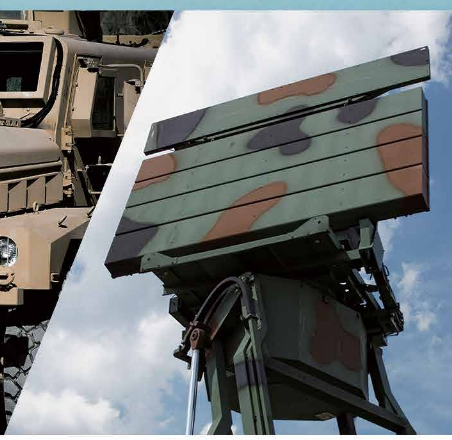
White Paper

Tower in a Teacup : How the Small Form Factor Transition is Reshaping Embedded and Military Computing

Single-Board Computers (VPX, PC/104, CompactPCI)
Computer-on-Modules (COMs)
Mini-ITX Embedded Boards
VITA 75 Compliant Rugged SFF Box Platforms
Fanless Embedded Computers



Introduction

The predisposition that “bigger is better” pervades in many areas, but in computing greater size is almost always a liability. Large configurations demand power and create heat. They consume precious space and potentially crowd out other vital systems. Even in a 60-ton armored tank, size, weight, and power (SWaP) remain at a premium. Such environments demand the sort of small form factor (SFF) solutions that have dominated embedded computing initiatives for decades.

Fortunately, computing manufacturers and standards groups have done remarkable work in bringing conventionally-sized systems down to diminutive proportions. Ever-shrinking circuit sizes enable one processor to contain the functionality of what previously required several discrete chips while delivering faster performance and consuming less total energy. Similarly, interconnects between components and devices continue to become denser and more efficient. Consider the now-ubiquitous Serial ATA hard drive interface compared to its Parallel ATA predecessor. The former is a fraction of the latter’s physical size yet offers roughly six times greater peak bandwidth (6 Gb/s vs. 133 MB/s, or 1.06 Gb/s). Similarly, the range of PCI Express connections available to system components enables ever-shrinking form factor possibilities while making leaps in performance bandwidth.

When paired with ruggedized enclosures, SFF designs can yield remarkable results. ADLINK’s HPERC line of rugged systems have a truly compact footprint. Consider the passively conduction cooled HPERC-KBL-MC, measuring just 223.7(L) x 177.8(W) x 98.7(H) mm (8.8 x 7 x 3.9 inches), including the VITA-75.22 form factor mounting brackets - literally the size of a bread loaf. Yet system features include options for a quad-core Intel Xeon® processor, quad Gigabit Ethernet, and GPGPU support via PCI Express x16 Gen 3 bus. HPERC systems are built with MIL-DTL-38999 high-speed connectors and designed to meet MIL-STD-810, allowing them to withstand battle-level shock, vibration, immersion, and temperature conditions.

Modern SFF designs can support defense forces and their data systems while on the move anywhere in the world, with or without network connectivity. The powerful server that used to fill the back of a Humvee can now be easily carried in the crook of an arm. Broadly speaking, SFF benefits fall into a few key categories:

- Small size for more powerful edge networks: Palm-sized motherboards paired with dense memory and storage components enable robust systems even smaller than the HPERC family. This means that space is no longer a restricting factor for powerful data collection and analytics capabilities at the network edge and beyond – free from the latencies and potentially troublesome access of cloud-based solutions. Intelligent, data-driven decisions can be made in the field, even in isolation, without the burden of large, heavy computing equipment.
- Scalability: SFF systems can often be networked, allowing for the melding of multiple systems into a more powerful whole. This melding can be done either externally, as through high-speed network links, or internally, as when stacking multiple PC/104 motherboards through shared busses.
- Cost-effectiveness: Small size and scalability contribute to making SFF an impressively cost-effective approach to computing needs. Unlike legacy solutions that might involve buying a single, large solution able to accommodate forecasted future needs, users need only buy as much computing power as is necessary to meet current needs. This means being able to have a much smaller solution footprint that can be added to if and when required.
- Portability: From "shoebox" form factors to NVIDIA's MXM interconnect for laptop GPUs, companies that cater to PC enthusiasts and gamers have spent over two decades devising ways to make top-end compute and graphics performance increasingly mobile. ADLINK is now building that accumulated experience and innovation into industrial/military-grade components and systems, enabling yesterday's tower server or workstation to become today's ultralight laptop or embedded SFF solution.
- Compatibility: With government buying mandates based around commercial off-the-shelf (COTS) hardware and software, selecting providers with deep support for and experience with industry standards and open architectures is critical. Such support is essential for solution flexibility, issue remediation, and cost containment. While some proprietary designs do exist in the SFF space, ADLINK remains committed to basing SFF solutions on industry standards from PC/104 to COM Express to Mini-ITX, always seeking ways to add value without sacrificing quality or compatibility.

