Military and Aerospace Systems Still Rely on Proven COTS Technology

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Because of its inherent benefits including decreases to development times and increases in component compatibility, COTS (commercial-off-the-shelf) has been adopted by a vast number of industries, including the aerospace, military and space exploration markets.

Most embedded systems within aerospace and military applications perform a function in some way related to mission-critical operation of the larger system and/or platform, making performance, reliability and functionality imperative to the design and manufacture of the embedded computing system. These systems must therefore operate flawlessly in very specific and defined ways while exposed to extreme environments, including high shock and vibration resistance, wide, dynamic temperature ranges, high humidity (or immersion), and the absolute vacuum of deep space.

Systems with Modularity

The very nature of COTS promotes modularity when designing an embedded system for aerospace applications. By using a common set of electronics modules in a standard enclosure you are creating the foundation for a plug-and-play architecture in a system that is easy to maintain and eventually upgradeable when needed. Taking advantage of new technologies as they become available becomes much simpler and much more cost effective and drastically decreases the subsystem time-to-market.

Multiple subsystems can also operate concurrently to offer more complex and redundant capabilities or to coordinate with mission operations. The major elements to consider in a cost-effective “plug-and-play” methodology include:

1. A widely accepted, open bus architecture, such as VME or CompactPCI,
2. A widely accepted real-time operating system and available driver software,
3. The use of a common enclosure design.

Incorporating Open Architectures

	Bus Architecture	
Subsystem Function	6U VMEbus	3U CompactPCI
SBC (with CPU, memory and I/O)	√	√
Networking & Communications (GbE, 1553, serial, SATA, etc.)	√	√
Real-world I/O (A/D, D/A, S/D, D/S, discretes...)	√	√
Graphics & Imaging	√	√
Mass memory	√	√
Platform-specific custom I/O	√	√
Powered enclosure	√	√
Physically smaller		√
Physically larger	√	

Table 1: Typical features of a cPCI system versus a VME system

Key to achieving a modular, flexible system is a mature, and well-defined, open systems architecture. System modules can then seamlessly operate together with a common protocol and a physical bus and mechanical interface. The two grandfathers of open architectures, VMEbus and CompactPCI, both have strong footholds within the high reliability embedded computing industry. Although VME was first on the scene, cPCI, with its smaller, rugged, 3U form factor, abundant number of user-defined backplane I/O pins and widely accepted use across industries as diverse as telecom, military and space, has been gaining ground within a number of applications that are limited in physical space. (See table 1)
Although physically larger with an inherently increased per-board surface area, standard 6U VME still has and a larger install base, though, and will continue to be a standard of choice for many applications to come.
It can be seen that subsystem functionality is similar, if not identical, between the two bus architectures, however the tradeoffs are more readily realized when partitioning these system functions over the available board space to fit into the available physical envelope of the intended vehicle platform. Open architecture also fosters industry-wide improvement, since various manufacturers' components interoperate with one another on the same system backplane and within the same enclosure. By starting with already available, modular, off-the-shelf building blocks, the program costs for system hardware and software development as well as for technology upgrades significantly reduces, since end users know that components from Company A will work with those from Company B with minimal time involved to integrate the two system components.

Other benefits include utilizing industry-proven and platform-qualified hardware, further reducing costs associated with continually re-inventing and re-architecting the embedded computing subsystem. Using known, proven system elements ensure that time-to-market and the pressures of qualification and testing decrease.

Changes in the Works

Human nature drives our search for continual improvement, and COTS is no exception. Developments to improve these standards and make systems more robust and flexible yet backward compatible are being spearheaded by companies looking to further increase the use of COTS components. One example is the recent expansion to Aitech's C10x series of high performance VME SBCs designed for use in both new and legacy military and aerospace applications.

