Ruggedization of MXM Graphics Modules

Ivan Straznicky
Curtiss-Wright Controls Defense Solutions
Ottawa, ON, Canada
ivan.straznicky@curtisswright.com

***Abstract*—MXM modules, used to package graphics processing devices for use in benign environments, have been tested for use in harsh environments typical of deployed defense and aerospace systems. Results show that specially mechanically designed MXM GP-GPU modules can survive these environments, and successfully provide the enormous processing capability offered by the latest generation of GPUs to harsh environment applications.**

I. Introduction

General Purpose Graphics Processor Units (GP-GPUs), with their hundreds of processing cores and dedicated floating point math libraries are increasingly being used to meet the intense processing needs of C4ISR military applications that require large amounts of DSP algorithm computation. Today's most advanced GP-GPU for embedded applications is NVIDIA's 240-core Fermi architecture device. NVIDIA provides the Fermi architecture, with all of its performance advantages, only in the MXM (Mobile PCI Express Module) mezzanine module format. The use of the MXM format also offers several advantages over a soldered down piece part approach to designing GP-GPUs. These include: leveraging of the significant electrical interface circuitry design work, additional functional density offered by the mezzanine form factor, and a surprising thermal benefit of that same form factor.

The downside of the MXM format, however, is that it is intended for applications such as notebook/laptop computers, blade and standard rack mount servers, and home theater electronics, in other words, benign environment applications. Thus, careful and extensive evaluation is required to determine if and how MXMs can be used in harsh environments typical of deployed defense and aerospace applications. Specifically, in order to be successful, the various risks of using the MXM format need to be understood, analyzed, mitigated through rugged design and/or other approaches, and tested. This paper will focus on the testing aspect.

II. Testing for Harsh Environments

To ensure that the MXM module and connector can meet the stringent ruggedness requirements demanded by the defense and aerospace market, Curtiss-Wright submitted samples to a complement of tests. These tests were designed to characterize and verify the MXM's ability to operate reliably in the harsh environments of embedded military system deployment. Leveraging in-house resources for ruggedization, testing and thermal analysis, test vehicles were designed and built to extensively investigate the MXM module and its connector. One of the test vehicles represented a rugged, air cooled 6U-size VPX GP-GPU product that contains two MXM modules, the VPX6-490 (see Fig. 1). Additional risk mitigation techniques were also developed, implemented and tested.

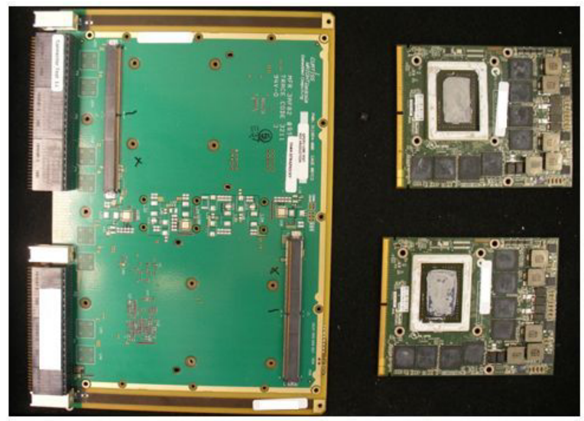


Figure 1. Photo of disassembled vibration test vehicle (MXM heat sinks and other metalwork removed)

A. *Shock and Vibration*

Using the 6U VPX rugged test vehicle shown in Figure 1, the MXM modules and connectors were tested to standard levels of rugged air cooled shock and vibration (see Table 1). These levels typically induce much higher displacements of UUTs than standard levels do on stiffer conduction cooled modules, even though the conduction standard levels are higher (e.g. 0.1 g^2/Hz random vibration). This test was thus a worse case for connector contact fretting caused by micro-motion, which is a primary failure mechanism of concern.

TABLE 1. SHOCK & VIBRATION TEST LEVELS AND DURATIONS

Tests	**Levels**	**Frequency range**	**Duration**
Sine vibration	10g	5-2000 Hz	10 minutes
Mechanical Shock	30g peak	N/A	11 ms, 18 hits total in 6 directions
Random vibration	0.002 g^2/Hz @5 Hz 0.04 g^2/Hz @15 Hz 0.04 g^2/Hz @2 kHz	5-2000 Hz	1 hour/axis (3 orthogonal axes)

Verification tests included visual and SEM/EDX inspection after all shock and vibration to measure any fretting or wear.

