Innovative 20nm Space FPGA Ceramic & Ruggedized Package Trends

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RT Kintex UltraScale Platform Announced in May 2020
High Bandwidth Compute Capability

Features

- 2760 DSP Slices: Multi-precision fixed and floating point modes
- 32 High Speed SERDES (12.5Gbps): 400Gbps aggregate BW
- Radiation Tolerance across all orbits TID >100Krad/si, SEL >80MeV-cm²/mg
- Robust 40x40 mm Ceramic Column Grid Array Packaging
- Machine Learning Ecosystem enables High Performance Edge Inference in Space

Meets Next Generation on Orbit Processing Needs

- Protos, Mechanical Samples: NOW
- Vivado SW, XPE*, Datasheet: NOW
- Production (Class B, Class Y): Sept 2020

*XPE Xilinx Power Estimator Tool, TID = Total Ionizing Dose, SEL = Single Event Latchup

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Introducing 20nm Technology: XQRKU060-CNA1509 Package

- Package Details: 40x40 mm ceramic flip chip package with Pb/Sn Cu ribbon solder columns
  - Same package construction/columns as current XQR5VFX130-CN1752 45x45 mm package
  - Qualification on track

- Enhancing the Thermo-Mechanical Integrity for High G /Vibration Environment
  - Introducing edge bonding to the package (Zymet UA2605-B)
  - To eliminate any Mechanical crack between the package the PCB interconnect
  - Enabling back bracket to stiffen the package in the System
  - Introducing Dynamic mounting to apply constant pressure on the package during the life time
  - Ensuring stable thermal contact between the package and the thermal solution

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<table>
<thead>
<tr>
<th>Bill Of Material &amp; Suppliers</th>
<th>XQRKU060-CNA1509</th>
<th>XQR5VFX130-CN1752</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 Bump</td>
<td>Eutectic Sn Pb</td>
<td>Same</td>
</tr>
<tr>
<td>Lid</td>
<td>4 corner Al2O3</td>
<td>Same</td>
</tr>
<tr>
<td>Substrate</td>
<td>Ceramic (Alumina)</td>
<td>Same</td>
</tr>
<tr>
<td>Chip Capacitors</td>
<td>Sn Pb with cap level space qual testing per MIL-PRF-3235</td>
<td>Same</td>
</tr>
<tr>
<td>Column</td>
<td>80 Pb/20 Sn with Cu ribbon</td>
<td>Same</td>
</tr>
<tr>
<td>Assembly Supplier</td>
<td>Kyocera San Diego</td>
<td>Same</td>
</tr>
<tr>
<td>Column Attach Supplier</td>
<td>6 Sigma</td>
<td>Same</td>
</tr>
</tbody>
</table>

Edge bonding passing 2500 cycles (see Zymet UA-2605-B Edge Bond Adhesive)
What are the options beyond 20 nm for Space?

