Unmanageable? Thermal management for embedded enclosures requires creative solutions

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From the telecom data center to enterprise applications to mil/aero programs, embedded computing packaging continues to pack faster/hotter processors into tighter spaces. Not only are the processors requiring more cooling, but often the enclosures are stuffed with more boards and components, taking away space from airflow. Electronics packaging companies have had to get creative to tackle some of the more challenging applications.

Common cooling types

There are many ways to cool an enclosure. Forced air is the most common because it is simple, cost-effective, and it is used in a a myriad of potential COTS solutions.

* **Forced air side-to-side** is used in horizontal-mount chassis, and push-pull configurations are also common. This method is typical in chassis from 1U to 6U.

* **Forced air bottom-to-top** is often used where space in not available for front-to-rear or where fan trays below the card cage are utilized. It is typical in subracks from 6U to 9U.

* **Forced air front-to-rear** is preferred in many applications, especially rack-mount where heat is evacuated out the rear. Some applications such as NEBS-compliant ones, require front-to-rear cooling. This method is typical in enclosures 7U and above.

* **Conduction cooling** is common for applications that are sealed or have little to no airflow and is often used in higher altitude applications such as ATRs. There are typically lower cooling level limitations for conduction cooled and costs can be higher.

* **Liquid cooling** can include direct spray cooling, liquid-flow-through the chassis walls, or liquid through the individual modules. Typically increases the complexity and the risks of leakage, etc, can be a barrier. Costs can be significantly higher.

* **Hybrids/special.** Common hybrids are forced air/conduction cooling. Often used to give a boost to cooling for conduction-cooled applications. Costs/complexity increase some.

Regardless of the cooling method, the challenges remain high for the various applications. In many mil/aero, mobile rugged, and energy/oil & gas applications, the enclosures often have critical SWAP (size, weight, and power) requirements and handle the harsh environments. For telecom applications, a key consideration is to balance the size/performance and compliance issues such as NEBS, acoustic noise, EMI, etc.

Evolving rugged mil/aero thermal management requirements

Although we didn’t think so at the time, electronic packaging companies for rugged applications had it relatively easy until recently. Not that long ago, VME-based and later CompactPCI applications were strictly bus-based, with in-line processors that got hot, but were manageable. A typical board might be less than 30 W/slot and certain IO and other boards would often be even less. Sure, there were cooling challenges. Anytime you try to minimize space and maximize performance, you are going to eventually run up to the laws of physics. But, today’s powerful dual-core processors are even more challenging. Whether they use the latest Stratix and Virtex FPGAs or Intel processors such as Sandy or Ivy bridge, the boards embedded systems are getting hotter. Even VME64x and CompactPCI are reaching 60 W/slot in some cases, although approx 30 W to 40 W/slot is more common. The chassis also needs to handle more extreme environments, including non-operating temperatures often from -40°C to 70°C.

Figure 1. Side-to-side airflow path across a 1U Slimbox horizontal chassis.

For typically communications-based defense applications, side-to-side cooling in SlimBox-type of enclosures is common. These VME64x or CompactPCI applications can be cooled with a side-to-side cooling configuration, often in open racks. See Figure 1 for an example of such as chassis with this cooling layout. But, other applications in certain enclosed racks will require front-to-rear cooling. These larger systems are typically in 8U or taller heights for applications using 6U Eurocard boards.

In avionics applications, the systems that often need be cooled have little to no airflow. Thus, a conduction-cooled enclosure is the best option (see Figure 2 for an example courtesy of our partner Wakefield Solutions). Wedgelocks will provide a thermal interface between the PCB and the chassis side walls. In many cases, the chassis side walls will have heat sink fins, which increase the surface area exposed to the outside environment, allowing for dissipation by natural convection to the cooler outside environmental conditions. An example of a hybrid design will have forced air move across the fins on the outside of a conduction-cooled enclosure, which can provide greater temperature management for higher power enclosures.

