Designing Enterprise SSDs with Low Cost Media

Jeremy Werner
Director of Marketing
SandForce
Everyone Knows…

• Flash is migrating:
  ► To smaller nodes
  ► 2-bit and 3-bit MLC

• $/GB decreases due to increasing transistor density (lower geometries)
  ► Addressing demands of the consumer market

• Major trade-off in terms of reliability, endurance, and performance

• Yet more than ever organizations want lower cost flash in the Enterprise Computing market!

Source: Gartner June 2011
Stepping up to the challenge

- Enterprise SSD Technology enable analyst’s forecasted growth
- Full system ASIC and FW co-design is critical
- Advanced critical, required capabilities including:
  - Advanced Flash ECC
  - RAID-like protection
  - Soft Error protection
  - End-to-End CRC
  - Native non-512 Byte sector support
  - Write Reduction Technologies
  - Power-Fail Protection
  - Consistent Low Latency Performance
  - Temperature Intelligent Technology
  - Predictive Failure Capabilities
Advanced Flash ECC

- Today’s State of the art
  - High Powered BCH
  - Data Randomizer
  - Advanced Read-Retry
  - 512Byte and 1KByte code words

- 2013 Requirements
  - Soft and Hard LDPC (Low Density Parity-Check)
    - 10-100x more correction than traditional BCH
  - DSP-Aided Intra-cell and Inter-cell equalization
  - Adaptive code-rates
  - 2KByte code words

Example LDPC code using Forney's factor graph notation

Soft and Hard LDPC and DSP Challenges

• Enables remarkable bit error correction capabilities ~10% RBER but design challenges include:
  - Adequate Error Floor (10^-16 UBER)
  - Efficient Iteration Requirements (1-1.5x)
  - Very high throughput (>2GB/s)
  - Low Latency (<2us)
  - Low Power (Zero-power idle, 50-100mW active)
  - Small silicon footprint
  - Flexible code rates (BOL v. EOL adaptive)
RAID-like Protection

• SandForce introduced RAISE in 2009
  ▶ Redundant Array of Independent Silicon Elements
  ▶ Page and Block level protection against uncorrectable errors
  ▶ RAID-5 like protection (single uncorrectable per stripe)
• In 2013 more advanced RAID-like protection will be needed
  ▶ Multi-die failure
  ▶ RAID-6 like protection (two uncorrectable per stripe)
  ▶ Advanced internal rebuild capabilities
End-to-End Data Protection

- Data Protected at System Level by End to End Data Protection
  - Although older concept not universally adopted yet
  - T10 DIF (520-Byte Sectors) is the most common for SCSI devices
    - Also proprietary solutions
      e.g. 524, 528 Byte
    - 4K + DIF sectors coming
  - NVM Express has Data Integrity support for PCIe SSDs
- Critical to support the larger sectors without performance or ECC loss
- Also must handle fancy pattern generation to account for multiple heterogeneous host and initiator infrastructure

Source: T10 [http://www.t10.org/ftp/t10/document.03/03-224r0.pdf]
End-to-End CRC

• End-to-End Cyclic Redundancy Check (CRC) must be supported for Enterprise SSDs
  ▶ Pre-requisite to prevent silent data corruption
  ▶ Apply and Remove as early as possible
  ▶ Manage the remainder and handle errors

• A Good CRC solution is LBA seeded
• Data Protection inside the drive
  ▶ Can protects Flops in the data path from SER and other errors
Power Fail Protection

- Guaranteeing data integrity is difficult
  - MLC much harder than SLC
  - Lower Page Corruption is a gotcha
    - Getting more complex – more than 1 page can be corrupted
- Absolutely Required in Enterprise applications
  - Previously written data
  - Data in flight
- Use backup power to protect against sudden power loss
- Designing for no DRAM simplifies the solution
- Monitor supercap health to ensure capability

Source: Electronic Design: MLC Challenges Mobile-Entry Barriers
Mixed-I/O Latency Distribution

- Average Latency = OIO/IOPS (simple)
- The latency distribution is critical for Enterprise QoS
- MLC/3-bit harder to guarantee read latency
  - Longer program + erase times
  - More ECC recovery events
Data Retention

- The Arrhenius model is an industry standard for estimating data retention life of floating gate technologies
- Used to derive the acceleration factor between a stress temperature and a use condition
  - Can be used to de-rate data retention
- Acceleration Factor Equation (AF):

\[
AF = e^{\left(\frac{E_a}{k} \times \left(\frac{1}{T_{Use}} - \frac{1}{T_{Stress}}\right)\right)}
\]

- \( E_a \) is the intrinsic activation energy (eV)
- \( k \) is Boltzmanns’ constant
  - \( 8.617 \times 10^{-5} \) eV/K
  - \( K = -273.16 \)° C
- \( T_{Use} \) = use temperature (K)
- \( T_{Stress} \) = stress temperature (K)

Data Retention Continued

• The Acceleration Factor highlights the potential differences between nominal and hot operation

• At 70° Celsius – Retention may be <1/35th of Retention at 40° Celsius
  ▶ 1 year becomes 10 days!

• Dynamic Read Scrub acts like a Flash refresh to ensure data retention when power is on

• Temperature aware technology can mitigate temperature and aid in optimizing management algorithms
Predictive Failure Analysis

• More intelligent large scale data centers, public and private cloud implementations are changing the classic paradigm
  ▶ Failures not catastrophic because of architectural data redundancies (country, data center, rack, server, drive)
• Willing to run way past warranty or specification
  ▶ Must be able to accurately predict drive failure
• Requires diagnostic, statistics and reporting features never capable on HDDs
  ▶ Up to the second reporting provides users a means to predict a failure
• Trade warranty liabilities for lower TCO and more intelligent usage model
Design for Media Flexibility

- Support for many flash devices is critical
  - Component availability fluctuates greatly
  - Early node support means lower cost and longer life!
- Every NAND is different
  - Makes solutions complex to design and qualify!
    - Page/Block size
    - Page/Block count
    - Spare Area
    - Planes
    - Commands
    - Interfaces
    - Reliability characteristics
    - Multi-LUN support
    - Performance/Response Times
    - Etc. etc. etc.

Visit the SandForce Exhibition Booth

World-class reliability, performance, & power efficiency for enterprise, client, and industrial SSD applications

- Visit us at booth #407 to see our DuraClass™ technology in action with the latest 24nm MLC flash technology and new non-HDD form factors like the JEDEC MO-300

- Stop by to enter our **free drawings** to win one of many different SandForce Driven SSDs from Corsair, Kingston, OCZ, OWC, Patriot Memory & Viking
  - Free drives given away approximately every 30 minutes!

- See other SandForce Driven™ SSDs in our partners’ booths

- Visit the many SandForce Trusted™ SSD ecosystem members