embedded industry doesn't work with the same rules as the consumer industry; we don't have an 18-month-operation-then-throw-it-away system lifespan. On the contrary, the embedded market requires long-term and reliable performance for years and sometimes even decades.

Intelligent, tightly integrated design

Success, as a company or a product, demands tested and proven ingenuity and innovation. Manufacturers must think out of the box when designing to make a single module that is highly efficient in power, cost, and performance per watt, per cubic inch. The whole idea of the small form factor, especially in the military market, is to reduce the system-level cost and make the package as small as possible so it can be deployed in heavily embedded applications like Unmanned Aerial Vehicles (UAVs).

Bus architectures like CompactPCI and VME have developed standards and specifications that focus on military requirements such as interconnections, cooling, shock, and vibration. The majority of the COM Express and PC/104 market is low-cost commercial-grade, and most design efforts target this market. Adapting these designs for multi-board military applications is not easily accomplished. Without accepted standards by the entire community, each small form factor supplier attempts to offer his own unique military multi-board solution, which may not have gone through an industry vetting process and acceptance by the military.

Most small form factor suppliers and others in the embedded industry were thrilled at the introduction of the Intel Atom, a highly efficient processor ideally designed for small form factors. The Atom is being integrated into modules designed for power-guzzling systems. But what's the benefit of taking a $50 processor chip with $45 I/O, putting it into a system that costs $3,000 to $4,000, and reducing the overall system power consumption by less than a mere 5 percent?

The most intelligent way to use the Atom is to design a small SBC – with processor, I/O, power supply, and everything else needed – on one board in one very small package. This can be accomplished by embedding the interconnect on the board and using reliable, secure, high-speed connectors like those used in SODIMM and DIMM technology. If you're shooting for a small form factor, why stack on a second board for I/O, like what's done in PC/104 designs? Instead, why not take advantage of Express Mini for GPS, solid-state disks, Wi-Fi, 1553 – whatever I/O you want to add? By tightly integrating I/O function, power supply, and other required components on the same board, designers will produce superior function at 1/20th the size and a fraction of the cost.

Putting all these system elements together to optimize packaging while providing high performance and low power consumption took General Micro Systems three years to accomplish. The company recently introduced Nano SBC technology and the Nano XP40x (Figure 1), which offers full Pentium performance in a module reduced to the size of an iPhone.

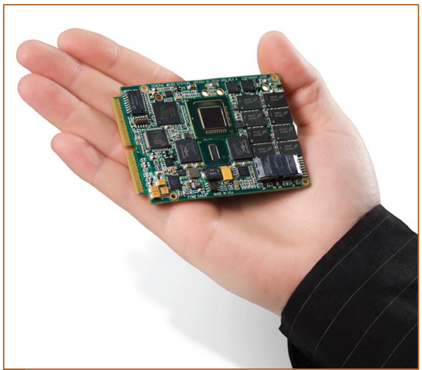

Figure 1 | GMS's new rugged SBC, available as a standard temperature (Nano XP40x) or conduction-cooled (Nano XPC40x) unit, delivers high performance and ultra-low power consumption in a single small form factor board.

Modules like this are ultra-small, weighing 7 oz. instead of 3 lbs., and provide overall system cost reductions as well as interoperability with five generations of processors in the same platform, creating a new, more accurate adherence to the definition of a "standard" module. Instead of \$2,000 or more, the XP40x system-level cost is less than \$1,000 in quantity. While COM Express boards are being offered for as little as \$500, it's important to note that these offerings still require a power supply, I/O card, interconnects, and packaging to operate, resulting in higher cost and all the inherent pitfalls of multi-unit systems.

Developing a product like this doesn't come about without design challenges, however. One of the biggest challenges is miniaturization of the components. To achieve this, the printed circuit board must be "blind and buried," a buildup approach to connection that avoids the layers of standard through-hole technology while the power supply, regulators, and all other parts are micro-miniaturized in much the same way as the components in cell phones.

Cooling has to be accomplished without adding the weight of aluminum or other metals to the module. To attain the kind of thermal resistance needed for the Nano XP40x, design engineers rejected gap pads, which transfer heat from the module's interior dye to the outer packaging. Gap pads operate with a thermal resistance of 18 °C to 19 °C, so designers knew that this method was not an option. Instead, they developed a patented cooling system that guarantees the module will run at 85 °C and shut off at 90 °C, offering a thermal resistance of only 5 °C. This cooling system, along with the SBC's small size and light weight, makes modules packaged like this a natural fit for small, severe environment applications.

Moving from multi- to single-board solutions

The embedded industry has traditionally relied on standard architectures and modules to allow for multi-board systems, upgrades, multiple vendors, and, most importantly, preservation of existing software. With current silicon technology and trends, the need for multi-board systems has all but been eliminated, along with the need for multiple vendors.