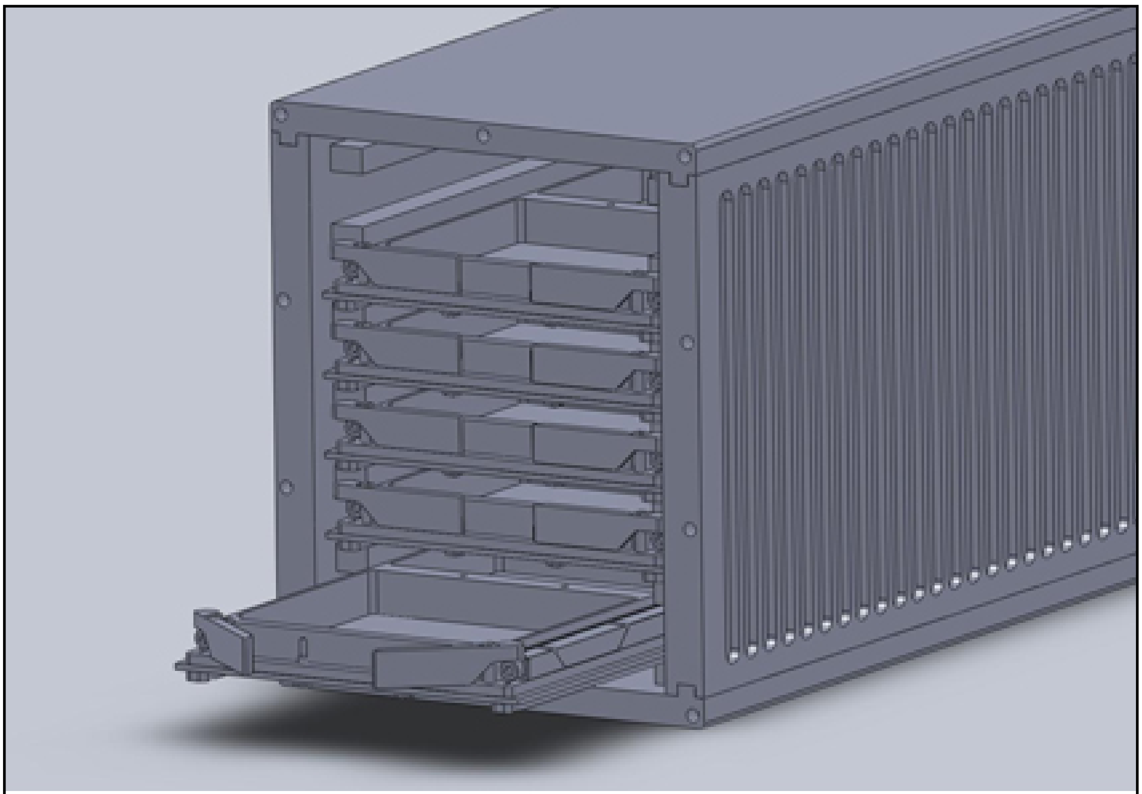

Figure 2. This ATR (Air Transport Rack or Austin Turnbull Radio) has a conduction-cooled design with wedge locks on the boards diverting the heat to the edges of the chassis. The image is courtesy of our partner Wakefield Solutions.

Front-to-rear cooling for telecom central office

The telecom central office has NEBS-compliance requirements. Thus, the systems should incorporate a front-to-rear cooling configuration. Utilizing leading technologies such as AdvancedTCA (ATCA), the chassis are typically at least 13U to provide enough cooling for the vertical-mount 8U high boards. However, many applications are using dual Sandybridge chips and the cooling required is climbing to 350 W per slot and beyond. Plus, the RTM section can add another 40 W to 70 W per slot of heat to dissipate. As a result, carrier-grade solutions have increased in size to 15U heights for additional air intake. Figure 3a shows a new 15U AdvancedTCA shelf geared to cool 400W/slot. Figure 3b shows thermal modeling for the enclosure. The image shows the air velocity (yellow and red is faster airflow). From examining the effects on each slot in the enclosure, the designer can incorporate air plenums, adjust fans, and more, to optimize the cooling.
The cooling criteria are more challenging in telco applications than many others. For example, chassis under test need to cool adequately at 40°C indefinitely in a failure condition (which can be done by turning off or removing one of the fans). The chassis also need to cool at 55°C for 96 hours. In addition, these applications have more stringent filtering requirements, which require more air pressure to overcome.

