Expanding Flash Memory Capacity through Stacking Methods

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High-Density Flash Packaging

- Flash Stacking
- Flex Integrated Modules
**Benefits**

**Highest Density NAND Solution**
- Stacking multiple lower density devices in a single TSOP footprint

**Component supply flexibility**
- Supports commodity NAND devices from multiple vendors

**Product Agility**
- Enables higher capacity SKUs with minimum design changes and manufacturing cycle time for UFD, MP3, Memory Card, etc…
Doubles the NAND storage capacity
  - Stacks two NAND TSOP devices

Mechanically Rugged and Reliable like a single TSOP
  - Extensive stack qualification and testing
  - Stack fits into a standard TSOP footprint

Flexible and Just-in-Time Component Support
  - Supports commodity 1CE and 2CE flash devices
  - 24 hour manufacturing cycle time (typical)

Low Profile Stack
  - Virtually the same height as two TSOPs

Proven and standard assembly process
  - Based on proven Value Stakpak® IP
  - 2GB products shipping since Q4’05

Double the Density of a Commodity Flash Device
• **Quadruple the NAND storage capacity**
  - Supports up to 32Gb in a single stack with 4 x commodity 8Gb devices
  - Supports up to 64Gb in a single stack with 4 x 16Gb devices
• **Mechanically Rugged and Reliable like a single TSOP**
  - Extensive stack qualification and testing
  - Stack fits into a standard TSOP footprint
• **Flexible and Just-in-Time Component Support**
  - Stacks up to 4 JEDEC standard TSOP devices (single or dual CE)
  - 24 hour manufacturing cycle time (typical)
• **Low Profile Stack**
  - 4.62mm MAX Height
• **Proven and standard assembly process**
  - Based on proven Value Stakpak® IP

**Stacking dimensions**:  
L x W = 20.3mm x 12.9mm MAX  
2-High = 2.34mm MAX Height  
3-High= 3.48mm MAX Height  
4-High= 4.62mm MAX Height

*Quadruple the Density of a Commodity Flash Device*
Flash Stacking Applications

- High-Capacity USB Key
  - 8GB w/1Gb devices
  - 16GB w/2Gb devices

- High Density Memory Stick
  - Double the capacity of conventional modules due to volumetric efficiency

- High Density SD/MMC Card
  - 2X devices in the same volume

- Small Form-Factor Memory products
- Portable electronic products requiring high capacity embedded Flash
  - MP3/Medial player
  - Digital still camera
  - Camera Phone
  - Ultra-Mobile PC w/integrated Flash drive
Flash Stacking can be enabled with minimal re-design

High Capacity USB Flash Drive

Small USB Flash Drive

Personal MP3 Player

Ultra Mobile PC – Flash on Motherboard

Doubling the Capacity With Minimum Device Design Changes
Case Study: 4GB USB Flash Drive

- PNY’s first commercial 4GB USB Flash drive using FlashStak X-2
- Product derived from existing 2GB drive using two single 8Gb TSOP devices
- Two 16Gb stacks were fitted in the existing housing with only minor modifications
- Stacks shipping in volume since Q405
Description
• **System Stakpak®** is a Flex Integrated Module (FIM)
• Integration of heterogeneous ICs and packages within a folded flex module
• Enables complex or economical form-factor optimized sub-systems
• Leverages Staktek’s extensive experience and IP with flex circuit assembly
• Complementary to SiP and PoP packaging
• Supports sub 2mm low-profile applications

Benefits
• **Best-in-class** silicon selection
  – Optimal feature set for targeted application
• Increased design flexibility
  – Time to market
• Enhanced yield
  – Cost efficiency

Flex Integrated Module (FIM) Overview
 Baseband Processor
 2x16 bit DRAMs
 2x16 bit Flash
 32 bit SRAM {Cache}
 Flex circuit
 Ball Attach

 Controller (BGA)
 Flash (TSOP)
 Flex circuit
 Ball Attach
System StakPak® Advantages

- **Best-In-Class silicon selection**
  - Integrate the devices YOU choose for optimal functionality/performance regardless of available packaging formats.
  - Use ANY off-the-shelf package formats (including bare die, CSP, SiP, PoP, TSOP, TBGA, etc.) without modification.
  - Integrate STANDARD packaged parts to shorten supply chain, minimize inventory, simplify forecasting and increase sourcing flexibility.

- **Increased design flexibility**
  - Exploit scalable flex circuit wiring resources for COMPLEX ROUTING requirements.
  - Integrate DISCRETE COMPONENTS within the module package.

- **Enhanced yield**
  - PRE-TEST individual packaged components.
  - Conduct ON-MODULE PRE-TEST of selected critical components.
  - REWORK defective components on-module, post-functional test.

- **FIM example – TSOP Flash + BGA Controller**
Summary

• FlashStak™ Solution
  – Double and quadruple TSOP stacking solution for NAND Flash devices
  – Create products with higher memory capacity
  – Many products will require minimal redesign to accommodate stacked Flash
  – Based on reliable, proven designs and production processes

• System StakPak® Solution
  – Rapidly integrate Best-in-class flash and controller solutions into single low-profile package
  – Maintain design/supply-chain flexibility
  – High-yield solution
• Bert Haskell – Director of Marketing, CEBU, Staktek, Inc.

