Micron Storage Solutions

SSD kill the mechanical disk Star

February 2017
Pilar Aguado | Alberto Gómez
Enterprise Sales EMEA
Who is Micron?

We are the 75% of your server value.

Our memory & storage solutions make your workloads faster, greener, just better.

- 4 NAND Flash Manufacturers
- 3 DRAM Manufacturers
- 2 Both DRAM & NAND for the Enterprise
- 1 The only firm with the next generation memory solution (3DXPoint)
Micron’s Major Brands

- Micron – Enterprise Focused
- Crucial – Business and Consumer
- Lexar – Consumer
- Ballistix - Gaming
Innovation – Customer Thought Leadership

World’s Largest Web-Scale Companies use Micron Memory & SSDs

Gartner: “By 2017, Web-Scale will be an architectural approach found operating in 50% of Global Enterprises”
Innovation – Customer Thought Leadership

Some of Europe’s Largest Firms
Industry Trends & Market Views

What is going on with Technology and the Market
NAND Scaling Trend

- 2D NAND scaling has slowed due to physics limitations
- 3D NAND enables further scaling with improved cell reliability
  - Vertical stacking allows large number of electrons per cell independent of scaling
  - No longer relying on lithography to continue scaling
  - Decreased interference between cells translates into higher cycling endurance
Micron’s Cell Technology Choice

- Micron Utilizes Floating gate cell technology
  - Smaller cell footprint
  - Charge isolation between cells
    - Preserves data retention benefits

- Others have focused on a charge trap storage node
  - Larger cell footprint
  - Charge dispersion between cells
    - Leads to data retention failure
Solid State Storage Eclipses Spinning Disks

- Dramatically Lower $/IOPS
- Rapidly Increasing Density
- No Moving Parts
  - Higher Reliability
  - Lower Power and Heat
  - Smaller footprint form factors

- IOPS per GB Decreasing
- Capacity Growth Slowing
- Performance Requires
  - Short Stroking
  - Striping Across Many
5100 ECO vs. 10K HDD
TOTAL COST OF OWNERSHIP

High Performance
Storage Solution

91% Fewer Drives
(22 vs. 240)

Identical Capacity

20X Higher Performance
(2046K vs. 96K IOPS)

66% Lower TCO
($65K vs. $165K)

10K HDD System – 900GB 10K HDD, MSRP of $375 per newegg.com, 400 IOPS, 7.6W, 24 HDDs per chassis, RAID5, 80% utilization; 5100 ECO SSD System – 7860GB, 93K IOPS, 6W, 24 HDDs per chassis; Chassis cost of $2200, $0.077/KWh, Cooling Factor of 1.7, 100% Read, Queue Depth 32, 4KB block size, 100% random

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SSDs Versus HDDs: A deeper look
Micron® S610DC SAS SSD

**KEY BENEFITS**
- 2X the Write Performance
- 26X the Read Performance
- 27% Lower Acquisition Cost
- Greater Capacity
- 80% Less Rack Space
- Fewer Drives to Manage
- Higher System Reliability

**SYSTEM COMPARISON**

<table>
<thead>
<tr>
<th>BEFORE</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dell R730</td>
<td>Dell R730</td>
</tr>
<tr>
<td>96 x 15K 300GB</td>
<td>8 x S610DC 3.84TB</td>
</tr>
<tr>
<td>- No Parity</td>
<td>- No Parity</td>
</tr>
<tr>
<td>- 28.8TB Usable Capacity</td>
<td>- 30.72TB Usable Capacity</td>
</tr>
<tr>
<td>- 57.6K Read/Write IOP</td>
<td>- 1.52M/120K Read/Write IOPS</td>
</tr>
<tr>
<td>4 x 24 Drive JBOD</td>
<td>Item</td>
</tr>
<tr>
<td>$4,550</td>
<td>$4,550</td>
</tr>
<tr>
<td>$30,240</td>
<td>$24,480</td>
</tr>
<tr>
<td>$5,200</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Total</strong></td>
</tr>
<tr>
<td><strong>$39,990</strong></td>
<td><strong>$29,030</strong></td>
</tr>
</tbody>
</table>

Dell R730, Intel Xeon E5-2660 v3, 64GB RDRAM, PERC H730 – www.dell.com – MSRP OCT15
15K SAS HDD - $1.05/GB – estimated
15K SAS HDD - 600 Read/Write IOPS
SSD Growth Rate

SSDs are the fastest growing segment of flash bit growth.

