Why DRAM Really Matters Inside SSDs

Chris Wojslaw
Sr. Manager - DRAM Technical Marketing

Santosh Kumar
Director - SSD AE/FAE

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Session Objectives
- DRAM’s Place Inside an SSD
- SSDs Features and DRAM Requirements
- Main DRAM Functions within SSDs
- Choose the Right DRAM for SSD Capacity
  - Case Study: DRAMs for 2017 Large Capacity Enterprise SSD
- Choose the Right DRAM for SSD Performance & Power
- Other Key DRAM attributes:
  - Organization
  - Form Factor
  - Reliability
  - Cost
- DRAM Longevity
- Conclusions & Call to Action
Typical SSD – Functional Block Diagram

- **Power Control**
  - 5V/12V In
  - PLP Control
  - Power 1.2V, 1.8V, 3.3V, Etc.

- **ECC Engine**
- **NAND Controller**
- **Host I/F**
- **Buffer Management**

- **SATA / PCIe / SAS**
- **NAND Data Path**
- **Our Focus Area Today!**
  - DRAM
- **NAND**
## SSDs Features and DRAM Requirements

- **Capacity:** Max Capacity
- **Performance (IO):** IOPS/MBPS/Latency/QoS
- **Performance (Others):** POR/SPOR/Resume
- **Power:** Active/Idle/Low Power Modes
- **Others**
  - Longevity
  - Cost
  - Reliability

<table>
<thead>
<tr>
<th>Features</th>
<th>Client SSD</th>
<th>Enterprise SSD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>OP (Over provision)</strong></td>
<td>0%</td>
<td>&gt;= 7%</td>
</tr>
<tr>
<td><strong>DRAM Cache</strong></td>
<td>Yes (Optional on Low-End SSDs)</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Performance (IO)</strong></td>
<td>Lesser consistency across workload, Latency less critical</td>
<td>Higher Sustained steady state Perf, Lower latency</td>
</tr>
<tr>
<td><strong>Performance (others)</strong></td>
<td>POR timing, Resume timing</td>
<td>POR/SPOR timing</td>
</tr>
<tr>
<td><strong>Data Retention (Power-off)</strong></td>
<td>1 year, 30°C</td>
<td>3 months, 40°C</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Low power modes support</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>PLP (Power Loss Protection)</strong></td>
<td>No</td>
<td>Yes (Hot plug use case)</td>
</tr>
<tr>
<td><strong>End-to-End Data protection</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>DWPD (Endurance)</strong></td>
<td>30 GB/day (client workload)</td>
<td>0.4 to 3 (Enterprise workload)</td>
</tr>
<tr>
<td><strong>UBER (Uncorrectable BER)</strong></td>
<td>$10^{15}$</td>
<td>$10^{17}$</td>
</tr>
<tr>
<td><strong>MTBF</strong></td>
<td>1.2 Mhr</td>
<td>2 Mhr</td>
</tr>
</tbody>
</table>
Choosing the Right DRAM: Capacity

- In a typical SSD, DRAM are used for:
  - FTL (Flash Translation Layer) Map Table
  - Logs
  - Data Buffering
  - Journaling

- General Rule of Thumb:
  
  SSD Capacity : DRAM Capacity = 1000 : 1

- Example: 1920 GB SSD requires ~2GB DRAM

- If Dynamic FTL implemented for Low End SSD
  
  → DRAM size can be drastically reduced
Case Study: Upcoming 16 TB Enterprise SSD

- By 2017, Largest Enterprise SSDs = 16 Terabytes Capacity (Estimate)
- Using Rule of [SSD : DRAM Capacity] = [1000 : 1], this SSD requires 16GB total DRAM
- Given max. DDR4 density is 1GB today, this would require 16 FBGA devices
- **NOT FEASIBLE** for thermal reasons & physical space to fit 16 DRAMs in 2.5” SSD

Solution: Collaborate with DRAM Suppliers on matching your SSD Roadmaps to our Higher Density, Smaller Package Memories
Choosing the Right DRAM: Performance

