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White Paper: How to Design a Small Form Factor Embedded Computer.... *The Right Way!*

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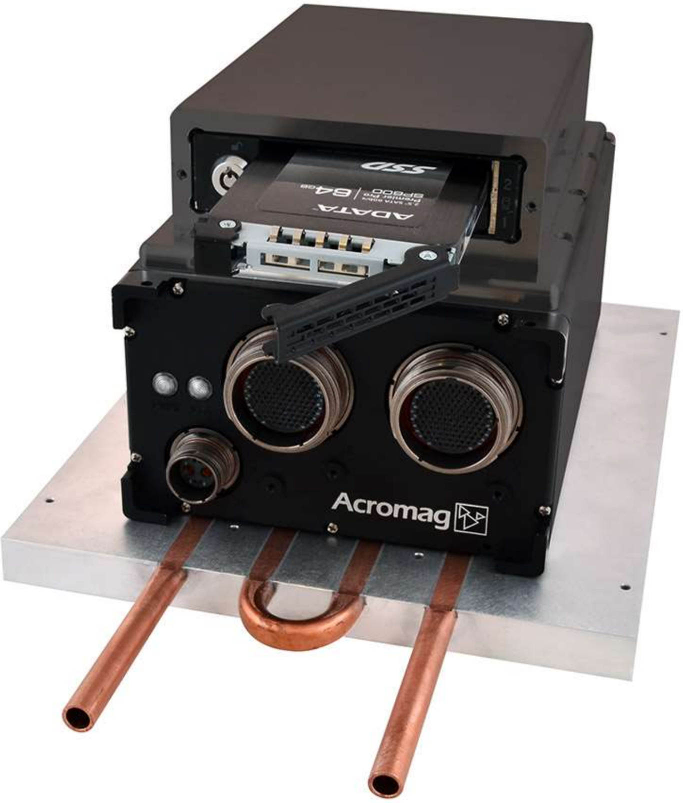

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I. Introduction

Customers have started to move away from the traditional rack-based system (VME and cPCI) or deployed applications and are looking for a modern alternative. VPX is one approach, but for many applications the capabilities of VPX are overkill or just too expensive. Small Form Factor (SFF) boxes are becoming an attractive alternative but quite often lack the processing power, flexibility and standardization that customers are used to seeing in their old rack-based systems.

