Thermal Analysis of Complete ATR Systems – A Comparison of Geometric Resolution in Computational Fluid Dynamics

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Ruggedized Air Transport Rack (ATR) enclosures are available in a variety of arrangements, accommodating an assortment of modular single board computers (SBCs) and power supplies. Advances in semiconductor and integrated circuit technologies, along with the growing desire for more compact packaging, foster a circumstance of continuously increasing power density in modules and systems. Consequently, there exists an increasing regard for thermal performance in design. Traditionally, performance estimates are acquired through the costly avenue of experimental testing components and systems. In scenarios where components do not meet thermal requirements without overheating, solutions are largely retroactive. A modern approach to estimating thermal performance and implementing proactive solutions is found in computational fluid dynamics (CFD). By numerically evaluating a 3D model of the system under investigation, CFD can yield valuable thermal performance insight prior to production.

Utilizing and profiting from CFD is not without significant amounts of labor. Aside from resolving the underlying physics associated with an ATR system, the engineer is likely burdened with the geometry alone. For example, a single SBC contains multiple materials, heat-generating sources, and contacting interfaces that all must be considered. A complete ATR system contains multiple SBCs, graphics processing units, switches, modular power supplies, and other modular electronics, all held in place by intricate wedge lock retaining mechanisms. Immediately, the CFD engineer is faced with the choice of making geometric assumptions to simplify the domain or to pursue the laborious task of resolving all relevant components. Each avenue has its pros and cons.

Making geometric simplifications to a model is typically the most inviting option when working with CFD, however all assumptions must be justified. Common assumptions include simplified wedge lock mechanisms, simplified VPX modules, and domain symmetry. If properly imposed, a simplified geometry can retain solution accuracy while significantly reducing computational requirements. On the contrary, fully-detailed simulations can require much more simulation setup and run time. Despite this, all asymmetries in heat transfer are captured, along with full spatial resolution of temperature. If the engineer is seeking overall system performance estimates, geometric assumptions should be considered. However, more specific investigation into the domain will require a more representative geometry, having less simplifying assumptions.

Recent CFD studies of Orion Technologies' 5-slot, ½ ATR system compares the impact of using fully-resolved and simplified geometries, seen in Figure 1 and Figure 2, respectively. Here, the fully-resolved domain involves a total of 80 heat-generating components and 50 individual wedge lock components, all in all 950+ contact interfaces having heat flux (energy exchange). Comparatively, the simplified domain incorporates a symmetry assumption, "dummy" wedge locks, and simplified VPX modules, resulting in ~150 contacting interfaces. After comparison, data from the simplified domain matches overall system heat dissipation within 1.7% of data from the detailed domain, achieved with a 35% reduction in CPU hours to convergence. When comparing individual module heat generation, distributions reported from the simplified domain do not exceed 9% variation from the detailed domain data. Over the course of this study, adopting geometric simplifications for many simulations saved an estimated 450 CPU hours alone. Additionally, an estimated 20 hours of labor was avoided in simulation setup time.

Like this scenario, many times CFD efforts for full ATR systems focus on thermal performance characterization and optimization. These studies are typically parametric in nature, thus potential time savings of incorporating geometric simplifications are multiplied. Not to mention, simplifying assumptions can drastically reduce simulation setup time as well. As a result, utilizing geometric simplifications can be very beneficial and should be considered when pursuing full-system simulations. However, every geometry should be evaluated on a case-by-case basis to determine the most appropriate simulation approach that will ultimately satisfy analysis objectives.

Orion has fully adopted advanced CFD methods to optimize both existing products and custom systems. ATR chassis range from ¼, ½, ¾, or 1 in size, can accommodate 3U or 6U cards, and can be customized to meet specific envelope and environmental requirements. By leveraging advanced CFD analyses in the development process of custom systems, Orion can design with confidence, knowing that a custom high-powered system will satisfy all customer requirements.

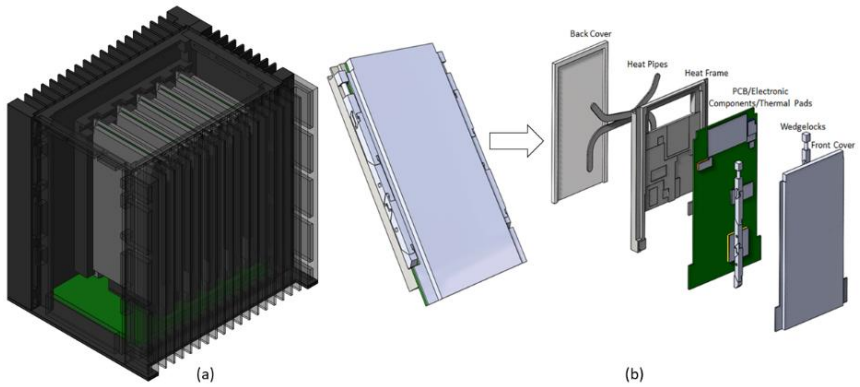

Figure 1: Fully-Detailed 5-Slot ½ ATR, (a) Complete System, (b) Single VPX Module

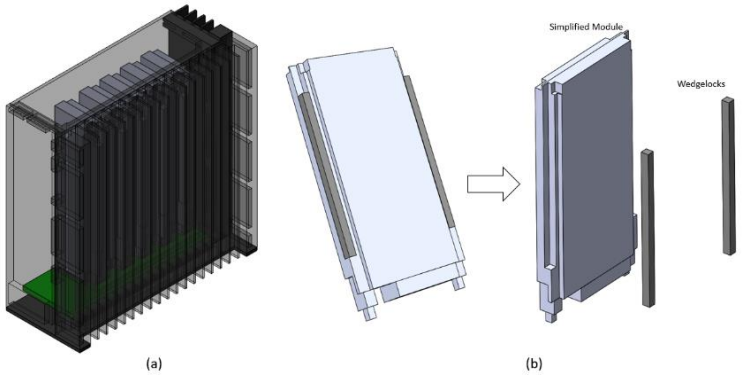

Figure 2: Simplified 5-Slot ½ ATR, (a) Complete System, (b) Single VPX Module

About Orion Technologies

Orion Technologies, LLC has specialized in the design of embedded electronics for over 20 years. Product offerings include both commercial off the shelf (COTS) and custom solutions to satisfy military, industrial, and commercial requirements. Orion provides customized single board computers, backplanes, power supplies, test equipment and rugged deployment chassis as well as full integration services. Orion places the customer at the center of the business, allowing them to design the most appropriate, affordable solution for each unique application. Orion maintains a dedicated workforce allowing for superior control of the total business process from the initial customer inquiry, through design & integration, to shipment of the final product. Orion strives to not be a supplier but a partner, forming relationships that allow them to better serve their partners.

Whether it's a small quantity, one-time requirement or a high-volume product for years to come, we would like to be your partner in embedded solutions. Website: www.oriontechnologies.com