The key for users is to develop a plan that enables the highest possible software preservation. Users' systems tend to evolve either in performance or additional function, where the base operating system and application software evolve and are not complete replacements or rewrites. Seeking out suppliers that can provide the most practical and value-driven system to meet their needs and a product introduction plan that offers a future path for the greatest preservation of existing software is critical to their future success.

Because other small form factors like PC/104 and COM Express look to accommodate a large variety of applications, they lack focus and thus, when designing a system for a specific application (like ruggedized systems), the result is less than optimal. Compact, single-board solutions will be the new standard for small form factor requirements. Future discussions regarding small form factors and standard design will focus more on the design intelligence used on a single board rather than the issues associated with multiple boards, such as their interconnection and interoperability. ➤

Ryan Steely *is the vice president of marketing at General Micro Systems. With more than 15 years of marketing experience and 8 years in the embedded sector, Ryan has brought an outside perspective to GMS's product development. After working with GMS since 2001, Ryan joined the GMS team in 2009.*

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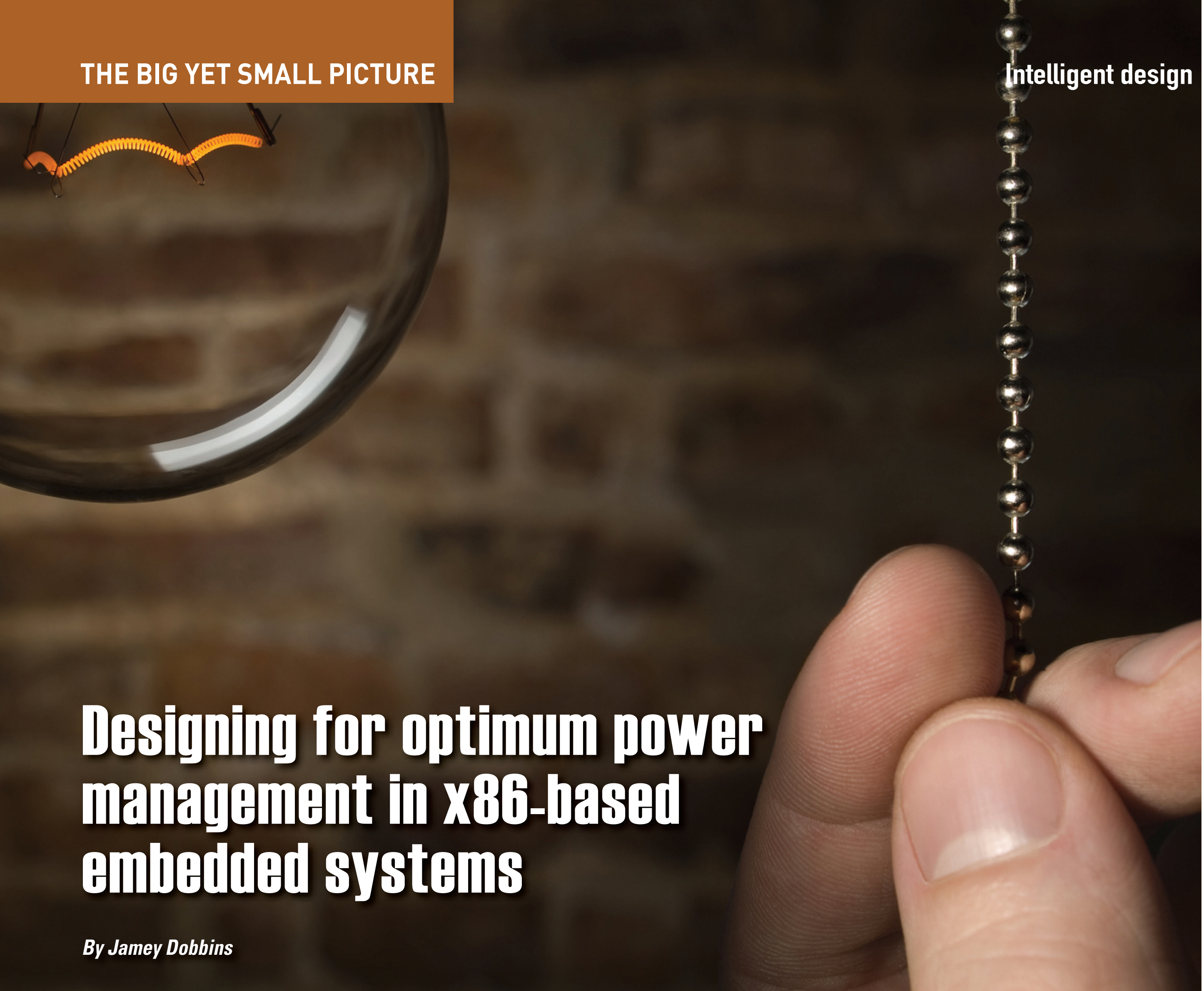

Designing for optimum power management in x86-based embedded systems

By Jamey Dobbins

With the onset of x86 technologies for the embedded market, small form factor systems have the potential to achieve optimum performance at low power levels. Utilizing an extensible embedded controller to perform low-level system functions is a valuable add-on that allows designers to manage the system at lower power levels than the x86 architecture alone.