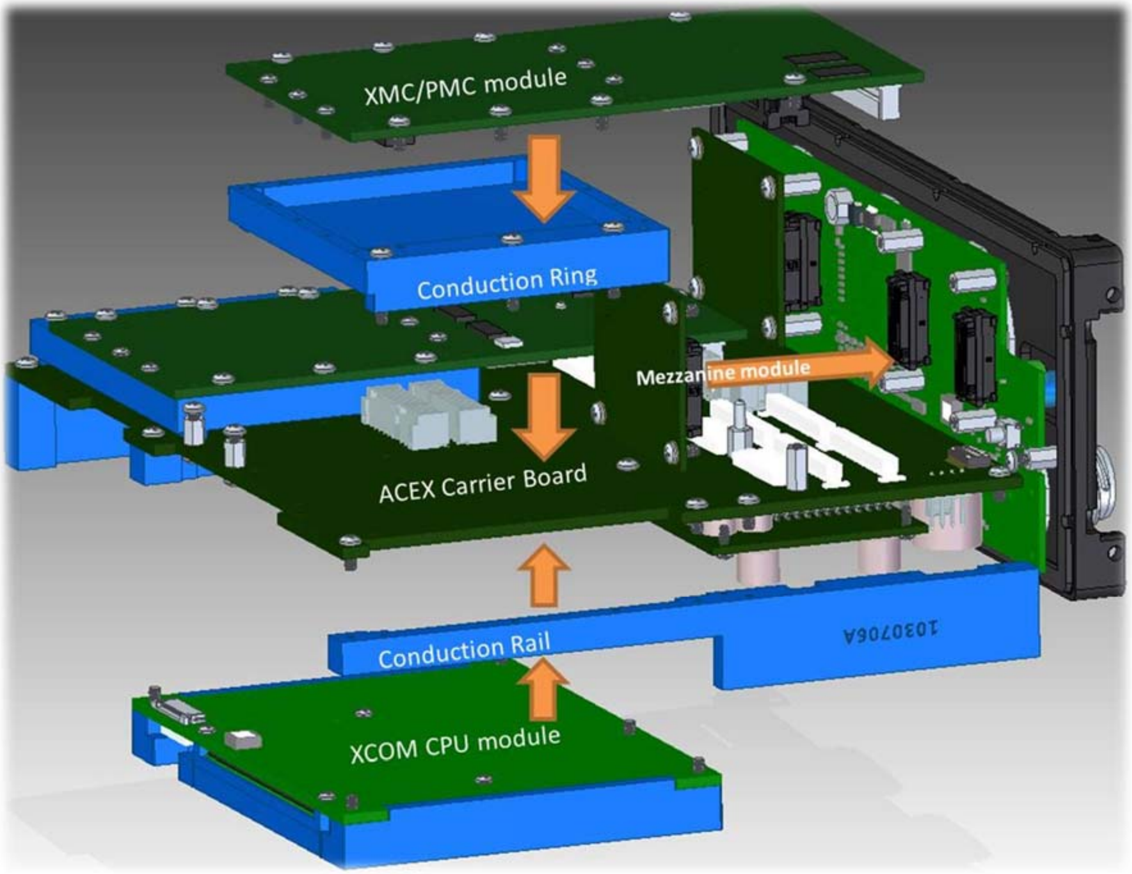
A new breed of SFF products are now coming to market that offer processing power, expandability, and even customization that customers were used to with their older systems, but at a fraction of the cost. These new SFF products are able to pull together a broad range of industry standards to meet the needs of military and industrial customers. By combining COM Express for the CPU, PMC/XMC slots for specialized expansion such as FPGAs and Frame Grabbers, and mini PCI Express slots for lower cost I/O, these new SFF products offer customers the processing power, flexibility and standardization they need for their deployed application.

II. Design it be Rugged

SFF boxes have to be designed from the ground up to meet the needs of deployed military system. This requires that the package is designed to manage heat, shock and vibration and EMI all while maintaining a small package size. Once the design is complete, extensive testing will be required to prove that the design meets the needs of the customer.

A critical element to this is thermal design. Heat within the box must be captured and rapidly transferred to the exterior surface. From there it can be removed by either conduction or convection cooling. Modern processor and PMC/XMC modules generate a lot of heat that if not controlled, can rapidly cause systems to throttle back and even shut down. The use of internal structures such as heat spreaders and conduction cooling rails are essential to a properly functioning design. In the image below (Figure 1), you can see how the CPU is designed with a heat spreader that connects to the bottom of the chassis, thus capturing the heat from the CPU and transferring it directly to the housing. This prevents the heat from the CPU travelling upward into the carrier and expansion slots. This is also true for the placement of the expansion modules (PMC/XMC and mini PCIe/mSATA modules). By placing them on heat conduction rails that make contact with the carrier, their heat can be routed to the outside without causing additional heat buildup around the CPU.

Figure 1



The conduction-cooling rails and heat spreaders not only conduct the heat to the external structure of the box, but are essential in providing additional stiffening of the enclosure needed to meet rigorous shock and vibration requirements of the customer. Having the CPU heat-spreader and conduction-cooling rails mounted directly to the outer box (Figure 2) also prevents resonant frequencies from being created on the carrier, reducing failures from being caused over time in high shock and vibration environments.