*Ceramic running into design and technology bottlenecks*

<table>
<thead>
<tr>
<th>Feature</th>
<th>HTCC (SIRF POR)</th>
<th>LTCC (870T)</th>
<th>Organic</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Temp</td>
<td>&gt; 2000°C</td>
<td>&lt; 1000°C</td>
<td>&lt; 250°C</td>
<td></td>
</tr>
<tr>
<td>Dielectric Material</td>
<td>Alumina</td>
<td>Special Ceramic</td>
<td>Epoxy Silica filled (&gt;80%)</td>
<td></td>
</tr>
<tr>
<td>Metallization</td>
<td>Fused W or Mo</td>
<td>Fused Cu</td>
<td>Cu</td>
<td>Resistivity: Fused W &gt;&gt; Fused Cu &gt;&gt; Cu</td>
</tr>
<tr>
<td>Substrate CTE ppm/C</td>
<td>7 ppm/C</td>
<td>11-12 ppm/C</td>
<td>13-15 ppm/C</td>
<td>PCB CTE 17-21 ppm/C</td>
</tr>
<tr>
<td>PKG Type</td>
<td>Pin / CCGA</td>
<td>BGA / LGA</td>
<td>BGA / LGA</td>
<td>BGA assembly much easier</td>
</tr>
<tr>
<td>Lamination process</td>
<td>One-time</td>
<td>One-time</td>
<td>Sequential</td>
<td></td>
</tr>
<tr>
<td>Via formation</td>
<td>Universal Punch</td>
<td>Universal Punch Tooling</td>
<td>Laser drill</td>
<td>Organic via density &gt;&gt; Ceramic</td>
</tr>
<tr>
<td>Min. C4 pitch</td>
<td>180um</td>
<td>150um - 180um</td>
<td>110um</td>
<td>7nm is 130um min.</td>
</tr>
<tr>
<td>Min. Dielectric thickness</td>
<td>100um</td>
<td>75um*</td>
<td>25um</td>
<td>*50um maybe available 4 layers</td>
</tr>
<tr>
<td>Line/Space um</td>
<td>75um/75um min.</td>
<td>40um / 40um</td>
<td>10um / 10um</td>
<td></td>
</tr>
<tr>
<td>Via/pad um</td>
<td>100um / 150um</td>
<td>50um / 100um</td>
<td>50um / 85um</td>
<td></td>
</tr>
<tr>
<td>Advanced node designs</td>
<td>Not feasible</td>
<td>May be feasible with pitch fan-out and derating</td>
<td>Exists 14L – 18L</td>
<td>Technology/design not feasible PDN, X-talk metrics challenging to meet with Ceramic</td>
</tr>
<tr>
<td>Applying Mech Pressure</td>
<td>~10-15PSI</td>
<td>~10-15PSI</td>
<td>~30-50 PSI</td>
<td>Next Gen need to stand for high Thermo-mech solution</td>
</tr>
<tr>
<td>Thermal solution, RJA</td>
<td>~ 3 C/W</td>
<td>~3 C/W</td>
<td>~/&gt;1.5 C/W</td>
<td>Next Gen need more thermal performance</td>
</tr>
<tr>
<td>Power W(Flux W/cm²)</td>
<td>&lt;/= 12 (5W/Cm2)</td>
<td>&lt;/= 12 (5W/Cm2)</td>
<td>&gt;/=25W (7W/Cm2)</td>
<td>Next Gen need to have more Performance/W by Adding more hard IP</td>
</tr>
</tbody>
</table>
Ruggedized Organic Packaging for Non Space Applications

Current (In Production)

- Monolithic 20nm/16nm
- Custom 4-corner Lid
- Pb-finish cap
- Underfill
- Eutectic C4 bump
- Eutectic BGA ball (1.0mm pitch)
- Current (In Production)
- Eutectic BGA ball
- Underfill
- Cu-pillar u-bump

Future

- Monolithic
- 4-corner forged Lid
- undercoat/overcoat
- XC cap (Sn-finish)
- Cu-pillar C4 bump
- Eutectic BGA ball
- XC LSC cap (Sn-finish)
- Stiffener ring

SSIT 20nm/16nm (non-HBM)

- Custom 4-corner Lid
- Pb-finish cap
- Underfill
- Eutectic C4 bump
- Eutectic BGA ball
- SSIT 20nm/16nm (non-HBM)
- Cu-pillar u-bump

SSIT (non-HBM)

- Cu-pillar u-bump
- Stiffener ring
- undercoat/overcoat
- XC cap (Sn-finish)
- Cu-pillar C4 bump
- Eutectic BGA ball
- XC LSC cap (Sn-finish)

Completed TV-based technology development & reliability assessment for next generation solutions
Today Challenges were addressed in 20nm Technology

- Determine application requirements
  - Size, weight and power
    - \(\rightarrow\) Xilinx
- Select overall system parameters
  - \(\rightarrow\) Xilinx

Assemble development vehicle
- \(\rightarrow\) COTS

Design deployment system

Space PKG solution need to be architected based on:
- Package Features
  - Interconnectivity
  - Line/spacing/Pad
  - Dielectric thickness
- Mechanical
  - Package structure
  - Assembly and Manufacture
- Thermal Management
  - Power Map;
  - Current Density
- Reliability

Where are we?

Given all of the above
- Can we extended thermal limit of FPGA in aerospace applications?
Past, Present, Future

We are here

We need to be there

We are ready for 20 nm and beyond
Adaptable.
Intelligent.