Balancing features and power consumption

Historically, both embedded systems designers and chip makers have focused on performance and form factor, with minimal effort devoted to power consumption. In recent years, however, low power and power management have come to the forefront in the embedded computing industry, particularly due to advancements in x86 technologies. With the introduction of the Intel Atom processor in 2008 and subsequent releases in the Atom family, embedded systems designers are adding value to leverage the advanced architecture and managed power characteristics of these low-power, high-performance processors. Low-power x86 processors are an ideal solution for applications that require a small form factor without sacrificing features, performance, or reliability.

Embedded systems designers should make low-power design and implementation an important area of focus at the board level and as they enable hardware, firmware, software, and operating system optimizations that accommodate power management and low-power operation throughout the system design stack.

By adding an extensible embedded controller to the sophisticated power management capabilities of x86-based processors, embedded systems designers can deliver a highly competitive embedded platform that creates the optimum balance between advanced features and low power.

Achieving efficiency with an x86 architecture

While some vendors focus on one aspect of the embedded system such as performance or a low price point, it is important to approach power management with x86 hardware from a systems design perspective. As a general rule, when embedded systems designers select the components to support the core processor and companion chips, they should architect for power delivery and power management at every level. Whether considering I/O components, attached devices, or entire subsystems, the components must interact both dynamically and in static configuration to optimize for power consumption versus performance trade-offs.

Embedded systems manufacturers can differentiate themselves by gaining a detailed understanding of the latest x86 processors on the market. For instance, becoming a member of the Intel Embedded Alliance allows embedded systems designers to gain early access to new designs, giving them the opportunity to

> "Extensibility is a system design principle that can be achieved by adding new functionality or modifying existing functionality, both tasks that an extensible embedded controller can accomplish."

explore all of the possible capabilities, combinations of features, and areas of optimization that are possible beyond the generic use cases.

A vendor's true value-add comes by combining flexibility, power, and performance trade-offs with scalability and management functions. Optimizing the design for a specific target application in collaboration with the end customer is ideal. One important value-add in particular, the extensible embedded controller, applies to a host of applications including transportation, medical, automation, retail, and other industries.

Optimization with an extensible embedded controller

Embedded systems often have a compelling need for a controller to perform low-level system functions. While traditional embedded controllers were limited in form and function, current embedded controller technology can perform vital functions that preserve power in the core processor.

Embedded controllers with limited functionality

Traditional legacy PC architectures included a type of embedded controller that performed a fixed set of functions for the system. This controller was typically a small 8051-based microcontroller with limited capabilities integrated inside a super I/O or similar device. Because the overseas manufacturer provided a fixed set of functions for the controller, designers couldn't obtain source code or change the device. An earlier version of the embedded controller might have handled a few simple functions such as controlling the power button, generating a few LEDs, and allowing the system to access the flash device.

Extensible embedded controllers for x86 architecture

The low-power x86 architecture, on the other hand, differs from the standard PC in that it adds many new features and dramatically changes system design. Today, embedded systems designers can look at embedded controllers in a new light – as feature-rich and extensible.

Extensibility is a system design principle that can be achieved by adding new functionality or modifying existing functionality, both tasks that an extensible embedded controller can accomplish. Taking the old concept of an embedded controller and extending it beyond fixed, limited functions can make the controller more useful and customized for embedded systems customers.

An extensible embedded controller allows designers to perform many diverse functions separately from the host processor. For example, systems designers often initialize I/O devices based on customer requirements, such as a display that requires unique initialization functions. Suppose the interface is very low performance and requires ongoing monitoring. It would be burdensome and inefficient for the host processor to monitor the interface, so the designer can manage that function with the embedded controller.

Unique functions for power management

The extensible embedded controller is a 32-bit ARM7-based microcontroller

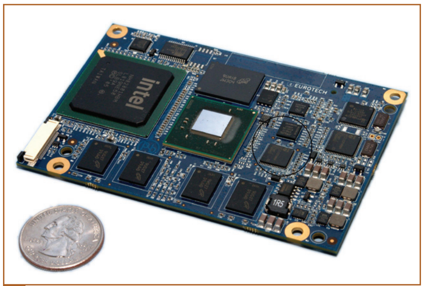

Figure 1 | An extensible embedded controller plays a key role in Eurotech's Catalyst LP Computer-On-Module (COM), based on the Intel Atom processor D510.