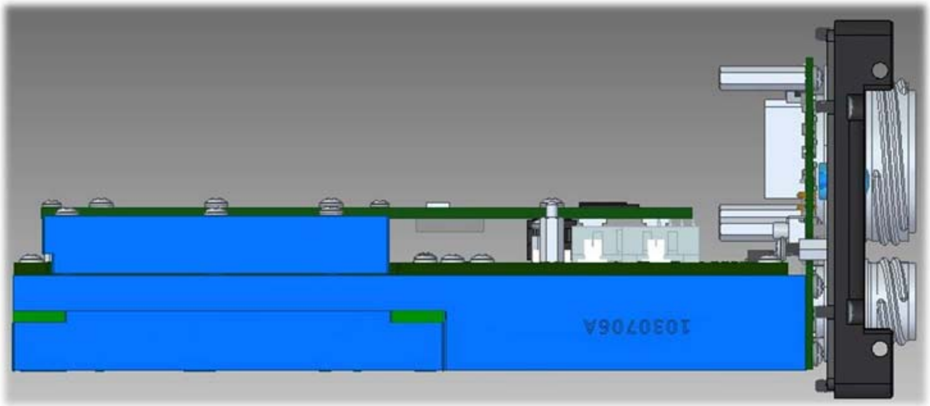


Figure 2 – Side view of CPU with conduction cooling and front panel.

For additional thermal control, CPU Power Management provides programmable power limits. This allows the user to “dial-down” the maximum power consumption of the CPU in applications where heat and/or power is a concern. For additional heat management, mounting the unit to a cooling plate (Figure 3) will help keep high temperatures under control.

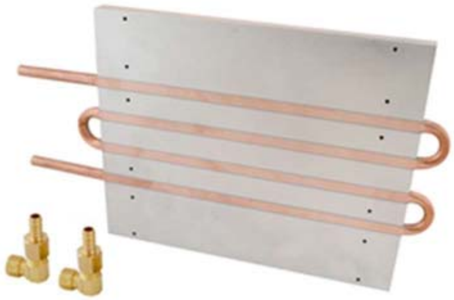


Figure3 – cooling plate

Building it “Rugged” means designing the system to accommodate all expected needs. This includes a power supply capable of meeting all expected expansion needs. Additional PMC/XMC and mini PCIe/mSATA modules as well as special defense industry power requirements such as MIL-STD-704 and MIL-STD-1275 should also be taken under consideration.

III. Design it be Powerful!

Most defense customers seek a balance between more processing power while still meeting the SWAP (size, weight and power) budget available for their application. Where budget (power and price) allows, Intel’s i7 is an ideal processor for the job. However, not all application need this much processing power nor the wattage required (TDP of 47 watts). As mentioned earlier, the Intel i7 CPU allows programming a lower power limit in the BIOS setup. This allow the designer of the SFF system to accommodate either requirement with a single component, adjusted to best fit the application’s needs. In addition, the CPU should not only be the latest generation but should be listed on Intel’s Embedded Roadmap (http://ark.intel.com) to insure longevity of design.

IV. Make it Expandable!

One of the key advantages of rack based systems has been their expansion capability to meet the needs of the application. This historically was done by adding specialized I/O boards on the backplane. In recent years, with the availability of smaller electronic packaging, using PMC/XMC modules for expansion has become the norm. The key advantage PMC/XMC modules offer is that they are based on well-established standards and provide a wide variety of functionality from multiple vendors. These include user programmable FPGA, graphics processors/frame grabbers, analog and digital I/O and a wide range of specialized communication modules. PMC/XMC modules have one other key advantage – they are often offered in a conduction-cooled design.

But great care must be taken in adding PMC/XMC modules with-in the SFF packages. Questions to be asked include:

1. Is there sufficient power available in the design to support the required PMC/XMC module(s)? How much powered is allocated to each slot?
2. How will the added heat be accommodated? Is there appropriate conduction cooling to meet the needs of the modules.
3. How is the I/O from the PMC/XMC modules accommodated? Are special cables and connectors required or has the designer provided a means of routing the I/O signals to the front panel connectors?

