VITA 47: Environmental considerations for VITA technologies

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Ruggedization levels for a shipboard environment typically differ from levels required for combat aircraft, and so on; hence ruggedization of plug-in modules is not a simple matter. While VITA 46 and 48 are also making headway in the equation, Ivan focuses primarily on VITA 47 and presents a temperature cycling example for demonstration.

What does it take for a plug-in module to be rugged enough for harsh military environments? The answer is not simple since there is a wide range of environmental levels and durations to meet depending on application and program requirements. Consequently, a product designed for one environment (such as shipboard) might not be rugged enough for another (such as combat aircraft). In addition, military programs typically require high availability over long program lifetimes, so high reliability is an integral element of plug-in module ruggedness. To answer the original question, three VITA standards factor into the equation: ANSI/VITA 46 (VPX), ANSI/VITA 47 (Environments, Design and Construction, Safety, and Quality for Plug-In Units), and VITA 48 (VPX-REDI). However, we will focus primarily on VITA 47, and a specific example of temperature cycling will serve to demonstrate what is required.

Standards for rugged applications

Several VITA standards and specifications are useful guides for rugged plug-in module design, among them ANSI/VITA 46 and VITA 48 (see sidebar), along with ANSI/VITA 47. The main purpose of ANSI/VITA 47 is to specify environmental requirements for various classes of COTS plug-in modules. The environmental classes range from benign to very harsh, and are intended to represent commercial and military mobile applications. According to the foreword in VITA 47, ìcertification of COTS plug-in units to this standard will facilitate the cost-effective integration of these items in larger systems.î

Click here to read more about ANSI/VITA 46 and VITA 48

VITA 46 and 48 recommend VITA 47 implementation

Both the VITA 46 and 48 specifications recommend that implementers consider meeting one or more of the environmental classes in ANSI/VITA 47 (see again Table 1). These classes are segregated by cooling type, for example, forced air cooling over components (EAC in VITA 47); forced air cooled heat exchanger (EFC); conduction cooled (ECC); and liquid cooled (ELC). Each cooling type has a range of levels for the following environments: operating temperature, non-operating temperature, temperature cycling, vibration, and mechanical shock. For example, the ECC4 class requires complying with the following environments:

- -40 ∞C to 85 ∞C card edge operating temperature
- -55 ∞C to 105 ∞C nonoperating temperature
- 500 cycles of temperature cycling between -55 ∞C and 105 ∞C
- 0.1g^2/Hz random vibration
- 40*g*, 11 ms mechanical shock

Meeting the VITA 47 standard

There is little guidance on how to actually meet the ruggedization levels in ANSI/VITA 47, with the exceptions of testing criteria and a section on construction requirements and recommendations. These, however, are not sufficient to produce rugged plug-in modules. Module vendors need to understand how to design their products to pass the ANSI/VITA 47 tests, or they risk facing a long and arduous test-fix-test process, which, even if completed, might not result in acceptable reliability due to limited test samples.

The example of temperature cycling

To understand the implications of ANSI/VITA 47 testing, consider the example of temperature cycling. The ANSI/VITA 47 standard requires a module to be exposed to 500 cycles of one of four temperature ranges (from -40/85 ∞C to -55/105 ∞C), with no performance degradation afterwards. Assuming a 10 ∞C/minute ramp rate and 25 minute total dwell times (10 minute temperature stabilization plus 15 minute dwell), the test duration can be as long as 28 days. It behooves the module vendor to maximize the chances of a successful test the first time around; otherwise, retests might be required, causing significant schedule delays.

For a rugged module design to be capable of successfully passing the ANSI/VITA 47 temperature cycling test, the designer must evaluate and mitigate the risks posed by the various associated failure modes (such as cracked solder joints, PWB barrel cracks, and so forth). Some of this preparation can be achieved through analyses like solder joint reliability analysis or finite element modeling/analysis. Specialized testing is also highly recommended to validate the analyses. For example, Curtiss-Wright Controls Embedded Computing performs extensive reliability testing on numerous samples to ensure that risky interconnects such as BGA/CSP solder joints and blind or buried PWB vias can survive harsh temperature cycling.

This kind of testing will become increasingly critical as lead-free parts become the norm and rugged module suppliers are induced to use them, and eventually to solder them with lead-free solder, either due to supply market forces or program requirements. Figure 1 shows how solder joint reliability is degraded when soldering a lead-free part with lead-free solder (ìCBGA All Pb-freeî data), compared to the reliability of the same part with tin-lead balls soldered with tin-lead (ìCBGA All SnPbî data).

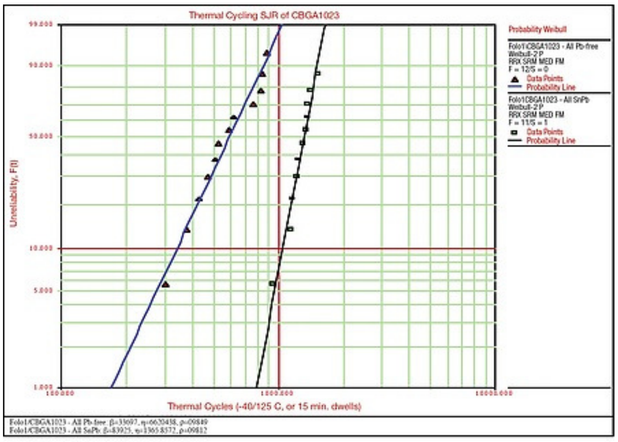

Figure 1

(Click graphic to zoom by 1.9x)

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Other ANSI/VITA 47 environments

Other environmental tests in ANSI/VITA 47 include operating and non-operating temperature, mechanical shock, random vibration, humidity, corrosion resistance, and Electrostatic Discharge (ESD) for LRMs. Similar to temperature cycling, analysis can be used to discover and mitigate risks posed by some of these environments (for example, vibration); however, others will require the benefit of previous testing experience to design in sufficient ruggedness. Testing is also used to validate the analysis results. This testing experience will produce the valuable, hard -won knowledge of what works and what does not for surviving harsh environments.