(see Figure 1). It is a very low-power device, and the designer should configure it for very low power consumption. In general, the extensible embedded controller can manage many diverse functions such as battery monitoring, A/D conversion, or even connectivity status monitoring including wireless connections and GPS interfaces. It can handle any low-performance function that requires some periodic servicing.

The true value-add the extensible embedded controller provides is power management and ultimately a lower-power device. While the controller handles vital functions, the core processor is free to go to sleep in many cases. From an overall system architecture perspective, the system has a high-performance processor, large DRAM subsystem, integrated cache architecture, small peripheral I/O functions, and monitoring devices that need to be monitored on a low-rate basis.

The ability to monitor these functions separately from the host processor provides an optimized, flexible infrastructure. The end system has a more efficient runtime operation that does not start up a large processor subsystem to do something that can be managed by a low-power infrastructure. The host processor runs a large operating system, perhaps one that is complex and has a large number of errors or fault conditions.

As a reliable, low-level manager of system operation functions, the embedded controller gives the designer flexibility to add management functions that are not inherently integrated in an off-the-shelf x86 processor (see Figure 2). For example, the embedded controller can control how a system's power rails and power regulation functions are managed and monitored.

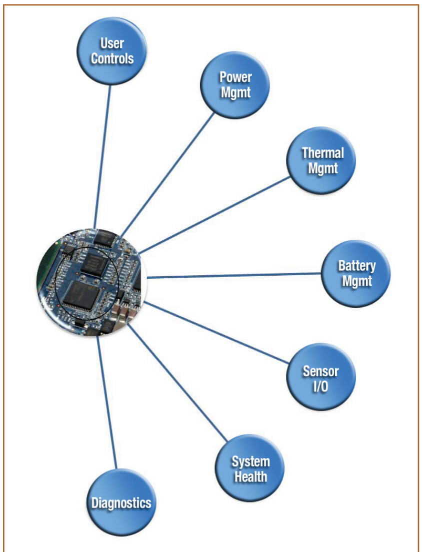

Figure 2 | Besides power management, an extensible embedded controller can handle other management functions that are not always integrated in an x86 processor.

Furthermore, the embedded controller can accommodate unique interface functions for power management at the point of power-on, during the boot-up session, during normal runtime, and during the shutdown or restart sequences. The controller can manage external sensors including power monitoring, environmental sensors, event monitoring, thermal monitoring, intrusion detection, and in some cases the detection of a catastrophic event. A fairly large range of sensor inputs are possible, leading to a highly reliable system.

Giving the host processor a rest

Many x86 manufacturers would have embedded systems designers believe their processors can perform all of these functions. They can, but when a designer starts adding several peripheral devices that all operate with asynchronous interfaces, it is more efficient to allow the host processor to rest. If the host processor is not running the main application or doing a high rate of data manipulation or graphics rendering, it should be asleep as much as possible. The better practice for low power is to save the battery to allow the processor to do the heavy lifting. The embedded controller is a valuable add-on, as it allows designers to manage the less important elements at much lower power levels than the x86 architecture alone can reach at this point, resulting in a balanced solution.

Jamey Dobbins *is an engineering manager at Eurotech. For the past three years, he has been the engineering lead on Intel Architecture projects, including Eurotech's Catalyst low-power Computer-On-Module (COM) product line. He is based in Eurotech's office in Huntsville, Alabama.*

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Editor's Choice

PC/104 and small form factors EDITOR'S CHOICE

By Jennifer Hesse

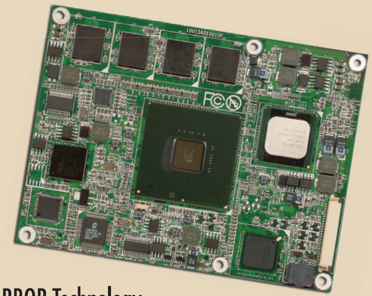
Mighty mini PC built for rugged apps

When it comes to rugged PCs, like with hot peppers, sometimes the smaller the size, the greater the power or, in the case of habaneros, the pungency. Stealth.com's new LPC-100 is the company's smallest and most powerful mini PC to date, measuring 4" x 6.1" x 1.45" and integrating the Intel Dual Core Celeron T3100 (1.9 GHz) or optional Intel Core 2 Duo P8400 (2.26 GHz) or T9400 (2.53 GHz) processors.

Weighing just 1.2 lbs, this paperback-sized SFF computer features 3D graphics with 16x9 capability, up to 500 GB internal storage, an external 12 VDC power adapter, and an optional solid-state hard drive. I/O includes three USB 2.0, two serial, one DVI-I video, and two PS/2 ports plus Gigabit LAN. Housed in a low-profile aluminum chassis, the LPC-100 is designed for rugged industrial and commercial applications such as digital signage, kiosks, thin clients, and HMI systems.