B. *Durability, Humidity, and Mixed Flowing Gas (MFG)*

A separate test vehicle was designed for testing MXM connectors under additional harsh environments such as humidity and mixed flowing gas (MFG). Humidity and MFG testing were performed according to Table 2 on eight samples for each test. Durability cycling consisted of the MXM rated 30 insertion/extraction cycles.

TABLE 2. ENVIRONMENTAL TEST LEVELS AND DURATIONS

Tests	**Levels**	**Duration**	**Specification**
Durability + Humidity	90-95% RH, 25-65 °C	500 hours (62.5 cycles)	EIA-364, TP 31
Durability + Mixed Flowing Gas	30 °C, 70% RH	20 days	EIA-364, TP 65

Performance verification tests included low-level contact resistance (LLCR), insulation resistance (IR), and dielectric withstanding voltage (DWV).

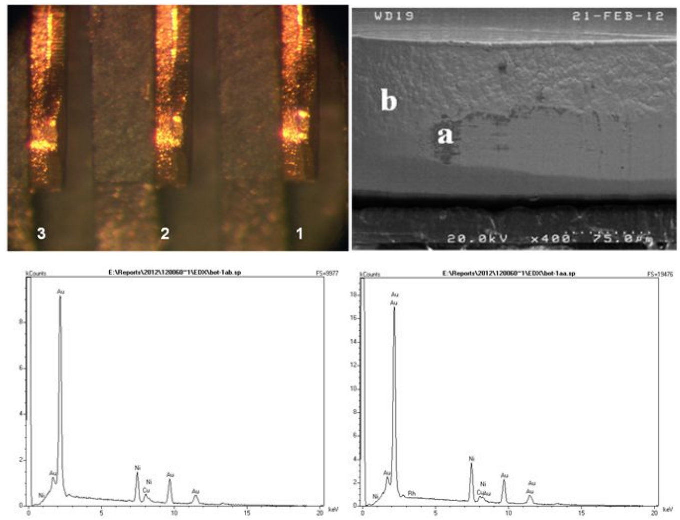
C. *Thermal Qualification*

Prototype rugged GP-GPU products with MXM modules were submitted to Curtiss-Wright's thermal qualification process. This process tests full functionality of the GP-GPU over a wide temperature range (in this case, -40 to 71°C) including cold and hot starts.

III. Results

The shock and vibration test results relied on visual inspection and SEM/EDX analysis of connector and MXM contacts to determine the level of wear. This is the most sensitive evaluation available for a connector system. In practice, electrical performance testing is often used to determine acceptability, however it has been shown that significant wear takes place before electrical failures are detected (Timsit, 2003 and Straznicky, 2007).

The visual inspection results at 30X magnification (see Fig. 2) indicated no wear-through of the outer gold plating on either the connector or MXM contact. The SEM/EDX results indicated that minor wear-through had taken place on the base case connector (but not the MXM contact), and that no wear–through had occurred on the mitigated case (see Figs. 3-5). The minor wear that occurred on the base case (no mitigation) was not deemed sufficient to cause an electrical failure, based on previous experience.



Figures 2-5 Clockwise from top left: Optical photo of contacts, SEM image, EDX charts (areas a and b)

The durability, humidity and MFG test results are shown in Table 3. No failures were recorded after sequential durability/humidity and durability/MFG tests. Failure definition was according to Mobile PCI Express Module Electromechanical Specification Version 3.0, Revision 1.1.

TABLE 3. ENVIRONMENTAL TEST RESULTS

Test	**LLCR (mΩ, max.)**	**IR (MΩ)**	**DWV**
Durability + Humidity	50.2 (unmitigated) 35.7 (mitigated)	>50,000	Passed
Durability + Mixed Flowing Gas	36.1 (unmitigated) 33.6 (mitigated)	N/A	N/A

The thermal qualification testing verified operation with full functionality over the extended temperature range (-40 to 71°C).

IV. Conclusions

MXM modules can be successfully used on specially designed, rugged carrier cards in harsh environments including extended temperatures, shock and vibration, humidity, and air-borne contaminants. Experience with mitigation approaches for other harsh environments (e.g. thermal cycling) can be used to further ruggedize MXM modules.

V. References

Straznicky, I. (2007). Fretting Corrosion of COTS Connectors. *CMSE Conference.* Los Angeles.

Timsit, R. S. (2003, March). Electrical Connectors for Electronics Applications. Kanata, ON: Timron Scientific Consulting Inc.