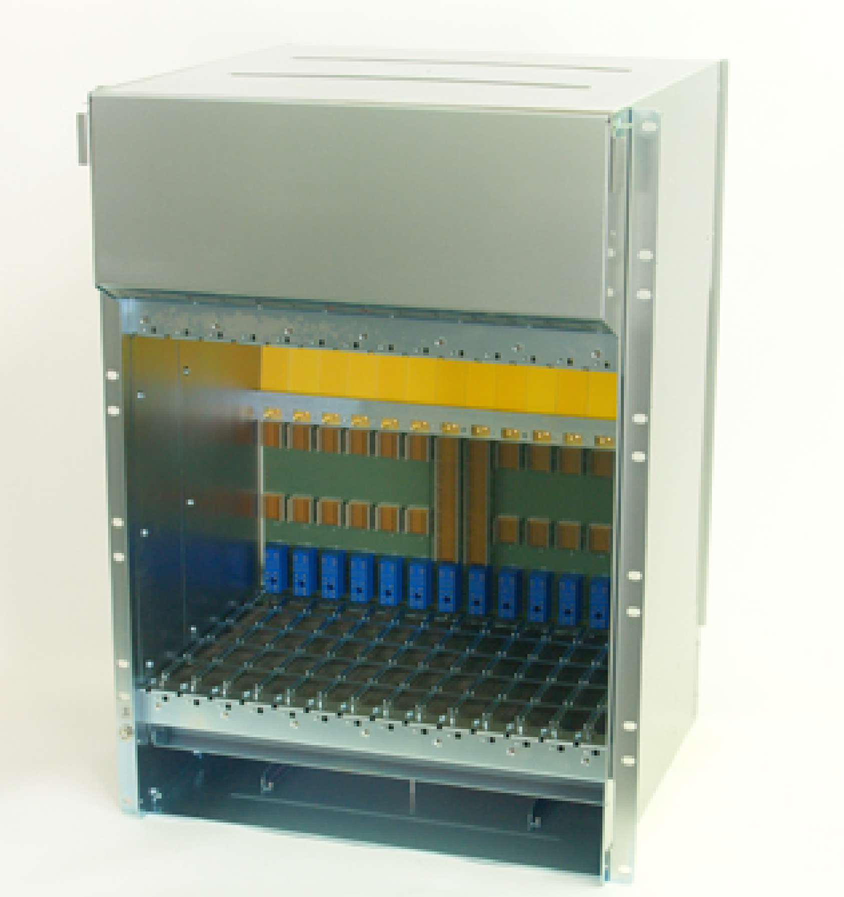

Figure 3a. A new ATCA chassis with cooling of 400W/slot.

