Delivering Nanosecond-Class Persistent Storage

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Storage Scaling Challenge

- Dramatic changes in Compute & Storage ahead
  - Cloud, Virtualization, Social Media, …

- Capacity & Performance Storage requirements exploding

Need to bridge gap between CPU & Storage
MRAM, *Fastest non-volatile memory with unlimited endurance*
combines memory & storage attributes:
*Nanosecond-Class Persistent Storage*

Enables new architectures for CISC, RISC & ZISC
ST-MRAM delivers 10x+ IOPS/$

Cloud Storage Needs:
- More content & users, instant access
- Better response times from storage
- Predictable balanced performance

Nanosecond-class MRAM Storage

<table>
<thead>
<tr>
<th></th>
<th>NAND</th>
<th>MRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>64Gb</td>
<td>1Gb</td>
</tr>
<tr>
<td>Latency</td>
<td>50us</td>
<td>45ns</td>
</tr>
<tr>
<td>4kB Write IOPS</td>
<td>800</td>
<td>400k</td>
</tr>
<tr>
<td>Cost/GB</td>
<td>1</td>
<td>50</td>
</tr>
</tbody>
</table>

500x Performance…

…at only 50x Cost/GB
ST-MRAM delivers 100x+ IOPS/W

Data Center needs:
- Number of servers & CPU cores exploding
- Better bandwidth & IOPS to handle Big Data
- More performance @ less power to scale up

High Performance, Power-Efficient MRAM Storage

<table>
<thead>
<tr>
<th>NAND SSD</th>
<th>MRAM SSD</th>
</tr>
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<tbody>
<tr>
<td>Density</td>
<td>64Gb</td>
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<tr>
<td>Power</td>
<td>80mW</td>
</tr>
<tr>
<td>4kB Write IOPS</td>
<td>800</td>
</tr>
<tr>
<td>Cost/GB</td>
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</tbody>
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500x Performance...

...at only 5x Power
Ultra Low Latency Memories

- Three new low latency memories on horizon
  - Spin-Torque Magnetic RAM
    - Optimized for performance – targeting nvDRAM
  - Phase Change RAM
    - Optimized for read performance – targeting NOR
  - Resistive RAM
    - Optimized for capacity/cost – targeting NAND

New system architectures required to fully take advantage of these new non-volatile memories
MRAM – Simplifying system design

- **Addressing a fundamental Problem of Storage:**
  - *Truly Non-Volatile RAM – Power Fail Data Protection*
  - *Eliminates complicated power fail management HW & FW*
  - *Reduces development time and effort for products*

- **Complementing DRAM and NAND**
  - *Making NAND perform better and last longer*
  - *MRAM for write caching, DRAM for read caching*
  - *More IOPS/$ and better IOPS/Watt than NAND*
1st Gen MRAM Progress

- Async SRAM & (Q)SPI I/F
- 256kb to 16Mb density
- 20/10Mpcs+ (e)MRAM shipped
- Today: Enterprise & Industrial
- Future: Growth in Auto & High Rel.
- Usage: Metadata storage & log
2nd Gen MRAM – ST-MRAM

- Targeted at persistent DRAM memory applications
- DDRx roadmap scaling from 64Mb to Gb densities
- Non-volatile Buffers & Caches for Storage Systems
- Initial use: Protecting data in flight & coalesce buffers
- Introduced initial product: 64Mb DDR3 ST-MRAM
- Delivered working samples to top OEMs
  - Evaluate & explore new system architectures
- Sampling DIMM modules for evaluation platform
  - 64MB and 128MB SO-uDIMMs and uDIMMs
- Developing PCIe FPGA eval platform
  - Close partnership with Altera and Gidel
  - PCIe Memory and Storage sub-system
Storage Solutions craving ST-MRAM

MRAM complements solid state & magnetic storage

*Improved response time due to low latency & high bandwidth*

MRAM as Buffer Memory
MRAM instead of low density DRAM

*Better performance & reliability*

MRAM as I/O & Network Cache
MRAM instead of NV-DRAM

*Better reliability & overall TCO*

MRAM as Fast Storage-Tier
MRAM in addition to SSD/HDD

*Better IOPS/$/W & reliability*
MRAM in SSD, HDD and Hybrid

- **Enterprise/Industrial SSD**
  - NV-Buffer, 2-8MB Program Data Buffer
  - NV-Cache, 8-128MB Write Cache
  - Power Fail Safe, Write Buffer & Caching

- **Hybrid HDD**
  - NV-Buffer, 2-8MB Program Data Buffer
  - NV-Cache, 4-32MB Media Management
  - Power Fail Safe, High Performance Hybrid

- **Enterprise HDD**
  - NV-Buffer, 8-16MB, Media Write Caching
  - NV-Cache, 32-64MB Write Cache
  - Power Fail Safe, Write Caching

Source: Aggregate Industry Analyst Projections, October 2011
Case Study: RAID – Dell & LSI

- Write Journal Memory for RAID Storage Systems
  - Storing Metadata Transactions
  - Rapid power loss data recovery
  - Superior data integrity
  - Fast transaction data log
  - No separate board level discrete devices, batteries or capacitors
Case Study: Solid State Drive

- Buffalo Memory announced a new Industrial SSD that uses Everspin MRAM for the cache.
  - Exhibited at the 15th Embedded Systems Expo in Japan
  - 4GByte SSD with 8MByte of MRAM cache

- “MRAMs are nonvolatile memories that use magnetic materials as elements and feature high-speed random access, high integration and non-volatility. There are three advantages in using MRAM as cache, compared with normal high-speed SSDs that use volatile DRAM as cache.”

- **MRAM unique value proposition:**
  1. Excellent resistance to power interruption
  2. Improve booting speed
  3. Excellent power-saving capability

   Motoyuki Oishi, Nikkei Electronics
Case Study All Flash Appliance

- The world’s first all solid state storage appliance
  - MRAM replaces capacitor-backed RAM solution
  - Protecting data in flight through storage in MRAM

- Overwhelming customer interest for this product
  - Initial use of Toggle MRAM in lieu of Capacitor Backed SRAM
  - Transitioning to ST-MRAM in lieu of Capacitor Backed DRAM
  - MRAM density deployed growing from MB to GB
Building the MRAM Ecosystem

- Increasing the awareness of MRAM’s advantages
  - Versatile use as memory or storage device
  - Persistent memory architecture element
- Optimizing memory host controller ecosystem
  - Enable mixed use of MRAM combined with DRAM
  - Increase availability for FPGAs and SOC development
- MRAM BEOL manufacturing eco system
  - Establishment of volume manufacturing at 300mm
  - Improving availability and cost of BE processing
- Expanding MRAM market opportunities
  - Scaling to Gb densities yields exponential growth
  - Developing persistent memory optimized interface