Enterprise and data center growth are the fastest growing SSD segments.

NAND Bit Demand Segmentation
SSD's GROW DEMAND SHARE

<table>
<thead>
<tr>
<th>Segment</th>
<th>2016-2020 CAGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>44%</td>
</tr>
<tr>
<td>Other</td>
<td>42%</td>
</tr>
<tr>
<td>Removable Storage</td>
<td>28%</td>
</tr>
<tr>
<td>Consumer</td>
<td>18%</td>
</tr>
</tbody>
</table>

Source: FSG, with BU collaboration

Table includes tablets with SSDs
Other includes HHD, Enterprise ID/ODM, A2MM, Network
Consumer includes MP3/MP4, DSC, DVC, Gaming, Graphics, 1
NVMe Servers Grow from $2B to $25B by 2020
$ / IOP Trend

- HP NVMe is the least expensive $/ IOP
- SATA is the lowest cost / GB but highest in $ / IOP
Server Based Storage Adoption
THE SERVERFICATION OF STORAGE

Frame-based Arrays
Transitions Rapidly to Server-based Storage

- “Serverfication” the server becomes the primary storage element both for legacy and next-gen applications
- Server based storage reduces the cost and complexity of legacy applications freeing up resources to focus on next-gen cloud-native apps

<table>
<thead>
<tr>
<th>Storage Type</th>
<th>CAGR</th>
<th>2012-2027 Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legacy SAN &amp; NAS</td>
<td>-17.8%</td>
<td>$10,000 - $3,000</td>
</tr>
<tr>
<td>Enterprise Scale-out Server-SAN</td>
<td>44.2%</td>
<td>$30,000 - $50,000</td>
</tr>
<tr>
<td>Cloud-Native Server Storage</td>
<td>22.7%</td>
<td>$20,000 - $70,000</td>
</tr>
</tbody>
</table>

Direct research shows 34% remain NAS/SAN

Storage Migration to Server-SAN 2012 - 2027
Latency Kills

Cost of Latency

Amazon: "...every 100ms of latency cost them 1% in sales”

Google: "...an extra 500ms in search page generation time dropped traffic by 20%”

Tabb Group: "...a broker could lose $4M per millisecond if their electronic trading platform is 5ms behind the competition”
<table>
<thead>
<tr>
<th>Protection Type</th>
<th>Technology</th>
<th>Access Time</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Based Protection</td>
<td>Block-Mode NVDIMM</td>
<td>DDR &gt; 100ns</td>
<td>NVMe SSD 25µs</td>
</tr>
<tr>
<td></td>
<td>3D XPoint™</td>
<td>DDR 100-500ns</td>
<td>SATA SSD 300µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Array Based Protection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All Flash Array Fibre Channel SAN</td>
<td></td>
<td>12ms</td>
</tr>
<tr>
<td></td>
<td>Hybrid Array Fibre Channel SAN</td>
<td></td>
<td>30ms</td>
</tr>
</tbody>
</table>
Memory/Storage Technology Hierarchy

- NVDIMM-N complementary to cost-optimized persistent memory like 3D Xpoint
- NVDIMM-P (enables use of media non-deterministic read/write latencies) gaining traction in JEDEC
- Applications beginning to take advantage of benefits of persistent memory
Micron SSD Portfolio by Market Segment & Future Trends

Current Solutions
- SAS  S600
- PCIe  9100/9200
- PCIe  7100
- SATA  5100
- NVMe  Coming Soon
- SATA  1100

Client
- OEM PC Solution
- Boot Solutions

Cloud
- Caching/High Cap
- New Storage
- Primary Storage
- Boot Solutions

Enterprise
- Primary Store
- Acceleration
- Caching/Boot
- Embedded

2018+
- SAS 24Gb/s
- PCIe Gen4
- Light NVM
- QLC/Large Cap
- NVMeoFabric

Planning for the Future Now... What trends interest you?

