# Military technology insider

By John Wemekamp

## Packaging innovation continues to push the limits

Without exception, embedded computing applications continue to demand more performance in less space. This is particularly true in the military and aerospace market but with the added complication that the equipment must operate and survive in the very harshest environments. Recent experience has reinforced the conviction that prolonged military operations in extremes of temperature, shock, vibration, sand, and dust require equipment designed with this objective from the outset. Achieving the highest levels of reliability, along with packaging competitive levels of performance and more power dissipation into less space, are challenges that face all COTS vendors.

### Basics of reliability

Electronic module reliability used to be expressed in the form of a relationship among maximum operating temperature, junction temperatures, component types, gate and connector pin counts, and some predefined operating environments. MIL-HDBK-217 was typical of this kind of reliability calculation: Vendors could apply their own interpretations to some of the factors in order to provide a competitive edge on a data sheet. The operating temperature and maximum junction temperatures are known to be significant factors, but there are many others, identified through physics-of-failure analyses. These are also significant but were never accounted for:

- The physical construction and materials of devices must be analyzed and tested for their susceptibility to shock, vibration, and thermal effects.
- Printed Wiring Board (PWB) material, layouts, and feature geometry can all contribute to failures. New materials are being introduced for lead-free and for low-loss, high-speed signaling and will require further testing and monitoring.
- New 0.5 mm pitch Ball Grid Array (BGA) devices make signal trace routing very complex, with very small line widths.
- Solder joint failure is a frequent source of unreliability. This is caused by differential expansion between components and the PWB stressing the solder joints, particularly of BGA packages. This failure mechanism is significant, even for commercial equipment designed for operation in controlled environments. Military equipment is subjected to much greater and more frequent temperature excursions, requiring extensive modeling and testing of solder joint behavior, particularly now that less-compliant, lead-free solders are being introduced.

> "With continuous incremental improvement in thermal performance, 6U will continue to dominate the top end of embedded computing and DSP applications."

The next generation of tactical, network-enabled fighting vehicles will require more embedded computing performance for cooperative engagements, using more powerful sensors and weapons systems while on the move. This is driving embedded computing designers to new levels of functionality and performance, making for more compact, power-hungry systems. Most rugged military applications have adopted conduction cooling as the most efficient form of packaging and cooling, one that also provides much additional protection from the effects of shock and vibration. The power dissipation capacity of conduction-cooled boards is affected by the way they are cooled. Most are fitted into a chassis, which is then cooled by either natural convection, conduction through one or more of the external surfaces, or by air or liquid pumped through heat exchanger plenums within the chassis. As air becomes less dense at high altitude, many aerospace applications supply either chilled air for cooling or use liquids instead.

### Controlling temperature

Still one of the most significant contributors to reliability is ensuring that maximum junction temperatures of all devices are not exceeded when mounted on a module, in a chassis, in its end-use environment. The 6U VME card size is still considered to be the ideal trade-off of real estate against thermal performance for military applications. The most advanced of these have now broken the 100 W power dissipation barrier by incorporating new testing, materials, and technologies:

- Metal thicknesses and component placement tailored to optimize the thermal profile over the complete module
- Improved thermal contact with the chassis walls by incorporating thermal interfaces above and below the wedgelock
- Challenging the traditional models of thermal contact resistance between the heat sink and the chassis walls (extensive testing shows that actual thermal resistance is well below the 0.3 to 0.5 °C/W that is often used)
- The introduction of embedded heat pipes for cooling high-power devices such as dual-core processors, so that heat is transferred equally to the thermal interfaces on both sides of the module, providing twice the effective cooling capacity for that device

With continuous incremental improvement in thermal performance, 6U will continue to dominate the top end of embedded computing and DSP applications. The introduction of VPX (VITA 46) and VPX-REDI (VITA 48) will extend this superiority still further with the optional increase in pitch to 1", offering yet more scope for additional cooling. The VPX6-185 dual-core 8641-D PowerPC SBC from Curtiss-Wright Controls Embedded Computing (CWCEC) incorporates the latest cooling refinements, including the application of heat pipes to a 6U conduction-cooled COTS product. The VPX6-185 SBC with patented heat pipe technology is illustrated in Figure 1. Even further improvement in thermal performance will be possible with liquid flow-through cooling when it is required for the most advanced applications.

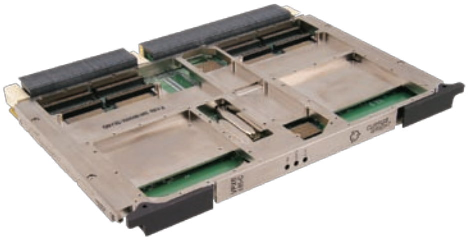

Figure 1

While 6U may occupy the top end of the market, there is also a rapidly emerging market for smaller, lighter embedded computers to fit into small platforms, such as Unmanned Aerial Vehicles (UAVs) and light helicopters. Additionally, there are urgent upgrade programs for many aging, deployed fighting vehicles. These will be implemented in an appliqué manner as and where space permits, making small form factors the ideal choice. Conduction-cooled 3U VPX will satisfy many of these requirements, having similar cooling capacity as a 6U module and extensive backplane I/O connectivity. In addition, they will have enough space to implement a fully capable dual-core SBC supporting the existing ecosystem of PMC/XMC mezzanines, all on a single module.

The 3U VPX with its *designed for rugged* pedigree provides a level of confidence that *ruggedized commercial* alternatives such as PC/104 or conduction-cooled MicroTCA will find difficult to achieve. Despite the attraction of repackaged commercial equipment for short-term, expeditionary use, military doctrine now anticipates much more prolonged campaigns, emphasizing the need yet again for long-term integrity and the highest levels of reliability over the full extremes of the operating environment.

*For more information,*
*e-mail John at*
*john.wemekamp@curtisswright.com.*