Flash Storage Solutions for Embedded Applications –

Making the Right Choice

Victor Tsai
Dir. Product Marketing
Integrated Memory Solutions
Agenda

• Embedded Storage Market Overview
• Design Considerations
• Needs for Customization
• Solutions for Embedded Storage
Embedded Storage Market Overview
Embedded Storage Is Everywhere!
Not Just in Mobile Phones and Tablets

Automotive
- In-Vehicle Infotainment

Industrial & Medical Devices
- Various Industrial Medical
- RFID and POS

Networking Appliances
- Infrastructure Equipment
- Enterprise Video / VoIP
- Servers
Embedded Flash Storage is Growing!

Source: SMART marketing + 3rd market research
Where is Embedded Storage Going?

Like all electronic evolutions…

• Smaller, Lighter
• Higher Density
• Faster
• Lower Power
• More Reliable
• Lower Cost
Design Considerations

• NAND technology
• Hardware interface and protocol standards
• Software support infrastructure
• Performance requirements and use cases
• Form factor
• Thermal constraints
• Customization for specific needs
• Product life-cycle
• Cost
NAND Process Scaling => Lower Cost

Relentless scaling to reduce bit cost while increasing bit production
NAND Flash Memory Endurance Trending Downward

Matching the right NAND technology to applications
- Price / Endurance / Density tradeoffs

Source: iSuppli Q4’12
Trend Away from Raw Memory Components

- NAND error correction and Flash management algorithms becoming too complex

![Diagram showing the Host Storage Subsystem and Block Storage Device with various components and their interactions.](image-url)
Leveraging Technology Standards

- Adoption from technologies originated from and driven by demand in consumer products: computers, mobile phones, and other consumer electronics products
  - Economy of scale → cost structure
  - Hardware/software support infrastructure
  - Industry technical know-how

- SATA, USB → PC
- CF, SD → Camera, Consumer Electronics
- eMMC → Mobile Phone
Form Factor Trends → Faster, Smaller

- Activities at JEDEC, SFF, SATA-IO, PCI-SIG, etc. driving smaller form factors, faster embedded storage standards

- mSATA
- SATA Slim
- M.2 (PCIe interface)
- mSATA-mini
- eMMC
# Technology Comparison (for Embedded Applications)

<table>
<thead>
<tr>
<th></th>
<th>SATA II/III</th>
<th>PCIe (AHCI)</th>
<th>PCIe (NVMe)</th>
<th>USB 2.0</th>
<th>CF</th>
<th>CFast</th>
<th>SD 2.x/3.0</th>
<th>eMMC 4.5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Command Protocol</strong></td>
<td>ATA</td>
<td>ACHI (ATA)</td>
<td>NVMHCI (NVMe)</td>
<td>SCSI</td>
<td>ATA</td>
<td>ATA</td>
<td>SD</td>
<td>eMMC</td>
</tr>
<tr>
<td><strong>Seq. R/W Performance (MB/s)</strong></td>
<td>~200/400</td>
<td>&gt;500</td>
<td>&gt;500</td>
<td>~40</td>
<td>~40</td>
<td>~100</td>
<td>~40</td>
<td>~100</td>
</tr>
<tr>
<td></td>
<td>~200/400</td>
<td>&gt;500</td>
<td>&gt;500</td>
<td>~40</td>
<td>~40</td>
<td>~100</td>
<td>~40</td>
<td>~100</td>
</tr>
<tr>
<td><strong>Random R/W Performance (IOPS)</strong></td>
<td>~30K</td>
<td>~50K</td>
<td>~50K</td>
<td>~1000</td>
<td>~100</td>
<td>~15K</td>
<td>~1000</td>
<td>~3K</td>
</tr>
<tr>
<td></td>
<td>~30K</td>
<td>~50K</td>
<td>~50K</td>
<td>~1000</td>
<td>~100</td>
<td>~10K</td>
<td>~1000</td>
<td>~100</td>
</tr>
<tr>
<td><strong>Peak Power Consumpt’n</strong></td>
<td>&gt;2W</td>
<td>&gt;2W</td>
<td>&gt;2W</td>
<td>~1W</td>
<td>~1W</td>
<td>&gt;1W</td>
<td>&lt;1W</td>
<td>&lt;1W</td>
</tr>
<tr>
<td><strong>Standby Power</strong></td>
<td>Tens of mW</td>
<td>Tens of mW</td>
<td>Tens of mW</td>
<td>Single-digit mW</td>
<td>Single-digit mW</td>
<td>Single-digit mW</td>
<td>&lt;1mW</td>
<td>&lt;1mW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>~100</td>
<td>~100</td>
<td>~40</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boot Support</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>User Configurable Memory</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Software Support</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Adoption Trend</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **ATA**: 200/400, >500, >500, ~40, ~40, ~100, ~40, ~100, >1W, <1W
- **ACHI (ATA)**: 200/400, >500, >500, ~40, ~40, ~100, ~40, ~100, >1W, <1W
- **NVMe**: 500, >500, >500, ~20, ~20, >1W, <1W
- **SCSI**: 1000, >100, >100, ~100, ~100, ~40, ~20, ~100, ~100, ~40, ~20
- **ATA**: 15K, ~10K, ~1000, ~100, ~40, ~20, ~100, ~100, ~40, ~20
- **NVMe**: 3K, ~1K, ~1000, ~100, ~40, ~20, ~100, ~100, ~40, ~20
- **ATA**: Tens of mW, Tens of mW, Tens of mW, Single-digit mW, Single-digit mW, Single-digit mW, <1mW, <1mW
- **ATA**: No, No, No, No, No, No, No, Yes
- **ATA**: No, No, No, No, No, No, No, Yes
- **ATA**: ☺, ☺, ☺, ☺, ☺, ☺, ☺, ☺
- **ATA**: 🔽, 🔽, 🔽, 🔽, 🔽, 🔽, 🔽, 🔽
Needs for Customization
Designed for Demanding Conditions