Stealth.com
www.stealth.com
RSC# 46028

COM Express braves harsh climates



Like the U.S. Postal service, SFFs deployed in harsh environments must weather the elements and deliver the goods as promised. Designed for this very purpose, the COM-630E from ARBOR Technology provides 1.1 GHz processing with the Intel Atom Z510PT CPU and can be designed with a non-conductive material coating to prevent corrosion caused by moisture, salt fog, rain, or other severe environmental conditions typically found in industrial, transportation, and military applications.

In addition to its Intel SCH US15WPT chipset and 1 GB soldered DDR2 SDRAM, the COM Express module packs in plenty of graphics capabilities with the Intel GMA500 chipset, which supports 2D/3D graphics, HD video, decode, image processing, and shader-based technology. Interface connectivity is easy to accomplish with eight USB ports, two IDE ports, and PCI and PCI Express slots through the carrier board. The COM-630E is fanless and rated for -40 °C to +85 °C operating temperature.

ARBOR Technology
www.arbor.com.tw
RSC# 46030

Industrial-grade SSD gets slim physique

Slimming down is not just a goal for those trying to fit into their old jeans; it's also a growing trend in embedded technologies. Viking Modular Solutions is getting into the thinning act by introducing the Slim SATA SSD, a rugged, caseless Solid-State Drive that's less than half the size of a 2.5" SSD. Conforming to the JEDEC MO-297 industry standard, the SSD offers a 3 Gb SATA II interface and sustained performance of up to 260 MBps.

Provided in densities of 25 GB, 60 GB, or 120 GB, Slim SATA features intelligent write management techniques and an advanced controller for data path CRC error detection and protection against flash page, block, and die failures. Equipped with AES-128 encryption and advanced SMART command support, Slim SATA can be configured using MLC or SLC flash technologies. The industrial-grade SSD is well-suited for embedded server and storage systems, gaming, and aerospace and defense applications.

Viking Modular Solutions
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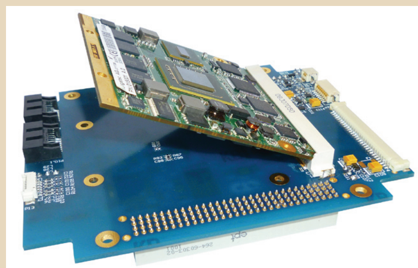
PCI/104-Express + Qseven = perfect match



Compatibility can be determined with the aid of a horoscope, online dating service, or a partnership between two SFF companies. Connect Tech and congatec have collaborated on a design that marries Connect Tech's PCI/104-Express SBC with congatec's Qseven module, creating a scalable CPU board with access to current and future generations of the Intel Atom processor. The Xtreme/CPU carrier board supports a full range of PCI/104-Express add-on cards and enables integration with any Qseven module.

Combining the modules adds Qseven's features to the PCI/104-Express board, rendering a total of four x1 PCI Express lanes plus GbE, LVDS, VGA video, two RS-232 and two RS-422/485, four USB 2.0, and two SATA ports. This I/O platform enables rapid prototyping and is available in customized versions for meeting specific price and time-to-market goals. With a temperature range of -20 °C to +70 °C, the Xtreme/CPU is targeted for low-power embedded applications.

Connect Tech
www.connecttech.com
RSC# 46031

congatec
www.congatec.us
RSC# 46032

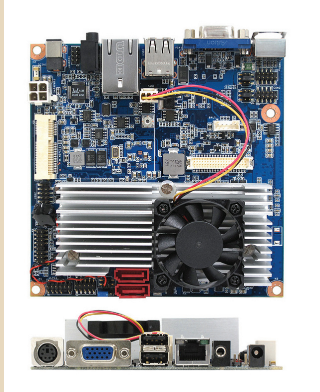
Kit gets the ball rolling on COM designs

While COMs can be used in a wide variety of applications, that flexibility doesn't do much good without software to develop those applications. After releasing a starter kit for nanoETXexpress earlier this year, Kontron has introduced another tool, the Kontron microETXexpress Starterkit VxWorks, to help developers jump-start COM designs and reduce time to market.

Validated for use under Wind River VxWorks 6.8, the kit comes with preconfigured components including a microETXexpress module with a 1.6 GHz Intel Atom Z530 or N270 processor, 1 GB DDR SODIMM memory, heat sink, Kontron ETXexpress-miniBaseboard, 12 V pico power supply, and other accessories. Additional features include a 2 GB USB stick with a preinstalled bootable VxWorks 6.8 demo image plus Wind River Tilcon Graphic demo applications and an 8 GB Wind River LiveUSB environment stick with Wind River Workbench 3.2 (30-day evaluation) and the Wind River Tilcon Interface Development Tool 5.7.

