Embedded Storage
*The Next Chapter, 2015 and Beyond!*

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Embedded Storage
Swissbit NA
## SSD Markets Defined

<table>
<thead>
<tr>
<th></th>
<th>Client/Consumer</th>
<th>Embedded/Industrial</th>
<th>Enterprise/Datacenter</th>
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</thead>
<tbody>
<tr>
<td><strong>Examples</strong></td>
<td><img src="image1.png" alt="Desktops, Laptops, Ultra-books, Tablets, etc." /></td>
<td><img src="image2.png" alt="“Fixed Function” Compute Systems" /></td>
<td><img src="image3.png" alt="Servers, Storage Arrays" /></td>
</tr>
<tr>
<td><strong>Platforms</strong></td>
<td>Desktops, Laptops, Ultra-books, Tablets, etc.</td>
<td>“Fixed Function” Compute Systems</td>
<td>Servers, Storage Arrays</td>
</tr>
<tr>
<td><strong>Usage</strong></td>
<td>Mostly Read (70/30), 8hr Duty cycle, 10 to 50°C 1 – 3Yr Service Life</td>
<td>Wide range of mixed Work loads, 24/7 Duty cycle, -40 to 85°C, 8 - 10Yr Service Life</td>
<td>Read &amp; Write Intensive, 1-5x DWPD, 24/7 Duty Cycle, 20 to 50°C, 5Yr Service Life</td>
</tr>
<tr>
<td><strong>Bottom Line</strong></td>
<td>Price &amp; Performance “Low Expectations”</td>
<td>Reliability, Endurance, LCM &amp; TCO “Mission Critical”</td>
<td>Performance, Capacity, Green &amp; Endurance “X Levels of Redundancy”</td>
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</tbody>
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Santa Clara, CA
August 2015
Historical Perspective

- **1992**
  - TAM: $270M
  - $22 / GB

- **2000**
  - TAM: $10.6B
  - $12 / GB

- **2010**
  - TAM: $18.7B
  - $1 / GB

- **2015**
  - TAM: $30B (est.)
  - $0.35 / GB

**Share of Market**
- **Embedded**: 5%
- **Client/Enterprise**: 100%
Embedded/Industrial Storage Market:

- Encompasses a broad range of applications and market segments
- Late Majority or Lag Consumer & Enterprise markets, in technology adoption from Interface to Form-factor to NAND technology
- Platform lifecycles (8 to 10 years) are not conducive to rapid changes in technology advancement
- Recent years show a steady, but cautious shift toward MLC NAND – driven by lower $/GB ASP

Key requirements are Reliability, Endurance, Lifecycle, Support and Cost
Consumer/Client & Enterprise/Datacenter markets dominate the Global Storage market demand, and in turn, drive the technology available to support current and future Embedded Computing Storage applications.

<table>
<thead>
<tr>
<th>Positives</th>
<th>Negatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓ Cost</td>
<td>↓ Reliability</td>
</tr>
<tr>
<td>↑ Density</td>
<td>↓ Endurance</td>
</tr>
<tr>
<td>↑ Performance</td>
<td>↓ Power Fail Safety</td>
</tr>
<tr>
<td>↑ Technology Adoption</td>
<td>↓ Lifecycle Management</td>
</tr>
</tbody>
</table>
Background: MLC NAND price point drives avg. 3 to 4x reduction in ASP, but is not without strings

Problem: Often effects of higher operating temps are overlooked in terms of data retention degradation

Solution Set: Firmware Features
1. Autonomous Background Media Scan
2. Read Retry
3. Adaptive control required to maximize

<table>
<thead>
<tr>
<th></th>
<th>1xnm MLC vs. 2xnm SLC NAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block/Page Size</td>
<td>P/E Cycles</td>
</tr>
<tr>
<td>4x/2x greater</td>
<td>94% fewer</td>
</tr>
</tbody>
</table>

Embedded Applications are not known for managed airflow
- NetCom – better understanding
- Industrial – designed for temp extremes, but for how long?
- Automotive – looking for 105 °C
Endurance

Background: Embedded SSD’s must support a broad range of use cases – from Read-only to 70/30 Read/Write to Write-Intensive.

Problem: JESD 219 does not address the majority Embedded Storage applications for Workload & Operating Conditions

Solution Set:
1. Know the workload via analytical and/or empirical means
2. Not all Page-Mode FTL’s are created equal (WAF)
3. Insure the behavior of the drive in last 3rd of life and beyond – UECC Management, Health Monitoring & Reporting and Fail Safe (Read Only with Read Refresh capability)

<table>
<thead>
<tr>
<th>JEDEC JESD 219 Standard</th>
<th>Client</th>
<th>Embedded</th>
<th>Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duty Cycle</td>
<td>8 hr/day (33%) @ 40°C</td>
<td>??</td>
<td>24 hr/day (100%) @ 55°C</td>
</tr>
<tr>
<td>Workload Random Sequential Repeated</td>
<td>24.36% 75.64% 0%</td>
<td>??</td>
<td>100% 0% 0%</td>
</tr>
<tr>
<td>Trim</td>
<td>Yes</td>
<td>Not Likely</td>
<td>No</td>
</tr>
<tr>
<td>Retention</td>
<td>1 yr @ 30C</td>
<td>??</td>
<td>.25 yr @ 40C</td>
</tr>
<tr>
<td>UBER</td>
<td>&lt;1 sector in 10¹⁵ bits read</td>
<td>??</td>
<td>&lt;1 sector in 10¹⁶ bits read</td>
</tr>
</tbody>
</table>
**Power Fail Safety**

**Background:** Embedded/Industrial applications require varying degrees of Surprise Power Failure tolerance – from minimal in-flight data loss ok to 100% no data loss.

**Problem:** MLC NAND (as compared to SLC) suffers from higher Read Disturb Sensitivity, Retroactive Data Corruption and Data Retention issues

**Solution Set:**
1. Managed Power Fail mitigation (inc. Host & Drive)
2. Optimized power down sequencing
3. Dedicated Pfail Circuitry

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Voltage

Time

- Operating Voltage
- Controller Halt
- Flash Halt (W/P)
- Controller Reset
• Embedded Flash Controller providers constantly challenged to improve both HW and FW features to enable lower cost media (NAND or other) solutions

• 2D planar NAND Development (SLC and MLC) has likely reached the end of the road

• 3D NAND is the new frontier to address Client/Consumer and Enterprise SSD markets, HDD Killer likely, but what about Embedded? If and When?

• SD, USB, eMMC, and SATA interfaces are primary choice for current platform design activity
And Beyond!

- Media – 2D transitions to 3D NAND for most applications, but Embedded will lag the greater market, …as usual

- Controller – ECC BCH (good enough), move to LDPC as required

- Supply Chain – Likely continued SSD supplier consolidation WW, know your Supplier/Partner AND their supply chain eco-system

- Form-factors – expect the trend to continue, follow the larger market lead - SATA, SD, eMMC, PCIe, UFS, …
Key Take-Aways

• The Semi’s compete and serve the larger Consumer/Client and Enterprise/Storage markets, 3rd party Memory Module manufacturers are focused on the Embedded Storage Market

• MLC based storage solutions place greater responsibility on the Embedded System Designer to make informed decisions on the technology to be used

• Embedded Customers and Storage Solution providers must work closer to insure the selected storage solution meets the application needs throughout the intended service life
Quality is not an act, it is a habit.

Aristotle, 352 BC

Thank You!

Join us August 11-13, 2015
Flash Memory Summit
Santa Clara Convention Center
Santa Clara / CA