Whether the modern SFF market evolved to meet increasingly demanding SWaP requirements from the military or those SWaP demands were a response to state-of-the-art developments in the SFF world, the end result remains: Organizations can now address the needs of increasingly mobile, connected, and analysis-driven workforces with unprecedented solution flexibility and performance. This white paper will provide additional insight on how this is being done and ways in which today's solutions can address various application needs.

SFF Building Blocks and Solution Types

Within the SFF space are a wide range of form factors with varying characteristics including dimensions, screw hole placements, types and number of I/O interfaces, and so on. This paper will provide an overview of the SFF form factors most commonly used in embedded and military computing applications.

Single-Board Computers (SBC)

As its name suggests, an SBC integrates every component necessary for operation as a functional computing system. SBCs feature communication ports, such as for integrating storage or networking, and are often deploy singly in kiosk or embedded applications, but they may also be deployed in multiples connected through various means, such as plugged into a backplane or stacked through onboard busses (e.g. PC/104).

Among the many SBC form factors, VPX has aged particularly well since its 2004 arrival. VPX was engineered specifically for defense applications and adheres to either 3U or 6U Eurocard configurations and communicate via switched fabric interconnects. For example, ADLINK's VPX3010 is a rugged 3U blade (measuring only 100 x 160 mm) featuring an Intel® Xeon® Processor D-1500 (up to 12 cores), up to 16GB of surface-mounted ECC DDR4 memory, an onboard 32GB SLC SSD, PCI Express Gen3 expansion, and two 10G-KR Ethernet. With conformal coating for environmental protection and both conduction and air cooled options, the VPX3010 can form the processing backbone of a rugged, extensible server solution in a wide range of military environments.

Stepping back a decade, the CompactPCI form factor continues to thrive in embedded and industrial settings. Featuring similar dimensions and 3U/6U implementations, CompactPCI blades generally emphasize lower-power processors for more economical, light-bandwidth applications. ADLINK's cPCI-6636 family features 7th gen. Intel Xeon® or Core™ i7 processor options, dual-channel DDR4, multiple Gigabit Ethernet configurations, and remote management via ADLINK's SEMA management services.

ADLINK's PCI/104-Express Rev. 3.0 specification CMx-SLx SBC is the latest descendent in a form factor line dating back to 1992's PC/104 design. The CMx-SLx measures 117.4 x 96 mm (4.62 x 3.78 inches), allowing it to fit and function in the most restrictive environments. The CMx-SLx is stackable with any industry standard PCI/104-Express, PCI-104, and PCIe/104 SBCs, making it a powerful way to upgrade legacy deployments. ADLINK outfits the CMx-SLx with a choice of three 6th Gen Intel® Core® i3 or Intel® Xeon® E3 processors, 8GB or 16GB of DDR4-ECC memory, 8GB to 64GB of surface-mounted SLC or MLC SSD storage, Gigabit Ethernet, a range of additional I/O ports, Intel HD

Audio, and Intel Generation 9 LP Graphics, capable of running three independent, simultaneous displays. ADLINK validates the CMx-SLx for standard and Extreme Rugged (-40° to +85° C) operating temperatures, relative humidity of up to 95 percent, and shock/vibration tolerance that adheres to multiple IEC and military standards. The CMx-SLx is built to excel in difficult, rigorous field environments and tackle tasks ranging from multiple-source, high-definition stream collection to network edge data analysis, potentially from a system no larger than a hardback novel.

Computer-on-Modules (COMs) & COM Express

Whereas SBCs typically integrate all necessary computing components onto a stand-alone mainboard, a computer-on-module (COM) is a smaller board with only the core system components integrated into it. The COM is designed to plug into a larger carrier board custom-designed with the specific I/O and peripherals required for the user's application. COM architecture allows system integrators to simultaneously develop software solutions using a reference carrierboard while the hardware team designs the custom carrier board, significantly reducing time to market. An additional advantage is that the core system of a solution can be easily upgraded by swapping in a newer or higher-performance COM as needed.