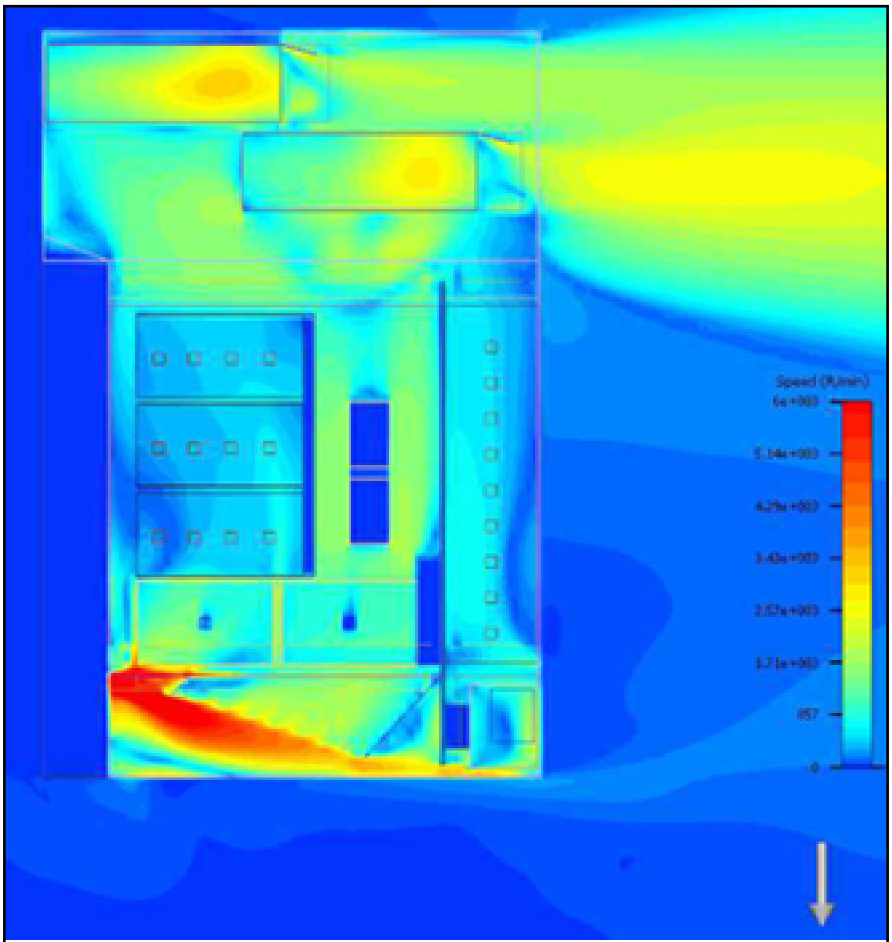

Figure 3b. The modeling shows the airflow path in the chassis with higher speeds in red.

Cooling demands for the data center

For data center applications, the challenges are quite different from mil/aero. But, the core criterion remains the same – packaging more performance into less space. In 1U to 4U heights typically, CompactPCI offers up to eight slots in horizontal-mount configurations. The speeds are to 533 Mbytes/sec across the backplane. With newer CompactPCI Express/serial versions, the bandwidth is higher. Since NEBS compliance is not a requirement in many of these applications, a side-to-side cooling configuration performs the task. This is also the case for horizontal-mount AdvancedTCA chassis in 2U to 6U heights (typical), offering tremendous bandwidth across 10G or 40G backplanes. In some cases, these ATCA chassis are dissipating over 325 W per slot.

In the data center, the chassis requires 55°C ambient cooling. With the increased chassis density, acoustic noise can be an issue. One rule of thumb is that using fewer but bigger fans cools the system with less acoustic noise.

Cooling configurations

Whether it's side-to-side cooling, front-to-rear, conduction, or another method, the embedded industry will continue to see cooling challenges.   Every supplier is trying to pack more functionality into less space, increasing the value proposition for their customers. Addressing thermal management while balancing issues such as acoustic noise, EMI, IO, and other special requirements, demands creative solutions in a myriad of configurations.

Justin Moll has been with Pixus Technologies since early 2012. He is providing his 15+ years of industry expertise to expand the company's presence in the USA.

Previously, he was Director of Marketing at Elma Bustronic, and has worked in the power connector industry at Elcon Products International (now a part of Tyco Electronics Connectivity). Justin has served as VP of Marketing for the StarFabric Trade Association, Chair of the VXS Marketing Alliance at VITA, and has been a guest speaker at several industry events. Justin has a B.S. in Business Administration from UC Riverside.