- DRAM Provides SSDs Improved bandwidths
  - DRAM Rule of thumb: Target 2X Interface Bandwidth

- Performance Improvement Realized from DDR4
  - Higher IOPS & Lowering latencies
  - Improved QoS (Quality of Service)
  - DDR4 can operate with 16 banks for higher concurrency

- DDR4 supports highest datarates: 2133, 2400, 2667
  - By 2016, DDR4 @ >2667 speeds are expected in MP
  - DDR3 max. speed = 2133
Choosing the Right DRAM: Power

- Higher performance & 38% reduction in component power by choosing DDR4 over DDR3/L
  - DDR4 has Low power & Temperature-Controlled auto refresh modes not available in DDR3/L

**DDR4 Energy Efficiency (Component level)**

- 20% reduction in power for DDR4 compared to DDR3
- 38% reduction in power for DDR4 compared to DDR3L

**Power Savings from DDR4**

- 22.5% reduction at 1DPC
- 38% reduction at 2DPC

<table>
<thead>
<tr>
<th>DRAM Type</th>
<th>RCD</th>
<th>Total DRAM Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDR3L</td>
<td>23%</td>
<td>22%</td>
</tr>
<tr>
<td>DDR4</td>
<td>22%</td>
<td>42%</td>
</tr>
</tbody>
</table>

*DDR4 RDIMM 2Rx4 16GB (Module) case

**Conditions**
1) 3sigma IDD used
2) Calculation method:
   - IDD4R*60% + IDD4W*30% + IDD2P*10%
Choosing Right DRAM: DDR4 Advantages

Reliability
Error Detection at CMD & Data Bus

CA Parity
CRC

Lower Power
Supply Voltage Reduction

1.5V → 1.35V → 1.2V
20% 11%

DDR3 DDR3L DDR4

Speed

2133 1866 3200

DDR3 DDR3L DDR4

Speed up to 3.2Gbps

• Besides DRAM, as NAND density increases, power consumption increases
Choosing the Right DRAM – Org. & Size

Organization

- X4: Simpler routing → less pcb layers
- X8, x16: Consumer/IT grade easier to procure versus X4

Physical size

- For 1.8”, M.2 and smaller form factors, FBGA packaged DRAM saves pcb space
  - PoP packages are smaller but harder to manufacture & not as reliable as discrete BGA
Choosing the Right DRAM: Density & Cost

Golden rule: As SSD capacity increases so must the DRAM density

Density:
- SK hynix supports mainstream DDR3 and DDR4 densities to enable entire SSD product line
- Increased flexibility to utilize different SSD SoC controllers

Cost:
- DDR4 retains small price premium over DDR3
- DDR3 vs. DDR4 crossover expected sometime in CY2016 (Depends on market)
- 8Gb vs. 4Gb DDR4 crossover also expected in CY2016 (Depends on market)
## 2015-16 DDR3 & DDR4 DRAM Roadmap

<table>
<thead>
<tr>
<th>Product &amp; Density</th>
<th>2H 2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDR4 8Gb</td>
<td>x4/x8</td>
<td>x4/x8/x16</td>
</tr>
<tr>
<td>DDR4 4Gb</td>
<td>x4/x8/16</td>
<td></td>
</tr>
<tr>
<td>DDR3 4Gb</td>
<td>x4/x8/16</td>
<td></td>
</tr>
</tbody>
</table>

- Need new technologies? LPDDR4? 16Gb DDR4? → talk to your DRAM supplier
Why DRAM Really Matters Inside SSDs

- Conclusions & Call to Action:
  - For client SSDs, where low idle & sleep power, lowest cost, low capacity are important, DDR3/DDR3L provides the best solution
  - For enterprise SSDs, where high sustained performance and large capacity are important, DDR4 is recommended
  - Advancements in Capacity & Performance for Enterprise SSD will drive solutions beyond 8Gb DDR4 – Talk with your DRAM suppliers directly

Thank You

Questions on this presentation? Please contact:
- Chris Wojslaw  chris.wojslaw@us.skhynix.com
- Santosh Kumar  santosh.kumar@us.skhynix.com