While "COM" refers to a component type, the COM Express series of standards defines various module interfaces aimed at different applications. For many years, ADLINK has been instrumental in helping guide the evolution of COM Express standards, including chairing the subcommittee that defined the Express COM.0 Revision 3.0 specification update. Part of this work includes deciding which feature characteristics each COM Express type will offer, such as number of PCI Express lanes, SATA ports, video output formats, and USB ports.

COM Express Type 6, for instance, emphasizes speed and multiple display outputs, making it an excellent fit for test and measurement equipment, medical imaging, and gaming solutions when built using the "basic" size standard (95 x 125 mm, or 3.7 x 4.9 inches). Alternatively, a Type 6 implementation might adopt the "compact" size standard (95 x 95 mm, or 3.7 x 3.7 inches) and target lower-power applications (5W-20W) in the automation, transportation, and robotics fields.

COM Express Type 7, in contrast, are "headless," meaning they omit graphics output capabilities. This approach is common in server systems, but, adapted into a "basic" size, Type 7 can become a powerful foundation for edge node solutions. To illustrate, the ADLINK Express-BD7 is a basic size COM Express Type 7 module that mounts to the Express-BASE7 ATX carrier board. The Express-BD7 features a range of processors, including the 16-core Intel® Xeon® processor D1577, up to 32GB of DDR4 ECC SODIMM memory, and two Intel 10G Ethernet controllers. Because of the solution's modular nature, an organization can build its system using the Express-BD7 today, then upgrade to a higher performance module in several years' time with little or no modifications required to the existing solution.

When combined with highly ruggedized enclosures, COMs can achieve incredible application results. Consider the military deployment of ADLINK's Express-BD7 COM Express Type 7 module at the heart of a Command and Control, Intelligence, Surveillance, and Reconnaissance (C2ISR) system. In real world testing, a military client procured a compact, modular C2ISR solution based on the Express BD-7, which measures only 125 x 95 mm, and tested it against a traditional, full-size server. For even comparison, the client ordered its ADLINK Express BD-7 variant outfitted with a 16-thread Intel Xeon Processor D-1539. The tiny system also allows for up to 32GB of ECC DDR4 SDRAM, two 10G Ethernet ports, PCIe Gen2 or Gen3 connectivity, 6 Gb/s SATA, USB 3.0, and a total thermal envelope of just 65W. The client's testing confirmed that ADLINK's Express BD-7 exceeded its requirements on performance, power consumption, size, and a host of MIL-STD ruggedness criteria. These criteria are the foundation for reliable, secure, and highly mobile C2ISR systems — exactly the sort of rugged IoT solutions answering the communication and analysis needs of modern defense, intelligence, security, and commercial missions.

Mini-ITX Embedded Boards

The Mini-ITX motherboard form factor arrived in 2001 as a smaller alternative to the ATX and micro-ATX mainstream PC form factors of the time. Measuring 17 x 17 cm (6.7 x 6.7 inches), Mini-ITX appeared at a time when it was becoming clear that most PC users would not upgrade their systems far beyond their factory configurations, so only a minimal number of component and I/O expansion features were necessary. Mini-ITX struck a compromise between full desktop-class expandability and compatibility with leading-edge processor, memory, and storage components. While originally aimed at enthusiast niches, a wide variety of case manufacturers supported both Mini-ITX and the various ATX form factors in their offerings, making Mini-ITX very affordable to adopt.

Not surprisingly, a product such as ADLINK's MI-220 proves adept at embedded applications that emphasize high performance within power and budget constraints. The MI-220 features processor options ranging from the Intel® Celeron® B810 to the Intel® Core™ i7-2710QE. Two DIMM sockets accommodate up to 8GB of dual-channel DDR3. Other board features include three SATA ports, one PCIe x16 slot, one PCI slot, one PCIe Mini Card slot, and rear panel ports spanning, DVI, VGA, HDMI, USB, audio, and dual Ethernet. With the advantages of Mini-ITX, implementers can leverage the affordable expandability of a board like the MI-220 that allows customization for low-power and low-noise solutions across military applications as well as medical, automation, transportation, and similar verticals.