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Micron® SSDs Deliver Data at the Speed of Now

<table>
<thead>
<tr>
<th>Consumer</th>
<th>Client</th>
<th>Cloud</th>
<th>Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MX300 SATA</strong></td>
<td><strong>1100 SATA</strong></td>
<td><strong>7100 NVMe PCIe</strong></td>
<td><strong>9200 NVMe</strong></td>
</tr>
<tr>
<td>- 3D NAND</td>
<td>- 3D NAND</td>
<td>- 16nm MLC NAND</td>
<td>- 3D NAND</td>
</tr>
<tr>
<td>- Energy efficient</td>
<td>- Energy efficient for increased battery life</td>
<td>- Low power</td>
<td>- Performance Flagship</td>
</tr>
<tr>
<td>- Hardware encryption</td>
<td>- Hardware encryption</td>
<td>- Enterprise-class hardware encryption</td>
<td>- Product line</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>M500IT SATA</strong></th>
<th><strong>5100 SATA</strong></th>
<th><strong>9100 NVMe</strong></th>
<th><strong>S600 Series SAS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- 20nm MLC NAND</td>
<td>- 3D NAND</td>
<td>- 16nm MLC NAND</td>
<td>- 16nm MLC NAND</td>
</tr>
<tr>
<td>- Industrial temps</td>
<td>- High performance and capacity</td>
<td>- Enterprise-class hardware encryption</td>
<td>- Enterprise-class hardware encryption</td>
</tr>
<tr>
<td>- Durable &amp; robust</td>
<td>- FIPS 140-2 Validated</td>
<td>- High performance</td>
<td>- FIPS 140-2 Validated</td>
</tr>
</tbody>
</table>

Micron’s 9200 NVMe PCIe SSDs: Blazing performance to revolutionize how you compute
Micron 5100 Series SSDs: flexibility for deployment and redeployment + security piece of mind
## Micron Storage Portfolio Roadmap

<table>
<thead>
<tr>
<th>Year</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2H</strong></td>
<td><strong>SAS</strong></td>
<td><strong>NVMe HHHL/U.2</strong></td>
<td><strong>NVMe U.2/M.2</strong></td>
<td><strong>SATA</strong></td>
</tr>
<tr>
<td>12Gb/s</td>
<td>Gen 3 x4</td>
<td>MLC up to 4TB</td>
<td>(25W) 1 to 3 DWPD</td>
<td>Client Focused</td>
</tr>
<tr>
<td>MLC up to 4TB</td>
<td>Gen 3 x8</td>
<td>TLC up to 11TB</td>
<td>(25W) 1 to 3 DWPD</td>
<td>TLC 256G - 2TB</td>
</tr>
<tr>
<td>1 to 25 DWPD, 2.5, 1.8</td>
<td></td>
<td></td>
<td></td>
<td>2.5, M.2</td>
</tr>
<tr>
<td><strong>1H</strong></td>
<td><strong>8200</strong></td>
<td><strong>9200</strong></td>
<td><strong>9300</strong></td>
<td><strong>2200</strong></td>
</tr>
<tr>
<td>12Gb/s (12W)</td>
<td>Gen 3 x8</td>
<td>Gen 3 1x8/2x2</td>
<td>Gen 4 x4 (2x2)</td>
<td>Gen 4 x4 (2x2)</td>
</tr>
<tr>
<td>MLC/TLC 400G - 16TB</td>
<td>TLC up to 11TB</td>
<td>MLC/TLC 800G - 24TB</td>
<td>(12W) 800G - 100TB</td>
<td>(12W) 800G - 100TB</td>
</tr>
<tr>
<td>1 to 10 DWPD, 2.5</td>
<td>(25W) 1 to 3 DWPD</td>
<td>(35W) 1 to 7 DWPD</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2018</strong></td>
<td><strong>24Gb/s Wide port</strong></td>
<td><strong>Gen 4 x8 (2x2)</strong></td>
<td><strong>Gen 4 x8 (2x2)</strong></td>
<td></td>
</tr>
<tr>
<td>800G - 32TB</td>
<td>800G - 32TB</td>
<td>(35W) 1 to 5 DWPD</td>
<td>(35W) 1 to 5 DWPD</td>
<td></td>
</tr>
<tr>
<td><strong>2019</strong></td>
<td></td>
<td></td>
<td></td>
<td>2TB - 16TB</td>
</tr>
</tbody>
</table>

- **Common Architecture**
- **Future Planned**
- **Under Investigation**

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HPC and Grid farms

- Checkpointing
  - Is it cheaper for me to lose the data than store it?
  - Store to central location, NAS or SAN, or do it on the compute node.
  - Can NVMe SSDs or/and NVDIMM help speed up the checkpoint process through lower latency and higher throughput.

- Boot from local drive
  - Does the speed of recovery of a node matter?
  - Reboots and reimage takes time. Speed it up with SSD.