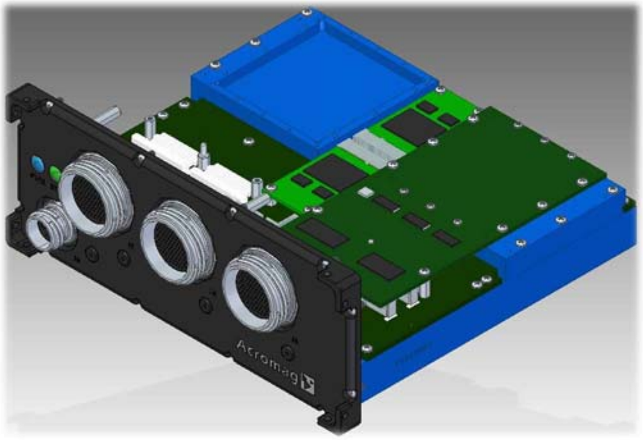


Figure 5 – ARCX with PMC and Mini PCIe card installed

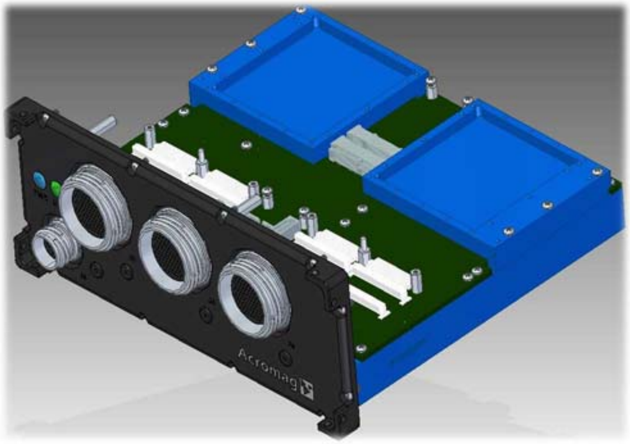


Figure 6 – ARCX internal electrics with conduction cooling and front panel metal work.

Since a well-designed SFF system should readily allow PMC/XMC module(s) to be added without changes to the design, the power supply must have the appropriate overhead from the start. Conduction cooling and I/O connections from J4/J16 should also be included in the base design without requiring modification by the user (Figure 6).

While PMC/XMC modules are designed to do the "heavy I/O lifting a second industry standard is starting to show up in SFF system designs. Mini PCI Express (Figure 5) was designed by the PCI-SIG standards group for implementation in laptop computers. Its small package size (30 x 50.95mm) and low power requirements are well suited for the SFF system. Although not capable of being used for complex function such as programmable FPGAs or frame grabbers, they are well suited for adding devices such as Wi-Fi or SSD (up to 256GB) memory to the system.

V. Make it customizable

One of the short comings of any SFF system that is designed to be conduction cooled is the ability to create custom I/O interfaces. In an air cooled open rack system, Rear Transition Modules (RTMs) can easily be added in the form of a daughter board (for example, Acromag's AXM modules for their FPGA boards). Acromag addresses this need with a User/Factory customizable module or custom mezzanine module extensions (Figure 7). These custom mezzanine modules electrically sit in the path between the PMC/XMC module's rear I/O (J4/J16) and the I/O connector on the front of the SFF box.

These mezzanine modules also allow customers to create special interfaces needed for specific applications. Examples of how these modules can be used include:

- RS424/Clock interface to a user programmable FPGA – The customer had a mix of LVDS and RS424 signals that they need to interfaced to a FPGA. The FPGA supported LVDS but not RS424 via rear I/O. In addition, they had to intercept and re-amplify a common clock signal used by the FPGA. A custom mezzanine module was created specifically for these requirements.