Kontron
www.kontron.com
RSC# 46217

Low-power Nano-ITX for 24/7 operation



Security DVR systems and other applications that operate round the clock can rack up the charges on electricity bills. These systems as well as battery-powered portable devices can benefit from the low power consumption (less than 15 W TDP) offered by BCM's NX510D. Designed based on Intel's two-chip layout architecture, which saves board space and provides efficient routing and heat flow, the Nano-ITX motherboard offers 1.66 GHz dual-core processing performance and Hyper-Threading Technology with the Intel D510 processor.

In addition to incorporating Gigabit LAN, GPIO, Mini PCI Express, two COM, and four USB ports, the NX510D features an onboard DC-in connector supporting 12 V DC power and Trusted Platform Module (TPM 1.2) for data security. The integrated Intel GMA 3150 engine enables dual-display functionality via 18-bit LVDS and VGA output and supports 384 MB video memory and DirectX9, making the board capable of driving display monitors in digital signage applications.

BCM Advanced Research
www.bcmcom.com
RSC# 46191

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Editor's Insight

By Chris A. Ciufo, Editor

'Tick, Tock!' Intel fools the clock. Again.

Every year the embedded industry's seminal events are the *Consumer Electronics Show* (CES) in January and the *Intel Developers Forum* (IDF) in late summer[1]. CES showcases the latest gadgets that will soon pervade the world (literally!), and IDF portends the fundamental computer tech that will materialize in the following year's CES. No longer chasing the highest clock speed as a performance metric, Intel continues to innovate around its *Pillars of Computing*. Here's what I gleaned from this year's IDF, held only a week ago in early September 2010 in San Francisco with a record crowd of 6,500 attendees.

CEO Paul Otellini made it clear in the opening keynote that Intel's *Pillars of Performance* have morphed into something more realistic for a world of always-on computing, "20 billion" Mobile Internet Devices (MIDs), and an increasingly unsafe world of targeted security breaches and organized crime-based hacks. The new *Pillars of Computing* are energy-efficient performance, aimed both at battery-operated small form factor doodads and hot-hot data centers; connectivity, including 10G Light Peak optical silicon interconnects and undoubtedly the wireless portions of the recent purchase of Infineon; and security.

Security pillar

The latter is a bit of a shocker, considering a year ago the third pillar was more generically "software." But Intel has handily absorbed software companies including Wind River and Virtutech (so they say) and is prepping to digest the company's biggest acquisition ever: the $7.6 billion purchase of antivirus company McAfee. Not much was said about McAfee during IDF, though Doug Davis, VP/GM of the Embedded and Communications Group, stated that McAfee can work with anti-theft software and LoJack that can "brick" and locate your laptop, but the right approach for "machines"[2] is to "block Day Zero attacks." He said the whole raft of existing Intel silicon security features such as VT, vPro, TXT, and so on "can be used in a whole different way … wait for 2011." The plan for the security pillar is to lower the number of attack surfaces, whatever that means. By the way, you might piece together Intel's security strategy by checking out the technical session "Securing Today's Data Centers Against Tomorrow's Attacks."

Beyond Core i3/i5/i7

Based on Intel's Nehalem microarchitecture on 45 nm and 32 nm, the Core i3/i5 family (Clarkdale/Arrandale/Westmere) follows the Core 2 Duo family (Penryn) in the company's classic "Tick" (new product) "Tock" (new technology) model. This year's IDF was a "Tock" year, and the 32 nm Sandy Bridge microarchitecture was announced. Key innovations beyond Nehalem include:

- In the processor cores, a decode micro-operation cache turns off the legacy x86 decode pipeline to lower power and increase performance through a shorter timeline. A 50 percent performance increase is obtained by doubling the number of load/store ports to two. Designers completely rebuilt the out-of-order and execution plan and doubled the SIMD instruction set with a 256-bit AVX addition to the SSE instructions for floating-point operations.
- In the graphics engine, it's now on-chip instead of an MCM in Core iX devices. There's double the throughput on shader logic, and many graphics-intensive functions have moved to dedicated logic to lower overall power.
- Core i3/i5 Westmere devices are the 32 nm shrink of Nehalem, but with Sandy Bridge the Northbridge/graphics are on-chip, allowing a new ring architecture to percolate to mainstream devices. The ring was first seen on Nehalem EX (server) Xeon versions and now runs up to 3 GHz at 96 GBps moving data between cores, graphics, and PCI Express channels.