Figure 2 shows some examples of what has not worked. From top left, clockwise, the failure analysis photos show:

- Pad cratering under BGA after vibration due to excessive local strains
- Salt bridge after 500 hour salt fog exposure due to direct exposure of module
- Connector contact fretting corrosion due to excessive micromotion during vibration
- ìFriedî processor due to insufficient cooling during high-temperature testing

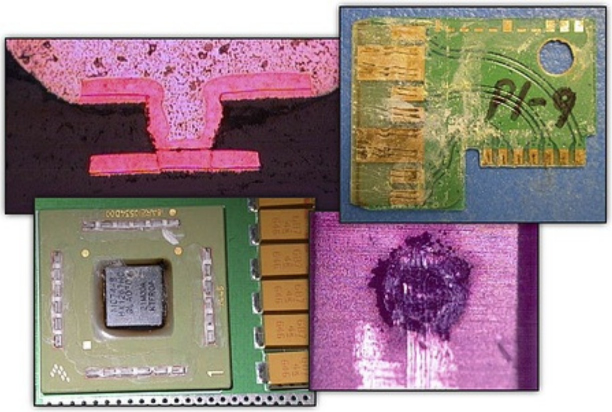

Figure 2

(Click graphic to zoom by 1.9x)

The discovery and resolution of failures such as these invariably leads to improved ruggedness. As more experience is gained, fewer and fewer failures are likely to occur, and customers will gain increased confidence in the module supplierís ruggedization capabilities. Of course, the previously mentioned analyses are also critical in gaining this confidence.

VITA specifications and beyond

The process of designing a plug-in module to survive harsh military environments, also known as ruggedization, requires substantial knowledge of and experience with the particular environments of concern and how they might cause electronics to fail. A small portion of this know-how is contained in key standards and specifications such as ANSI/VITA 47, and also ANSI VITA 46 and VITA 48; however, the ìrest of the icebergî resides within companies that have focused on ruggedization and reliability for a long time. Sadly, as the saying goes, there is no free lunch.

ANSI/VITA 46 and VITA 48 pave the way

The VITA 48 (VPX-REDI) family of specifications is a close mechanical complement to the increasingly popular VITA 46 (VPX) specifications. VPX and VPX-REDI both contain many features applicable to rugged plug-in module design, with conduction-cooled packaging typically ranking among the most important. Conduction-cooled modules are frequently used in rugged military applications because of their high shock and vibration resistance, good cooling performance, and ability to be housed in a sealed chassis for protection against harmful contaminants.

Additionally, the VITA 46 standard provides guidance on conduction features for 3U and 6U cards that stem from the IEEE 1101.2 standard (Mechanical Core Specifications for Conduction Cooled Eurocards). This makes VPX modules compatible with chassis designed for either conduction VME orCompactPCI cards, for example, by changing the backplane to one populated with VPX connectors. VITA 48 takes the conduction concept further by providing increased functional density (via 0.85" and 1" pitches), improved cooling, and two-level maintenance compatibility (with *Line Replaceable Modules* or *LRMs*). Note that both VITA 46 and 48 also standardize air-cooled module features, and VITA 48 is standardizing Air Flow Through (AFT) and Liquid Flow Through (LFT) for very high-power cooling.

Another critical rugged feature of the VITA 46 and 48 specifications is the high-speed connector they specify. This connector was originally chosen for its high-speed performance, but needed to be tested to determine its ruggedness. An ensuing extensive testing program proved that it was more than up to the task. Table 1 summarizes the test results with details available at www.vita.com/VITA46ContechTestReportrev1.4.pdf. It is worthwhile to note that the levels and durations of the various environmental tests met or exceeded the requirements of the highest levels in ANSI/VITA 47, ensuring that the connector was capable of operating in harsh environments.

Environmental/Mechanical Test	Specification/Standard	Result
Mechanical Shock	MIL-STD-1344A, Method 2004.1, Test Condition A (50 g, 11 ms)	Pass
Random Vibration	MIL-STD-1344A, Method 2005.1, Test Condition V, letter D (0.1 g^2/Hz, 50-2000 Hz), 1.5 hours/axis	Pass
Bench Handling	MIL-STD-810F, Method 516.5, Procedure VI	Pass
Vibration/Temperature	Random Vibration plus –40 to 100°C	Pass
Humidity	MIL-STD-1344A, Method 1002.2, Type III (240 hrs.)	Pass
Salt Fog + SO_2	ASTM G85, Annex A4 (cycle A4.4.4.1), two 24 hr. cycles	Pass
Dust and Sand	MIL-STD-810F, Method 510.4, Procedures I and II	Pass
Dust & Vibration	Dust: MIL-STD-810F, Method 510.4, Procedure I Vibration: Same as Random above	Pass
Durability with Misalignment	EIA-364-09, 500 mate/unmate cycles	Pass
Electrostatic Discharge (ESD)	EN 61000-4-2	Pass
Current Overload	IEC 60512-3	Pass

Table 1

(Click graphic to zoom by 1.4x)

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