The above SFFs, along with many others, can serve a broad variety of applications anywhere in the world – and even beyond it, as embedded SFF solutions have provided navigation and control for many spacecraft, including the U.S.'s now-retired space shuttle fleet. Below we present examples of how SFFs are utilized in embedded computing solutions.

VITA 75 Compliant Rugged SFF Box Platforms

ADLINK's HPERC systems are another example to showcase how SFFs can deliver rugged yet versatile solutions for military needs. Packaged in a VITA 75 Rugged Small Form Factor, the HPERC series offers a footprint of only 223.7 x 177.8 mm (8.8 x 7.0 inches), which is small enough to mount under a vehicle seat or tote in a backpack. The system accommodates external storage and peripherals via MIL-DTL-38999 connectors while maintaining an IP67-rated sealed enclosure. Equipped with Intel® Xeon® or Core™ i7 multi-core processor, up to 16GB of ECC RAM, quad Gigabit Ethernet, and NVIDIA graphics for GPGPU processing, the HPERC relies solely on passive conduction to cold plate or air convection cooling.

The heavily ruggedized nature of ADLINK's design lets the system function in virtually any environment, from arctic to tropical, while withstanding levels of shock and vibration expected in military engagement-type scenarios. In one application, a defense system provider integrated an ADLINK HPERC system into its medium altitude reconnaissance surveillance system, a military plane designed to perform a range of airborne intelligence gathering for informing field personnel actions. The craft employs a formidable range of sensors, including thermal imaging, up to four HD video cameras, multiple radio frequencies, and a VORTEX downlink. Feeds from all these sensors flow into the high performance, rugged HPERC system. This makes the mission-critical computing system fast enough to handle image and signal processing across all input streams in real-time and beam them to waiting teams for immediate action.

Fanless Embedded Computers

Rackmount systems are commonplace in data centers and even small business "data closets" due to their performance capabilities, reliability, and easy servicing. However, many applications with these requirements do not have the necessary space for such systems. Fanless embedded computers such as ADLINK's Matrix line can help. Matrix embedded computers provide the PCI and PCI Express expansion capabilities necessary to accommodate specific-function peripherals, such as video encoding cards for surveillance capture. They also incorporate a backplane architecture for easier and more cost-effective upgrading of key components. Rugged construction suits high-vibration settings, such as transportation or factory floors, and fanless operation provides long term reliability.

ADLINK's current flagship MXC-6400 Series of the Matrix line integrates a quad-core Intel® Core™ i7-6820EQ, which boasts a maximum Turbo Frequency of 3.5 GHz, while supporting silent, fanless operation. Industrial-friendly features include two front-mounted, hot-swappable SATA 3 Gb/s ports, a remote on/off power switch connected to the front panel, three Gigabit Ethernet ports, and ADLINK's SEMA management services, which allow for remote admin monitoring of system conditions. Extended operating temperature support is from -40°C to 85°C (-40°F to 185°F), and operating vibration tolerance stands at 5 Grms (5-500 Hz, 3 axes) when used with CFast or SSD storage media. Brimming with front panel I/O ports and convenient access to PCI/PCIe card expansion, the MXC-6400 exemplifies the level of performance, durability, and upgradeability that embedded computers can bring to tough environments with very little space to spare.

As another example of ADLINK fanless systems in the field, consider the ADLINK SETO-1000. A 1U, conduction-cooled server running dual Intel® Xeon® Processor E5 chips, dual 10G Ethernet, and dual Gigabit Ethernet, an Asian military deployed SETO-1000 systems into remote areas lacking 4G connectivity. These regions tended to be environmentally harsh, with wild swings in humidity and temperature. Even though owners operated the servers from high atop long extension poles (for optimal wireless broadcast and reception), customized design focused on internal cooling, IP65 ruggedness, and exceptional stability allowed the SETO-1000 to run up to six virtual machines around the clock, processing incoming video streams from area Wi-Fi cameras and uploading to a data center. Moreover, thanks to ADLINK's application platform software, remote management capabilities, and system management APIs, ADLINK was able to help the buyer go from order to successful deployment in a fraction of the time alternative solutions would have required.

Trends in SFF

Even though small form factor systems have been a force in computing for over 30 years, there seems to be no sign of slowing in the SFF market. If anything, the range of opportunities for SFF in government, military, and vertical markets is expanding faster than ever.