Atom "all growed … smaller"

Beyond all the "Tock" technology hype, I didn't expect Intel to announce any substantive new devices or initiatives, but I was wrong. The Nokia/Intel MeeGo initiative buckled under the pressure of iTunes and introduced AppUp, an "apps store" of tools and toys for Atom-based doodads. Today, that's mostly netbooks and a few embedded platforms, but Intel is clearly targeting cellular handsets with Atom, despite pundits' views of Atom still being too much silicon against ARM. The best place for Intel software resources is either AppUp.com for MeeGo or software.intel.com for the heavier stuff.

Intel's message of "Atom everywhere, transforming everything" lies behind their announcement of a six-device Atom roadmap. The CE4200 Groveland with an onboard H.264 encoder was introduced for consumer devices; the Z6xx dual-core handheld was revisited; Oak Trail for tablets was disclosed, along with a sexy proof-of-concept ultra-ultra-thin Canoe Lake netbook technology mule; and the E600 Tunnel Creek was revealed as the official home for embedded devices. Of particular note, eight versions of Tunnel Creek will eventually ship, including Stellarton with a built-in Altera FPGA sea-of-gates. Which one of these (if any?) will be in a cell phone?

Once again, Intel met my expectations for technology leadership, innovation, and even a surprise or two. At this "Tock" technology confab, the company whet the world's appetite for Atoms in cell phones, more CPU horsepower in servers and laptops, new embedded security, and a wireless media experience called *WiDi* (wireless display). The company clearly stopped the clock one more time, or maybe turned it ahead by 12 months.

Chris A. Ciufo
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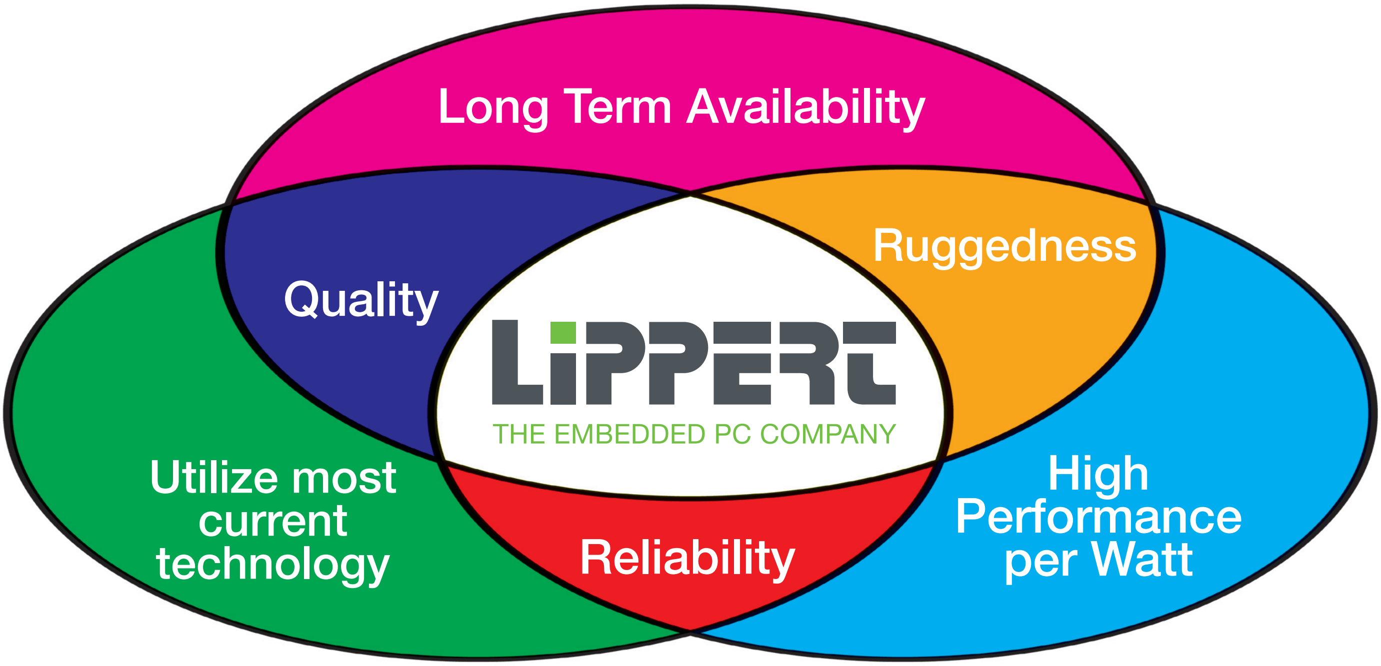
cciufo@opensystemsmedia.com

[1] The *Embedded Systems Conferences* are must-attend events, but hardly considered game-changers nor the place where innovation first appears.

[2] I took "machines" to mean servers, PCs, and all manner of MIDs and embedded doodads.



