Thermal Management Strategies for Extreme 3U cPCI Embedded System Applications

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Planned thermal management designs – such as this MEN Micro F50C PowerPC 3U board with custom CCA adapter frame and convection-cooled rack system – enable system designers to adapt standard boards to accommodate higher temperature performance without requiring extensive redesigns.

As the cooling challenges of 3U CompactPCI (cPCI) embedded system applications multiply due to increased processing power, reduced package sizes and more hostile environments, new thermal management options and industry standards continue to evolve.

Chip and board manufacturers have already done a vast amount of work to mitigate thermal management concerns. But implementing final housing assemblies of complete 3U cPCI solutions for extreme applications such as railway, avionics, industrial automation or medical engineering requires additional strategies to take full advantage of the speed, power and versatility of the components inside. Fortunately, the right choices can actually minimize design complexity, streamline performance and reduce time-to-market.

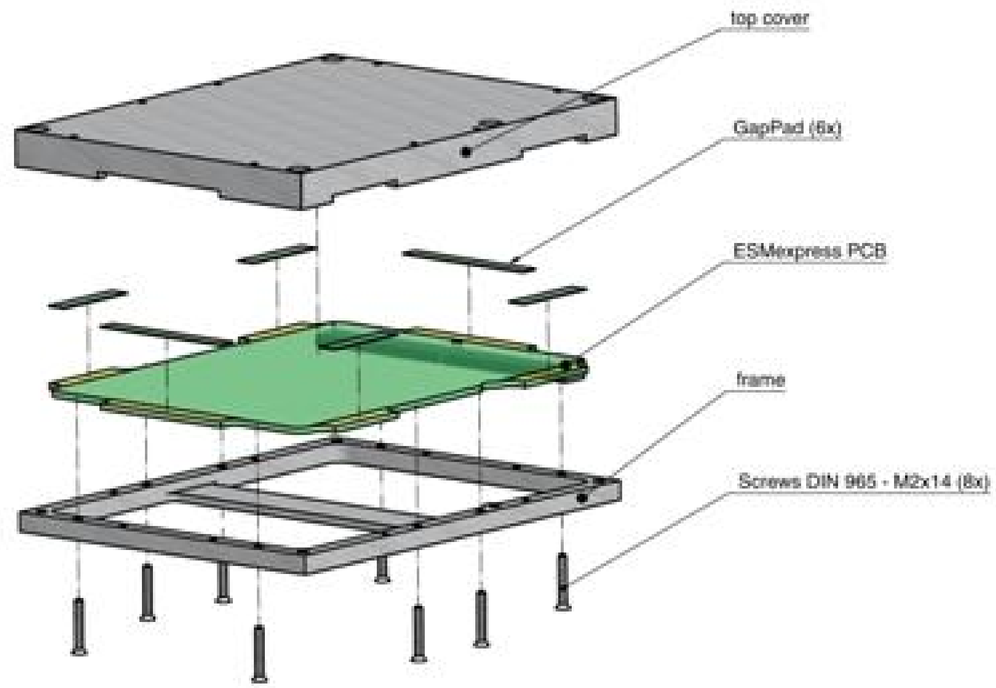
Selecting appropriate strategies based on application needs.
Embedded systems designers experienced with complex thermal issues found in harsh environment applications might be comfortable with the calculations, conduction-cooled designs and components needed to address prevailing

conditions. Those new to extreme operating environments might have more confidence in working with vendors who can shorten their learning curve. Yet, both can streamline budgets and lead times by adopting proven solutions based on pre-conceived designs or standards.

Whatever your experience level or comfort level in addressing thermal management issues, a range of approaches offers a balance of cost and convenience. While some applications depend upon industry standards that address cooling concerns in their basic specification, others benefit from a variety of component building blocks to achieve cost-effective resolution of thermal management issues.

* Do-it-yourself custom designs. Even if thermal management issues are relatively new to you, you might consider evaluating and integrating independent component designs for infrequent, non-critical applications. CPUs with lower power requirements, heat pipes or heat sink devices and other add-on engineering techniques can all be used to upgrade a basic embedded system design into a harsh-environment design.