- Long product lifetime in the field
  - Extended endurance and reliability requirements
- Data retention at high storage temperature
- Power loss protection
  - Also for crash dump application, separate from main storage application
- High shock tolerance
  - Transportation, defense, military
- Thermal constraints
  - Industrial temp (-40°C to 85°C) for MLC needed
- Use Case:
  - For telecom, NEBS compliance is a costly, major undertaking
  - Once the equipment is certified and deployed, it is in the field for a long time
Robust Industrial Designs Yield Higher Reliability

- Robust design tools are a must
  - Signal integrity
  - Thermal management
  - Robust mechanical design

Cadence Allegro PCB layout simulations
Matching Application Needs

• Workload
  – Mostly read or write
  – Sequential or random access more important
• Startup time and specific latency requirements
• Power and thermal constraints

→ Driving the need for FW optimization and customization
Custom Requirements

• Data Security
  – Data encryption – AES crypto engine
  – Secure Erase
  – e.g. gaming application, military/defense

• Custom Burn-In
  – MLC Flash endurance screening

• Device Health Reporting
  – P/E cycle count
  – Reserved block count
Product Life-Cycle Mismatch

• Mismatch in product life cycles among NAND, controller and end application

NAND Process Nodes
~18 months
Product Life-Cycle Mismatch

- Mismatch in product life cycles among NAND, controller and end application

![Graph showing mismatch in product life cycles among NAND, controller and end application.](image)

- NAND Process Nodes
  - ~18 months

- Controller Life-Cycle
  - Typically 2 NAND generations

- Time

- Volume
Product Life-Cycle Mismatch

- Mismatch in product life cycles among NAND, controller and end application

**NAND Process Nodes**
- ~18 months

**Controller Life-Cycle**
- Typically 2 NAND generations

**Embedded Application**
- Life-Cycle: >5 yrs.

**Typical Life-Cycles**

<table>
<thead>
<tr>
<th>Application</th>
<th>Life Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>&gt;5 yrs.</td>
</tr>
<tr>
<td>Servers</td>
<td>&gt;5 yrs.</td>
</tr>
<tr>
<td>Networking</td>
<td>&gt;5 yrs.</td>
</tr>
<tr>
<td>Industrial</td>
<td>&gt;10 yrs.</td>
</tr>
<tr>
<td>Medical</td>
<td>&gt;10 yrs.</td>
</tr>
<tr>
<td>Telecom</td>
<td>&gt;10 yrs.</td>
</tr>
</tbody>
</table>
Managing Product Life-Cycle

Considerations:

• Longevity of interface technology and software backward compatibility

• Supplier’s product life-cycle management strategy, technology migration path
  – Form, Fit, Function
Solutions for Embedded Storage
Embedded Storage Solutions Tailored for Verticals

Servers Storage

USB

mSATA

SATA Slim

NVDIMM

Industrial Medical

Telecom Networking

M.2

eMMC
Embedded Storage Solutions Tailored for Verticals

Servers Storage

Automotive

Industrial Medical

Telecom Networking

SSD

eMMC

SD
Embedded Storage Solutions Tailored for Verticals

- Servers Storage
- Automotive
- Industrial Medical
- Telecom Networking

- CFast
- mSATA-mini
- CF
- eMMC
- SD
- eUSB
- SSD
- microSD
- μSSD
Embedded Storage Solutions Tailored for Verticals

Servers Storage

Automotive

Industrial Medical

Telecom Networking

SSD

mSATA-mini

eUSB

SATA Slim

mSATA

SD

eMMC
Take-Aways

• Flash storage for embedded applications is taking off to double by 2016

• Leveraging standards and solutions driven by consumer applications

• Design considerations and product customization specific to embedded applications

• Diverse solutions for different market segments

Make the right choice for your application
QUESTIONS?
Thank You