Embedded SSD
Product Challenges and Test Mitigation

Flash Memory Summit, 2015

ATP Electronics, Inc.

Overview

- Embedded SSD Product Challenges
  - The Factor of Industry Focus & Validation Challenges
  - The Factor of Memory Transition
- Embedded SSD Mitigation
  - Full Scale Testing – Product Development
  - Full Scale Testing – Mass Production

The Factor of Industry Focus & Validation Challenges

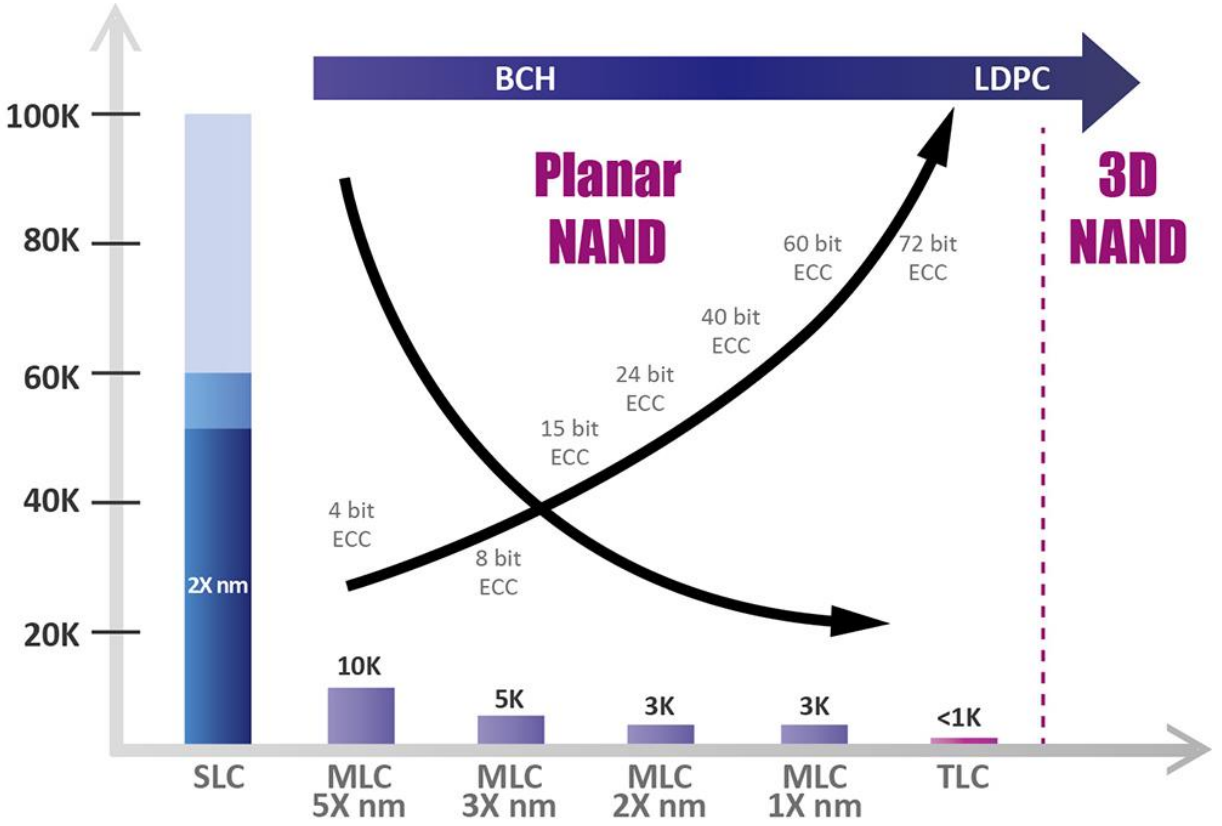
- NAND Industry Focus
  - Trend Controller / NAND Design:
    - Higher ECC requirements and other NAND controller requirements such as data randomization and Read Retry/Recovery Functions
    - Focus on maximizing endurance/cycling
  - Trend / SSD Level:
    - The cost advantages of die shrink with progressively higher densities to maintain ASP
    - Focus on enterprise and client usage models