• 20 years experience in the electronics industry
  – Manufacturing Engineer (Eastman Kodak)
  – R&D Management (MCC, SDC)
  – Product & Technology Marketing (AMD, Motion Computing, Staktek)

• Over 30 publications, 5 patents

Appendix: Additional information

- For reference only (not part of presentation)
  - FlashStak™ 2-X: 2 Product SKUs
  - FlashStak™ Reliability Test Conditions
**2CE FlashStak**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Density</th>
<th>Single CE part#</th>
<th>Stack Height (mm)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hynix</td>
<td>4Gb</td>
<td>HY27UG084G2M-TXX</td>
<td>2.21</td>
<td>Production-ready</td>
</tr>
<tr>
<td></td>
<td>8Gb</td>
<td>HY27UH088G2M-TXX</td>
<td>2.21</td>
<td>Production-ready</td>
</tr>
<tr>
<td>Micron</td>
<td>4Gb</td>
<td>MT29F4G088ABWP-XX</td>
<td>2.27</td>
<td>Production-ready</td>
</tr>
<tr>
<td>Samsung</td>
<td>256Mb</td>
<td>K9F56080D-PCB0</td>
<td>2.25</td>
<td>Production-ready</td>
</tr>
<tr>
<td></td>
<td>4Gb</td>
<td>K9K8G08U0M-XXXX</td>
<td>2.25</td>
<td>Production-ready</td>
</tr>
<tr>
<td></td>
<td>8Gb</td>
<td>K9K8G08U0M-XXXX</td>
<td>2.25</td>
<td>Production-ready</td>
</tr>
<tr>
<td>Toshiba</td>
<td>8Gb</td>
<td>TC58NVG3D4CTG00</td>
<td>2.45</td>
<td>In production</td>
</tr>
<tr>
<td></td>
<td>16Gb</td>
<td>TH58NVG4D4CTG00</td>
<td>2.45</td>
<td>Production-ready</td>
</tr>
</tbody>
</table>

**4CE FlashStak**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Density</th>
<th>Dual CE Part#</th>
<th>Stack Height (mm)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micron</td>
<td>8Gb</td>
<td>MT29F8G08FA8WP-XX</td>
<td>2.20</td>
<td>Sampling</td>
</tr>
<tr>
<td>Samsung</td>
<td>8Gb</td>
<td>K9W8G08U1M-XXXX</td>
<td>2.32</td>
<td>Sampling</td>
</tr>
<tr>
<td></td>
<td>16Gb</td>
<td>K9WAG08U1M-XXXX</td>
<td>2.32</td>
<td>Sampling</td>
</tr>
</tbody>
</table>

Others currently being developed under NDA
## FlashStak™ Reliability Test Conditions

<table>
<thead>
<tr>
<th>Test</th>
<th>Reference</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAST</td>
<td>JESD22-A110</td>
<td>96 hours at 130C, 85% relative humidity using continuous bias.</td>
</tr>
<tr>
<td>Temperature Cycle (Component Level)</td>
<td>JESD22-A104</td>
<td>Condition B, soak mode 1 for 1000 cycles at -55C to 125C</td>
</tr>
<tr>
<td>Temperature Cycle (Module Level)</td>
<td>JESD22-A104</td>
<td>Condition J, soak mode 2 for 1000 cycles at 0C to 100C. 30 minute cycles with a temperature change rate of 10C/minute.</td>
</tr>
<tr>
<td>Constant Acceleration</td>
<td>Mil-Std-883, 2001</td>
<td>Condition A: 5000g</td>
</tr>
<tr>
<td>Vibration</td>
<td>JESD22-B103</td>
<td>Four sweeps of 20g peak sinusoidal vibration from 20 to 2000Hz in each of the three mutually perpendicular axes for a total of 12 sweeps.</td>
</tr>
<tr>
<td>Precondition</td>
<td>JESD22-A113</td>
<td>Use appropriate soak and reflow profile depending on device MSL.</td>
</tr>
<tr>
<td>Mechanical Shock</td>
<td>JESD22-B104</td>
<td>Condition B; 5 shocks at 1500g with 0.5ms durations in each of the three mutually perpendicular axes for a total of 30 pulses.</td>
</tr>
<tr>
<td>Solderability</td>
<td>JESD22-B102 J-STD-002</td>
<td>Reflow test or Dip &amp; Look method</td>
</tr>
<tr>
<td>Solder Analysis</td>
<td>J-STD-001</td>
<td>solder impurities per J-standard</td>
</tr>
<tr>
<td>Lead Inspection</td>
<td>Internal</td>
<td>Verification of lead inspection equipment accuracy and repeatability for pitch and coplanarity using a known golden standard.</td>
</tr>
<tr>
<td>Ionic Contamination</td>
<td>IPC-TM-650, Method 2.3.25</td>
<td>Liquid solution of 75% IPA and 25% DI water. Resistivity measured in Megaohm-cm and converted to equivalents of NaCl mg per square inch.</td>
</tr>
</tbody>
</table>