For newer applications, the rugged 6U single-slot SBC offers up to 1.4 GHz of processing power via the G4+ PowerPC (PPC) MPC7448 processor, the highest performing Freescale PowerPC. For legacy applications, the board features pin-to-pin backplane and I/O compatibility with previous Aitech processor boards employing the PPC MPC74xx processor family allowing easy, cost-effective upgrades to newer technology. For increased flexibility among any number of applications, the SBC provides numerous I/O capabilities allowing for system expansion and the incorporation of additional functionality as the end customer’s desire for enhanced subsystem capabilities expansion arises and the need to mitigate the growing menace of inevitable component obsolescence.

This combination of advancing new COTS technologies while maintaining the old – also known as “incremental upgrades” – will continue to be a trend within the industry, since few programs have the budget to institute sweeping new replacements at the subsystem level once newer technologies begin to become available.

Thermal Management – A Multi-Faceted Concern

Figure 1: Aitech’s newest expansion to the C10x series accommodates both legacy and future embedded VME applications.

Although it simplifies much of the integration process in developing an embedded computing system in military and aerospace applications, COTS technology does not come without its pitfalls. Heat-induced failures in any system or subsystem are a large concern, and COTS-based systems are no exception. The potential for extreme temperatures and rapid, exaggerated, constant temperature cycling ranges combined with the extreme cost of an irreparable catastrophic failure within a critical application requires close consideration.
Heat generating characteristics of on-board electronics, especially on today’s more densely configured boards and components, can create a variety of problems at much lower temperature swings if the systems can’t dissipate heat aggressively from the active devices. As a rule of thumb for today's complex "system-on-a-board" COTS designs, subsystem reliability decreases approximately by half with just a 10°C rise in temperature. With these temperature extremes a normal occurrence in systems typically employed in military and aerospace applications,

thermal management continues to be a critical element in systems design.

The repeated heating and cooling cycles puts severe mechanical stresses on system components, threatening long-term system reliability. If the Thermal Coefficients of Expansion (TCEs) for system components and the printed wiring boards on which they are mounted are not well matched, the problem becomes even more prevalent. Having boards and components with significantly different TCEs can cause adjacent portions to contract and expand at different rates, which can induce heat-related electrical and mechanical failures.

Other Considerations

Heat is not the only detrimental factor to system reliability, although it plays a part in several other circumstances that can lead to premature failure as well. Following is a brief review of some semiconductor package deterioration factors, and in each case, the effects of higher device die temperatures can exacerbate the problems, another reason managing system temperature extremes is so important.

Metal Electromigration. This condition is one of the most common failure modes in modern metal oxide substrate (MOS) semiconductors and is affected by advances in semiconductor designs. As semiconductor line width geometries decrease, device functionality increases. Yet, higher line densities generate a larger current density (charge per unit volume), which increases the resulting electromagnetic field (EMF). Over time, increased EMF in MOS devices can induce metal ions from the metallization lines within the semiconductor to move or migrate, ultimately forming a chain of metallic molecules that can bridge thin insulating oxide layers and cause internal shorts.

Electrostatic Discharge. While MOS device failures due to electrostatic discharge (ESD) are well known, not all device failures are related to a single static discharge or even several smaller repeated ESD discharges "punching through" the insulating oxide layers. Smaller static discharges can partially damage the oxide layer and cause dormant or hidden (latent) defects. If not detected, mitigated or circumvented, these latent defects will cause premature failure in deployed systems. Continuous application of an EMF across a damaged, pitted insulating layer, coupled with higher device die temperatures, will accelerate metal ion migration across the partially failed insulation layers and cause early bit failures as well.

Charge Trapping. The accumulation of free electrons in small charge "trapping sites" within thin insulating oxide layers of memory devices – due to repeated data storage and erasure over time – can eventually short the gate oxide layer, resulting in bit failures. In some instances, charge-pump and gate line impulse techniques have proven useful in mitigating this problem.

COTS continues to evolve within the realm of military and aerospace applications. End users see tangible results in terms of cost and time-to-market savings that further advance the use of open standard technology and pave the way for more product developments as well as increased applications. But, as with any technology, nothing is foolproof and solid precautions based on tried-and-true and well understood engineering practices will still need to be taken to ensure that the design of your embedded system continues to provide you with reliability, security and peace of mind.