- Cable Equalizer Circuit – The customer needed to install an XMC-based Frame Grabber. The module required external magnetics and a cable equalizer circuit for each of the connected channels. All of these functions were designed on to the custom mezzanine modules.
- Internal cabling to accommodate Mil-Std-1553 - The customer installed a mini PCI Express card with Mil-Std-1553 and a GPS-based clock pulse. The design required the use of internal cable but the customer wanted to route these signals through the available D38999 I/O connectors. A custom module was designed that the added mating connector on the custom mezzanine modules that then routed the signals to unused pins on the D38999.
- GPS antenna cabling – Not all custom features require mezzanine modules. Customers with special cabling and connector needs can be accommodated with only slight modification of the front housing. The Acromag ARCX front panel electronics is designed with notches to allow cabling and connectors to access the front panel metal work without alteration.

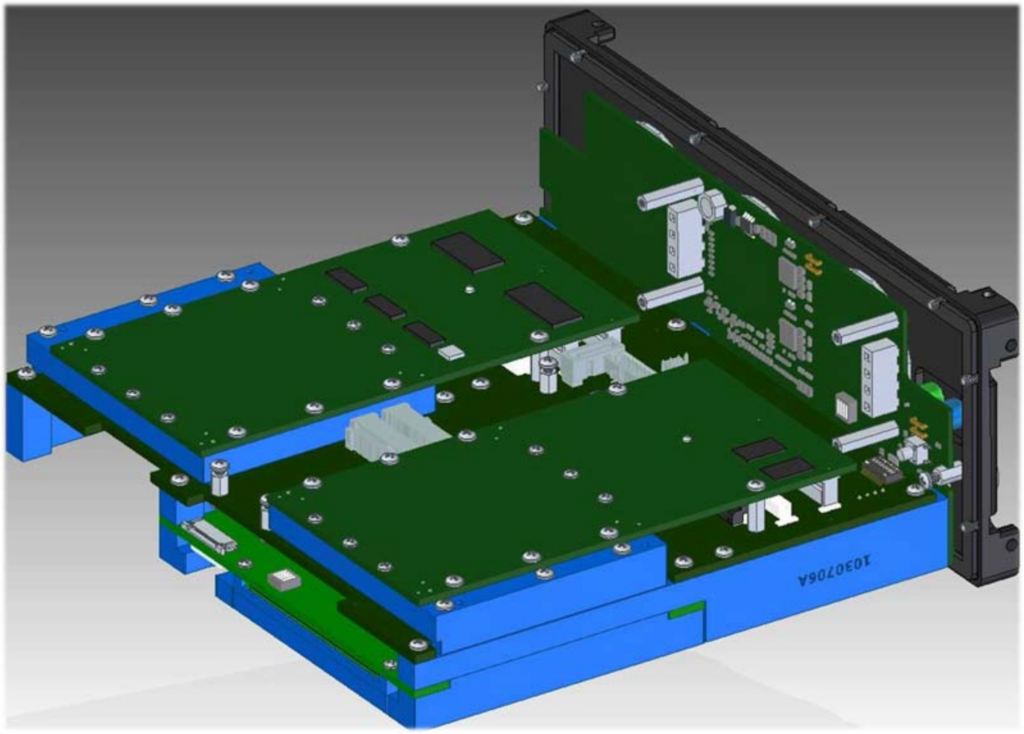


Figure 2 – Internal ARCX electronics showing the location of custom mezzanine modules with standoffs

VI. Conclusion

The new breed of Small Form Factor systems now offer the processing power, expandability and customization that were available in older rack-based systems. These new SFF designs incorporate a broad range of industry standards to meet the needs of military and industrial customers. Combining COM Express, PMC/XMC and mini PCI Express offers customers the processing power and flexibility in a “standardized” package well suited for deployed applications.

About Acromag

It is an AS9100 and ISO 9001-certified international corporation with a world headquarters near Detroit, Michigan and a global network of sales representatives and distributors. Acromag offers a complete line of embedded computing and I/O solutions including bus boards, single-board computers, FPGA modules, embedded computers, COM Express, mezzanine modules, wiring accessories, and software. Industries served include military, aerospace, manufacturing, transportation, utilities, and scientific research laboratories.

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