STT-MRAM – A High Performance Complement to Flash Memory

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Everspin Technologies
Overview

- STT-MRAM Technology Background
- STT-MRAM Technology Specifications
- STT-MRAM Use Cases
- Silicon Data
STT-MRAM Technology Background
MRAM Technology Evolution

- **Toggle MRAM**
  - Production since 2006
  - 256kb – 16Mb
  - 35ns Parallel (SRAM), SPI, QSPI
  - Commercial, Industrial, Automotive

- **STT-MRAM (iMTJ)**
  - Production 2015
  - 64Mb ST-DDR3, 90nm node
  - Commercial

- **STT-MRAM (pMTJ)**
  - 256Mb ST-DDR3, 40nm node, Prod. 2017
  - 1Gb ST-DDR4, 28nm node, Prod. 2019
  - Commercial
MRAM States

- **Magnetoresistance Effect**
  - Parallel = Low
  - Anti-Parallel = High
  - MR = \((R_{high}/R_{low}-1)\)*100%
  - RA = Rlow * Area

- **Aluminum Oxide (Toggle)**
  - MR ~40% at 25C
  - Higher RA material

- **Magnesium Oxide (STT-MRAM)**
  - MR >120% at 25C
  - Lower RA material
STT-MRAM Integration

- **Magnetic Tunnel Junction (MTJ) integrated between metal layers**
  - No changes to transistor integration
  - Fast development on advanced nodes

- **Simple 1T-1MTJ structure**
  - One transistor select device
  - Cell area constraints similar to DRAM
  - MTJ connected directly to Bitline
STT-MRAM Operation

- **Read Operation**
  - Low voltage to avoid disturb
  - Detect High or Low resistance state
  - Low power

- **Write Operation**
  - Current direction determines state
  - Some overdrive required for low BER
  - Too much overdrive impacts endurance
STT-MRAM Technology Specifications
Memory Performance with Persistence

- **Non-Volatile:** Maintains data without power or refresh
- **Fast:** Read/write similar to DRAM
- **Endurance:** Handles memory workloads

T. Andre
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Santa Clara, CA

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256Mb ST-DDR3 and 1Gb ST-DDR4

<table>
<thead>
<tr>
<th>Feature</th>
<th>256Mb ST-DDR3</th>
<th>1Gb ST-DDR4</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD / VPP</td>
<td>1.5V</td>
<td>1.2V / 2.5V</td>
</tr>
<tr>
<td>Data Retention</td>
<td>3 months / 70C</td>
<td>3 months / 70C</td>
</tr>
<tr>
<td>Endurance</td>
<td>1e10 cycles</td>
<td>1e10 cycles</td>
</tr>
<tr>
<td>Uniform Lifetime Writes per Chip</td>
<td>320 PBW 3.8 years</td>
<td>1280 PBW 15.2 years</td>
</tr>
<tr>
<td>Peak Bandwidth per x16 Chip</td>
<td>2.67GB/s</td>
<td>2.67GB/s</td>
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STT-MRAM Use Cases
Enterprise Storage
SSD QoS Improvement

- 25% - 45% latency improvement
- Latency improvement is architecture dependent
Storage Accelerator

STT-MRAM in Server Storage Accelerator

In Partnership With:

SMART Modular Technologies

Optimized Log Management
9x Improvement In Overall Storage Performance*
No Special Drivers Standard NVMe
No Stored Charge Liability
# 1GB STT-MRAM Storage Accelerator

<table>
<thead>
<tr>
<th>Category</th>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance</strong></td>
<td>Available Capacity</td>
<td>1GB</td>
</tr>
<tr>
<td></td>
<td>Persistent Memory Modules</td>
<td>256Mb Perpendicular STT-MRAM</td>
</tr>
<tr>
<td></td>
<td>Sequential Read/Write</td>
<td>Up to 6,000 MB/sec</td>
</tr>
<tr>
<td></td>
<td>Random 4KB Read</td>
<td>Up to -230MB/sec</td>
</tr>
<tr>
<td></td>
<td>Random 4KB Write or Sustained 4KB Write</td>
<td>Up to 1,500,000 IOPS</td>
</tr>
<tr>
<td></td>
<td>Random 70/30 Read/Write</td>
<td>Up to 1,460,000 IOPS</td>
</tr>
<tr>
<td></td>
<td>Average Latency Read/Write (QD1)</td>
<td>6 μsec (read), 7 μsec (write)</td>
</tr>
<tr>
<td></td>
<td>Worst Case Latency Read/Write (QD8)</td>
<td>10 μsec (read), 11 μsec (write)</td>
</tr>
<tr>
<td><strong>Endurance</strong></td>
<td>Drive Writes per Day</td>
<td>Unlimited uniform access</td>
</tr>
<tr>
<td></td>
<td>Data Retention</td>
<td>Power on - infinite; Power off - 3 months at 50°C</td>
</tr>
</tbody>
</table>

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<tr>
<th>Category</th>
<th>Parameter</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interface</td>
<td>PCIe Gen3 x8 (8GT/s), Non-volatile Memory Express (NVMe)</td>
</tr>
<tr>
<td></td>
<td>Access Modes</td>
<td>Block mode (NVMe)</td>
</tr>
<tr>
<td></td>
<td>PCIe Card Form Factor</td>
<td>Half Height, Half Length (HHHL)</td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Power Consumption 70/30 Read/Write</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operating Temperature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-operating Temperature</td>
</tr>
<tr>
<td></td>
<td>OS</td>
<td>Linux, Windows</td>
</tr>
<tr>
<td></td>
<td>Management</td>
<td>Self Monitoring Analysis and Reporting Technology (SMART) commands</td>
</tr>
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</table>
Fabric Accelerator

STT-MRAM in Fabric Accelerators

Higher Performance With Bypass Assist

- Acts as power loss protected write burst data buffer on the fabric/network controller card for offload engines
- Providing at point persistent write data completion
- Eliminates the multi-microseconds latency path before data can be committed to a persistent device

Provide bigger working persistent memory region

Enables product differentiation
Data Retention

- 1Gb Data Retention
- Accelerated Testing at Elevated Temperatures
- Demonstrates 10yr at 85C
Endurance

- **1Gb Endurance**
  - Accelerated Testing at elevated voltages
  - Well behaved TDDB Weibull distribution
  - Testing validated 1E10 cycles through every page
Write Operation

- **1Gb Write Operation**
  - Normal switching distributions
  - Wide operating range
Summary
Summary

- **1Gb STT-MRAM is here!**
  - Built on 13 years of MRAM production experience

- **STT-MRAM delivers 2.67GB/s write and read performance per chip**
  - ST-DDR4 interface with JEDEC DDR4 compatible footprint

- **STT-MRAM delivers over 1 Exabyte lifetime writes per chip**
  - Supports a lifetime of write data buffering with low chip count

- **STT-MRAM delivers highly reliable solutions**
  - Demonstrated reliability and persistence without capacitors or batteries
  - Large persistent memory capacity improves QoS