Ruggenedization of MXM Graphics Modules

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Outline

- Introduction – What is an MXM Graphics Module?
- MXM Use in Rugged HPEC Systems
- MXM Ruggedization Risks
- Harsh Environment Testing
  - Shock & Vibration
  - Environmental Testing
  - Thermal Testing
- Conclusions
Mobile PCI Express (MXM) is an interconnect standard for GPUs in laptops and servers
- Allows for easy upgrades with standardized socket
- MXM-SIG controlled by nVidia
- Latest specification revision is 3.0
- Type A (82 x 70mm) and Type B (82 x 105mm)
- Module integrates GPU, memory and power supply onto a small PCB
MXM Use in HPEC Systems

- Benefits for use in HPEC systems
  - Allows for easy upgrades with standardized socket
  - Leverages electrical interface design work
  - Functional density offered by mezzanine form factor
  - Thermal benefit offered by mezzanine form factor
  - Some GPUs are only offered in MXM form factor

- Drawbacks of MXM use in rugged HPEC systems
  - Not designed for harsh environments
## MXM Ruggedization Risks

<table>
<thead>
<tr>
<th>Risk</th>
<th>Description</th>
<th>Test</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector contact fretting</td>
<td>Vibration can cause fretting corrosion failures</td>
<td>Shock and vibration</td>
<td>Stiffening and possibly lubrication</td>
</tr>
<tr>
<td>Contact corrosion</td>
<td>Exposure to humidity and contaminants can corrode contacts</td>
<td>Humidity and mixed flowing gas</td>
<td>Custom connector (if required)</td>
</tr>
<tr>
<td>GPU cooling</td>
<td>GPU can be 50W+</td>
<td>Full operation over extended temp. range</td>
<td>Thermal design analyzed prior to test</td>
</tr>
<tr>
<td>Temperature range</td>
<td>Components on MXM are commercial temp. range</td>
<td>Full operation over extended temp. range</td>
<td>100% ESS during production or pre-screening</td>
</tr>
</tbody>
</table>

The above list of risks is not exhaustive…
Shock & Vibration Testing

- Rugged air cooled test vehicle
  - 6U (233x160mm) VPX with 2 MXMs
  - Higher displacements than conduction, :: worse case

- CWCDS shock & vibration test specification

<table>
<thead>
<tr>
<th>Tests</th>
<th>Levels</th>
<th>Frequency range</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sine vibration</td>
<td>10 g</td>
<td>5-2000 Hz</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Mechanical shock</td>
<td>30 g peak</td>
<td>N/A</td>
<td>11ms, 18 hits total in 6 directions</td>
</tr>
<tr>
<td>Random vibration</td>
<td>0.002 g²/Hz @ 5 Hz</td>
<td>5-2000 Hz</td>
<td>1 hour/axis (3 orthogonal axes)</td>
</tr>
<tr>
<td></td>
<td>0.04 g²/Hz @ 15 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.04 g²/Hz @ 2 kHz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Shock & Vibration Testing

- Performance verification: Visual inspection and SEM/EDX of connector contacts
  - Provides the earliest indication of fretting issues, well before electrical testing
  - Database of previous tests used to correlate wear severity to probability of electrical failure

**Example of Severe Fretting Corrosion on Connector Contact causing Electrical Failure**
S&V Test Results

- Base case (stiffened but not lubricated)
  - Degree of fretting wear varied across each of two connectors (more wear on ganged power and ground pins)
  - Worst case wear was through outer gold plating, but large majority (85-90%) of nickel underplating still intact
    - This amount of wear is not associated with electrical failure
  - Typical wear (signal pins) did not penetrate outer gold plating

Sample analysis images (left to right): Optical, SEM (worst case), SEM (typical signal), X-section (worst case)
S&V Test Results

- Mitigated case (stiffened and lubricated)
  - No gold wear-through on any pins
  - Lubricant may need further testing (e.g. dust + vibration)

Sample analysis images (left to right): Worst case (mitigated), EDX (area ‘a’), EDX (area ‘b’), X-section
Environmental Testing

- Custom test vehicle
  - 6U-ish with 2 MXMs
  - Connections for LLCR (low-level contact resistance)

- Environmental test specification

<table>
<thead>
<tr>
<th>Tests</th>
<th>Levels</th>
<th>Duration</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability + Humidity</td>
<td>90-95% RH, 25-65°C</td>
<td>500 hours</td>
<td>EIA-364, TP 31</td>
</tr>
<tr>
<td>Durability + Mixed Flowing Gas</td>
<td>30°C, 70% RH</td>
<td>20 days</td>
<td>EIA-364, TP 65</td>
</tr>
</tbody>
</table>
Environmental Test Results

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

- Pass/fail defined in MXM Module Electromechanical Spec (e.g. LLCR of 55 mΩ max.)

- All tests passed

<table>
<thead>
<tr>
<th>Test</th>
<th>LLCR (mΩ, max.)</th>
<th>IR (MΩ)</th>
<th>DWV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability + Humidity</td>
<td>50.2 (unmitigated)</td>
<td>&gt;50,000</td>
<td>Passed</td>
</tr>
<tr>
<td></td>
<td>35.7 (mitigated)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durability + Mixed Flowing Gas</td>
<td>36.1 (unmitigated)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>33.6 (mitigated)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thermal Qualification Testing

- CWCDS thermal qualification test
  - Performed on 6U and 3U products
  - Temperature extremes are beyond specification (-40 to 71°C)
  - Multiple cycles (but not a thermal cycling test)
  - Multiple cold and hot starts after soak
  - Functional stress test

- Results
  - Pass (no functional failures)
Conclusions

- The use of MXM modules in harsh environments demands a comprehensive risk evaluation.

- Three areas of testing were used as examples of risk assessment: shock & vibration, environmental, and thermal qualification. Other tests are also required.

- The full suite of test results shows that MXMs can be successfully deployed in harsh environments, when integrated into specially designed, rugged carrier cards.

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Thank you

Q & A