The Factor of Industry Focus & Validation Challenges

- Less attention to ….
  - Escalation of validation costs on newer process node
    - Change of reliability characteristics -> wider test coverage due to added variables, larger sample siz, longer testing periods, attention to lower industry attention areas, especially ***data retention***
    - Maintained production level screening system for DPM stability

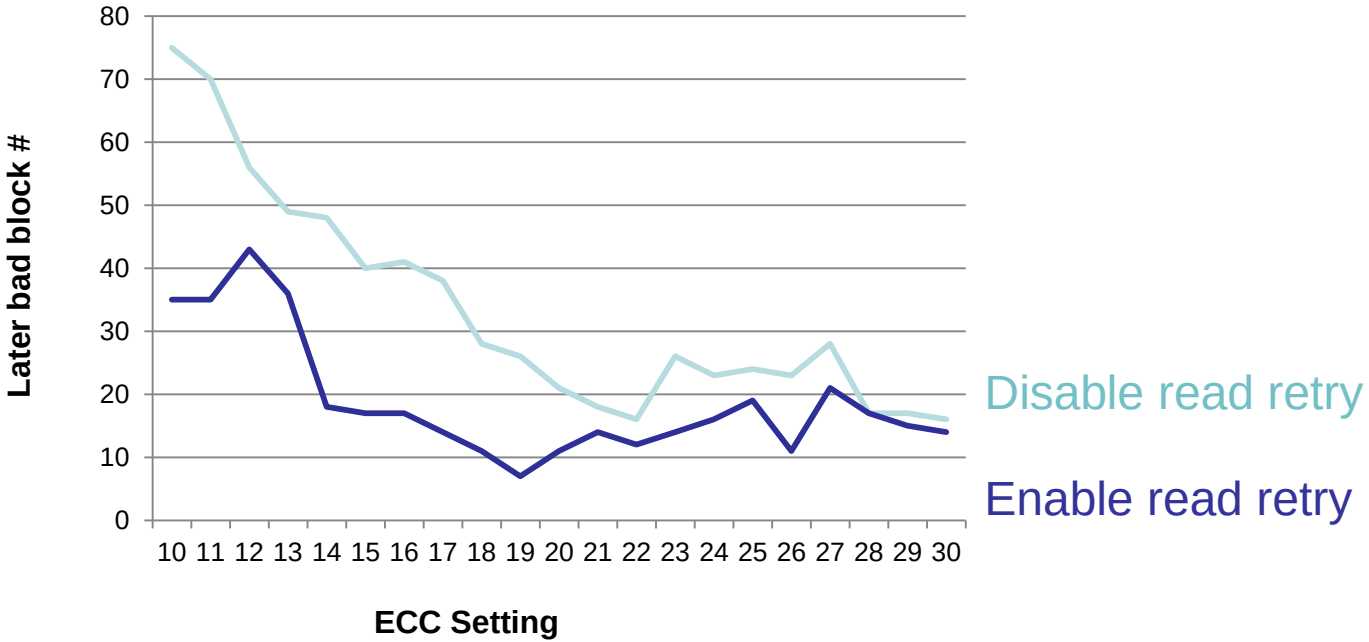
The Factor of Memory Transition

- Reduce Endurance and Increase ECC requirement



The Factor of Memory Transition

- Indispensable Read Retry Function



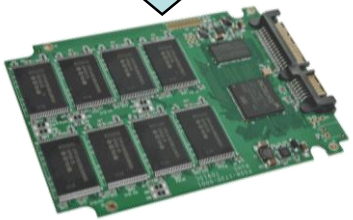
Technology Migration and Consistency in Performance

Page/Block Sizes

(Average 16K/page MLC)

Larger Density Per Die

(128Gbit Mainstream)