Topping today's embedded computing headlines, edge and fog computing have become key SFF deployment areas and a core requirement in most broad Internet of Things (IoT) strategies for data-driven organizations. Fog and edge computing are relatively new terms, and some people are unaware of their differences or how they are distinguished from cloud computing. Essentially, edge applications gather data at the source from environmental sensors, video cameras, and so on, and pre-process them. Edge systems feed collected data up to fog systems, which sit between the edge and the cloud, and can then aggregate, analyze, and filter data, along with other functions. Fog can then send data upstream into the cloud for further refinement, big data analysis, and storage.

This chain of data collection and processing is bi-directional. Edge applications can pass data to fog nodes as well as receive information back from them, and the same is true between fog nodes and the cloud. Generally speaking, the closer one gets to the network edge, the smaller systems become. In a military setting, field soldiers each might have a dozen data sources streaming off their armor, all of which might be gathered by one squad member toting a battery-powered gateway system —perhaps something like an ADLINK HPERC — or a larger fanless embedded computer mounted in a Humvee. Several such gateways, in turn, might feedback to a server running at the company/battery/troop headquarters.

Not that long ago, minimal computing power was needed for video capture. A digital video recorder could capture a TV or surveillance camera stream with fairly modest processing resources. The game changes when that one video stream grows into high-def or 4K resolution and then multiplies across multiple cameras, then multiplies again with feeds coming from multiple people — all accompanied by other data sources, such as LiDAR cameras, laser sighting, long-range microphones, GPS, and more. Depending on the circumstances, there may be a need for this data to be processed, analyzed, and visualized in the field, especially if cloud latency and/or connectivity results in too much delay. Even relaying to fog nodes may be infeasible. SFF systems can provide the intelligence needed at the edge without significant increase to SWaP parameters.

Some of the above data transmission and latency concerns may be impacted by another impending trend: 5G wireless connectivity. The cellular communication successor to 4G LTE, final 5G specifications are expected in April 2019 (Release-15) followed by April 2020 (Release-16). These 2020 specifications will likely yield approximate data rates of 1 Gb/s for hotspots and 100 Mb/s for client nodes. These are generally faster than 4G performance, but excitement over 5G is less about speed and more about markedly lower latency, higher network bandwidth, and higher signal reliability. This last point in particular will dovetail with SFF systems in "noisy" RF environments, such as factory automation. Similarly, higher bandwidth will be needed to maintain consistent performance in dense IoT applications, where hundreds or thousands of devices might be vying for connection. This will also enable the ability to pull much more data from edge devices.

The rise of in-vehicle computing will clearly benefit from the advantages of SFF. Of course, cars have relied on microprocessors for decades, but between integrated

communication systems, in-car entertainment, in-car sensor analysis (think of the visual recognition needed for back-up guidance), real-time navigation, and soon inter-car communication for collision avoidance, the need for more powerful processing and graphics in vehicles demands high performance embedded systems. Other transportation fields including freight, rail, nautical, and military are also seeing an increase in SFF adoption.

As mentioned earlier, data centers have their own challenges, and organizations constantly search for ways to reduce space and energy demands. Data center downsizing continues to affect organizations of all sizes, but it intersects with SFF trends when a data closet can be reduced to a small box with a handle, such as a fanless embedded computer. Such measures allow data-driven organizations to become increasingly mobile. Mobile workforce benefits are well documented, but when IT infrastructure can be similarly mobilized, including through enablement of mobile virtual servers, then an entirely new set of cost savings and IT flexibility emerges.

Conclusion

Between 2018 and 2025, analysts expect the number of IoT devices, already numbering above 7 million, to more than triple. Many, perhaps most of these, will carry multiple types of sensors, resulting in a global sea of data. Increasingly, small form factor computing will be critical to separating signal from noise and turning the world's chaotic ocean of information into actionable data.

in today's world, signal analysis is ubiquitous and can be found in applications ranging from noise-canceling headphones to AI-enhanced health monitoring to drone fleets taking automatic control of defensive maneuvers. In each case, increasing functionality requires more intelligence as close to the device as possible. SFF computing provides this proximity or even integration when possible.

Manufacturers and solution integrators like ADLINK continue to innovate year after year in the SFF arena – reducing footprints, improving performance/energy ratios, increasing durability, and containing costs. ADLINK's commitment to the small form factor market is to bring industrial-class computing into more environments and with broader, deeper benefits than ever before.

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