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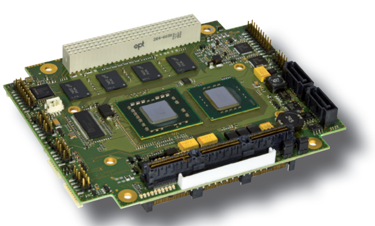

Cool XpressRunner-GS45

Model	Format	CPU, Clock	RAM (max)	Miscellaneous	LEMT
CoreExpress-ECO	CoreExpress®	Intel® Atom™ processor Z5xx 1.1 ... 1.6 GHz	2 GB soldered	2 x PCI Express, SDVO, USB	✔
Cool LiteRunner-ECO	PC/104	Intel® Atom™ processor Z5xx 1.1 ... 1.6 GHz	2 GB soldered	LAN, SATA, USB, Micro SD	✔
Cool LiteRunner-LX800	PC/104	Geode™ LX800 500MHz	256 MB soldered	Mini-PCI, CF slot 2 x LAN	✔
Cool SpaceRunner-LX800	PC/104-Plus	Geode™ LX800 500 MHz	256 MB soldered	2 GB SSD	✔
Cool RoadRunner-945GSE	PC/104-Plus	Intel® Atom™ processor N270 1.6 GHz	2 GB soldered	2 GB SSD, SATA	✔
Cool RoadRunner-LX800	PC/104-Plus	Geode™ LX800 500 MHz	1 GB	CF slot	✔
Cool XpressRunner-GS45	PCI/104-Express	Intel® Core™ 2 Duo processor 1.2 ... 2.26 GHz	1 GB	GB LAN, SATA, USB	✔
Hurricane-LX800	EPIC	Geode™ LX800 500 MHz	1 GB	LAN, USB, uDiskOnChip	✔
Hurricane-QM57	EPIC-Express	Intel® Core™ i7 processor 1.06 ... 2.53 GHz	4 GB	LAN, SATA, USB, Display Port	✔

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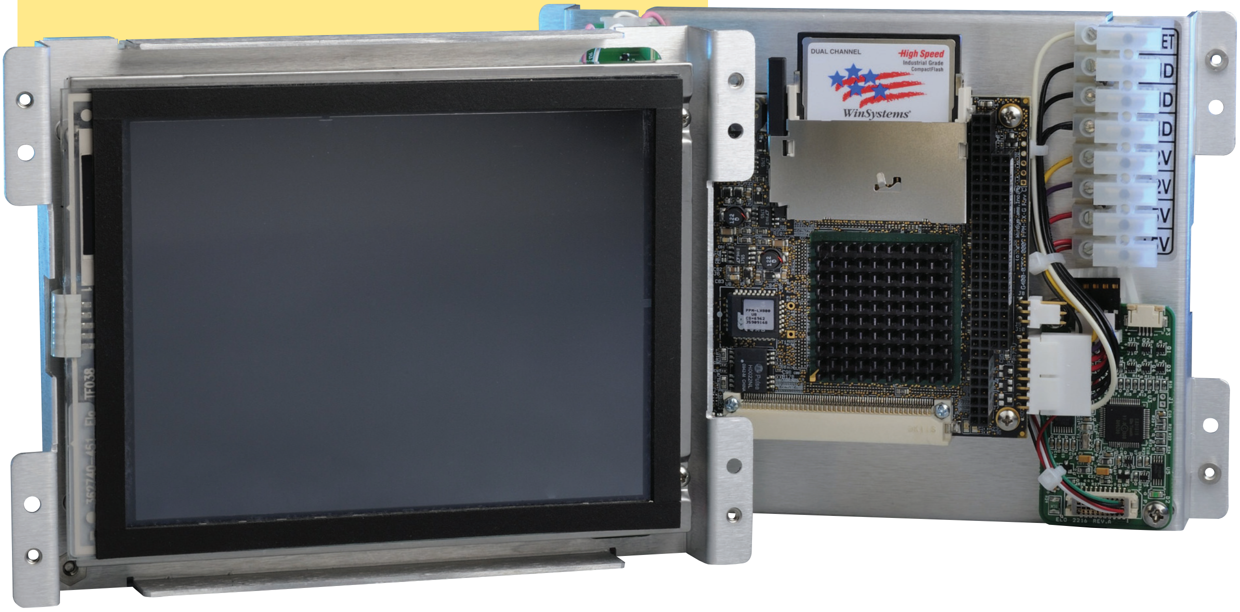

The PPC3-6.5 is a ready-to-mount flat panel subsystem that combines a small yet powerful industrial-grade SBC, touch screen, and color panel in a compact, robust package. Less than 2-inches thick, it is ideal for automation, instrumentation, transportation, and control applications requiring tight system integration and minimal space.

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