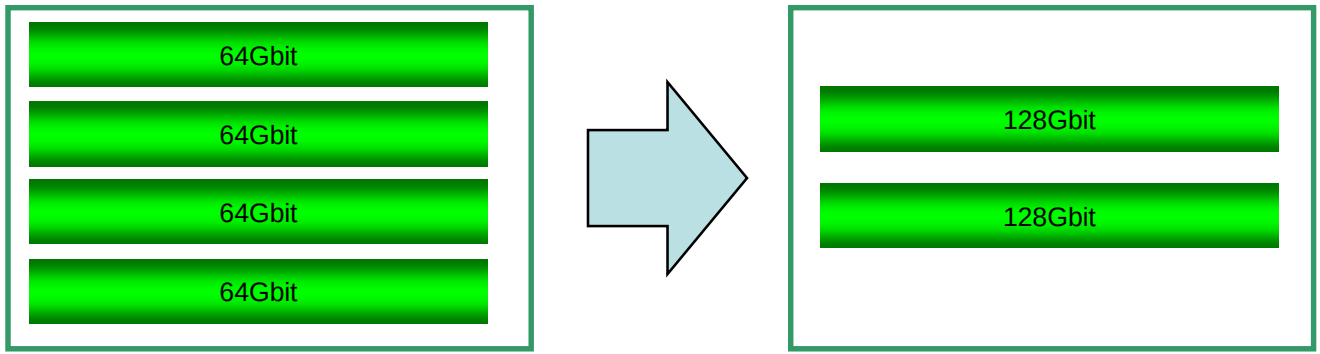


(Average 2.5” SSD Density)

Technology Migration and Consistency in Performance

Fewer Die Per Same Density SSD

20nm 32GB Embedded SSD



16nm 32GB Embedded SSD

Technology Migration and Consistency in Performance

Embedded SSD Tendencies

Typically Smaller Density Requirements

Often Smaller file sizes data transfers

Workload Tendencies Toward Random Write

Technology Migration and Consistency in Performance

Typically Smaller Density Requirements

Often Smaller file sizes data transfers

Workload Tendencies Toward Random Write

Risk of Higher WAI and Endurance Issues

Risk of Performance Erosion

Risk of Power Failure

Level 0
No Concern

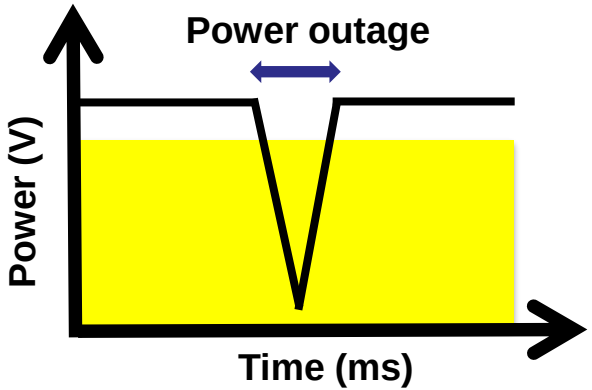
- **Lost Unsaved data**

Level 1
How Important is Your Saved Data?

- **Lost Unsaved & Saved data**

Level 02,03
Fatal/ Lost All Data or Drive not recognized

- **Lost File Allocation Table**
- **Disk cannot be found**



Technology Migration and Consistency in Performance

- Mitigation on Product
  - Overprovisioning
    - Maintained user space with larger on board NAND usage
  - Multi-plane NAND
    - 2 plane and now 4 plane organized NAND
  - Utilization of controller cache
    - Firmware optimized per usage model
  - Firmware optimization by usage model
    - Auto-scan, auto-refresh, early refresh algorithms in addition to traditional wear leveling

Embedded SSD Mitigation: Test Area Deep Dives

IC/SSD Validation

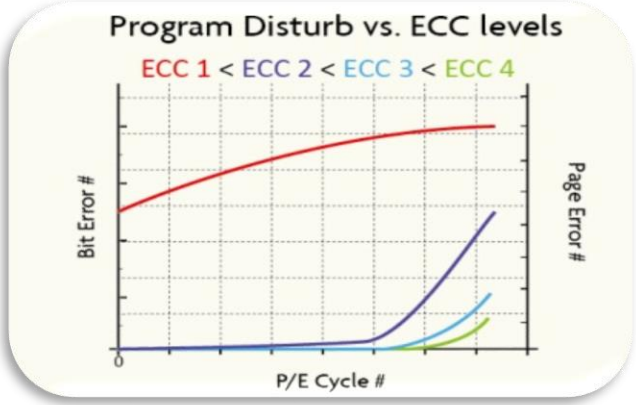
- Ensuring the reliability & function of new NAND die + SSD

Mass Production

- Screening out defects & assuring complete reliability at scale

Mitigation: Full Scale Testing (SSD Validation)

- IC Level Test, Confirmed at SSD Level
  - Reliability characteristics (Endurance, Read Disturb, Data Retention) over *wide temperatures, and Cross temperature*
  - Set up spec, criteria and features for SSDs



Mitigation: Full Scale Testing (SSD Validation)

- SSD Level Test (1)
  - Performance: Lower/middle densities and a lower CE count for embedded/industrial application SSDs.
  - Endurance: NAND trending continues towards larger page size (8K/16K) and embedded/Industrial usage models are often utilizing much smaller file transfers. This can result in a very different write amplification factor which affects the endurance of the SSD.