However, where the volume and variety of conduction-cooled applications warrant it, an ongoing effort to keep abreast of thermal management advancements and new materials, technologies and components can be worth the effort in terms of improved performance. For example, spring-loaded heat-sink screws with self-leveling features that help keep the entire heat-sink surface in full contact with a chip housing have been shown to provide more consistent thermal conductivity than adhesive-mounted heat-sink devices. They can also be more forgiving in the cases of misalignment during assembly or of vibration in field installations.



The Computer-On-Module execution of the ANSI-VITA 59 RSE standard currently under development includes rugged mechanics and a metallic frame for reliable heat transfer from the processor to the unit's enclosed aluminum housing.

Integrated system platforms.

For the convenience of satisfying a progression of embedded system requirements in a compatible family of board, card and rack solutions, look for suppliers that offer a broad range of modular options.

Being able to upgrade the performance of proven off-the shelf convection-cooled hardware to conduction-cooled applications, all within a compatible platform, is advantageous in multiple respects. It complements the familiarity and convenience of standard board formats available for immediate prototyping operations and processors in a range of clock speeds as well as software compatibility, common bus interfaces, etc., with confidence in thermal performance for harsh environment applications.

Look for versatile I/O capabilities too – including standard USB and Ethernet ports, FPGA-controlled connections and SATA ports with transfer rates up to 150 Mbytes/second – to offer built-in support for applications involving graphics, touch screens, serial interfaces, fieldbus controllers, binary I/O and mass storage.

While it is easier to thermally couple critical components with the enclosure wall if the device has only one PCB (printed-circuit board), it is not possible to cool a 19" rack system with several plug-in boards in this fashion. Since the cards' surface cannot be connected directly to the enclosure wall, the heat needs to be brought to the contact surface between the plug-in board and guide rails. At the same time, this contact surface must be thermally optimized and maximized. (Figure 1)

One new 3U cPCI modular board and rack system with off-the-shelf availability of both Intel- and PowerPC-based platforms uses add-on frames to adapt affordable convection-cooled boards to conduction-cooled rack applications, if necessary. The board-matched frames, featuring tailor-made heat sinks plus wedge-lock technology for improved mechanical and thermal coupling, transfer heat efficiently from the CPU to the frame and housing of the rack enclosure. The completed enclosures are rated for operating environments ranging from -40°C to +85°C1.

A key advantage of this frame-mounted approach is that it typically maintains 20%-30% more available space than traditionally engineered VITA-conforming convection-cooled boards. Added benefits of the fully integrated board-and-rack solution include shock and vibration resistance plus a completely sealed enclosure for EMC protection and compliance with IP-65 standards to resist dust and water intrusion. (Figure 2)

* Reliance on industry standards. Designers wanting to get the most out of their available space without worrying about all the details of thermal management and other integration issues can choose to follow appropriate industry standards addressing those concerns. One such example of a total system solution for harsh-environment performance is the new ANSI-VITA 59 RSE (Rugged System-on-module Express) standard currently being finalized by a working group of hardware and software companies.

This approach – originally proposed by MEN Micro as the open-system ESMexpress System-On-Module Standard – is a next-generation solution to the Computer-On-Module (COM) approach originally implemented in the COMexpress (PICMG COM.0) standard. It offers multiple built-in benefits beyond issues of thermal management alone – including low power consumption, high-speed serial busses and versatile I/O options – with compact, versatile COM modules mounted on 3U cPCI boards.

Inherent design features – such as a metal frame surrounding the circuit board, a protective aluminum enclosure, high-pressure screw connections, optional heat sinks and auxiliary thermal paths to channel heat to fan-cooled enclosures – enable ESMexpress designs to dissipate up to 35 watts of power and accommodate extended operating temperatures from -55°C to +125°C. (Figure 3)

Some ESMexpress modules also benefit from the use of compact, low power consumption processors like the Intel Atom that can provide up to 1.6 GHz of processing speed with a total power requirement of 7 watts or less.

Identifying your bottom line.
While there are finite physical limits to electronic circuitry and materials, constantly evolving components, system designs and standards continue to expand the practical boundaries of extreme embedded system performance. For embedded system designers pressured by the increasingly complex demands in evolving applications, staying informed about these specific industry advancements can be every bit as critical as being knowledgeable about underlying principles of thermodynamic design.

But whatever strategy you use to implement appropriate thermal management for your application, knowing the total thermal resistance (Rth) of your design and other variables of power and temperature will allow you to calculate the bottom-line performance of real-world applications according to the following formula:

?T = Tinternal – Tambient = Pv * Rth

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