Mitigation: Full Scale Testing (SSD Validation)

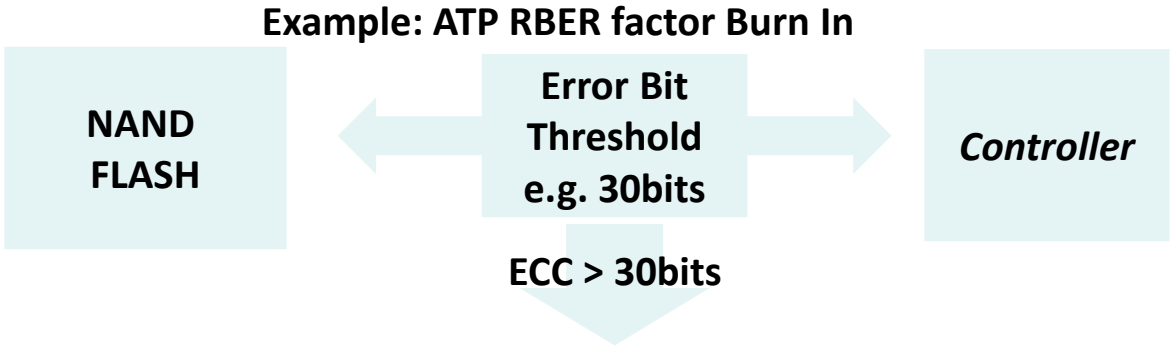
- SSD Level Test (2)
  - Power Fail Factors
    - Stand-alone HW solution, Industrial grade capacitors w/o degradation or flammability concern
  - Power Cycling RDT
    - Sudden, targeted power-off in write/erase operations
    - Multiple test patterns & Random power off delay timing
  - Power On/Off Test
    - Simulate sudden power off in read operations (OS boot-up application)

Mitigation: Full Scale Testing (Mass Production)

- Reliable and scalable MP validation
  - Proper production level screening mechanisms to ensure quality
- Challenges
  - Trade off between SSD production burn in time versus operational efficiency
  - Variance of NAND RBER (Raw Bit Error Rate) and ELFR (Early Life Failure Rate) as process matures
  - Variance in the same factors by wafer production lot / date code

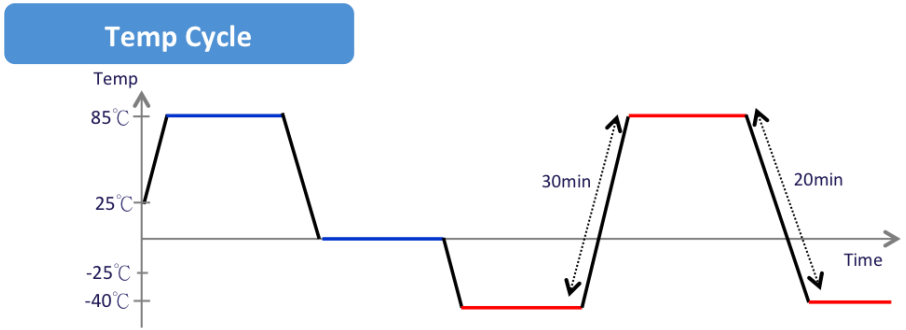
Mitigation: Full Scale Testing (Mass Production)

- Mitigation: Efficiency in Test
  - Capability to utilize intelligent production level test based on NAND characteristics rather than pure brute force copy/compare



Mitigation: Full Scale Testing (Mass Production)

- Mitigation: Efficiency in Test
  - Capability to utilize acceleration factor of temperature during burn in
  - Experience building to further optimize test over volume and process mature



Higher Temperature: Burn in Acceleration Factor
Temperature Cycling: Production/Assembly Quality

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