



New Strategies to Overcome 3bpc Challenges

Controller's Perspective

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Technologies

Executive Summary (1)

- Smaller feature sizes and more bits/cell raise new **Problems:**
 - Far worse statistics
 - Variations over space and time
 - At target cycle counts we obtain BERs of 10^{-1}
 - Consumer products require power efficient and low gate-count controllers
 - Larger Blocks
 - Slower programming times

Executive Summary (2)

- Solution requires a new approach:
 - DSP is required to track device statistics and adapt read/write operation
 - Near optimal power\footprint efficient and adaptive ECC
 - New memory management algorithms

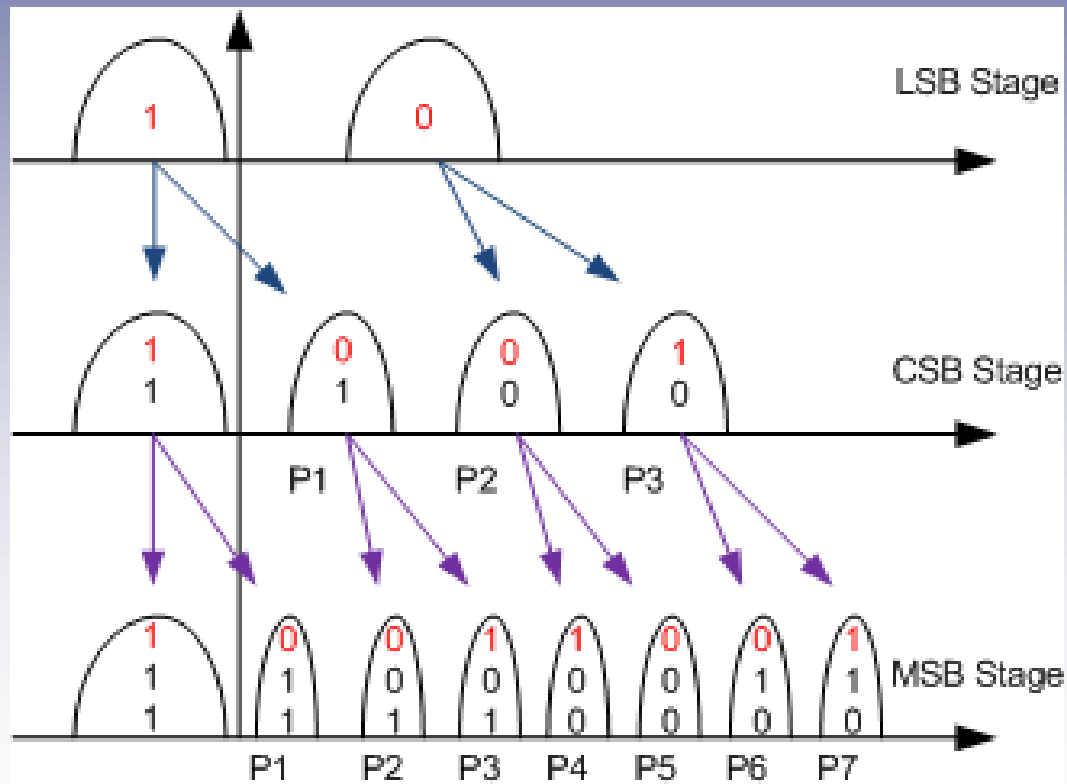
Executive Summary (3)

- Value:
 - 3bpc with 2bpc reliability:
 - few hundreds -> 10K cycles
 - 2bpc with 1bpc reliability:
 - few thousands -> 100K cycles
 - Recover what was previously unrecoverable (BER = 10^{-1})
 - Meet stringent Power/Performance requirements

- Brief overview of 3bpc devices
- Reliability challenges of 3bpc devices
- Memory Management
- Controller example
- Summary

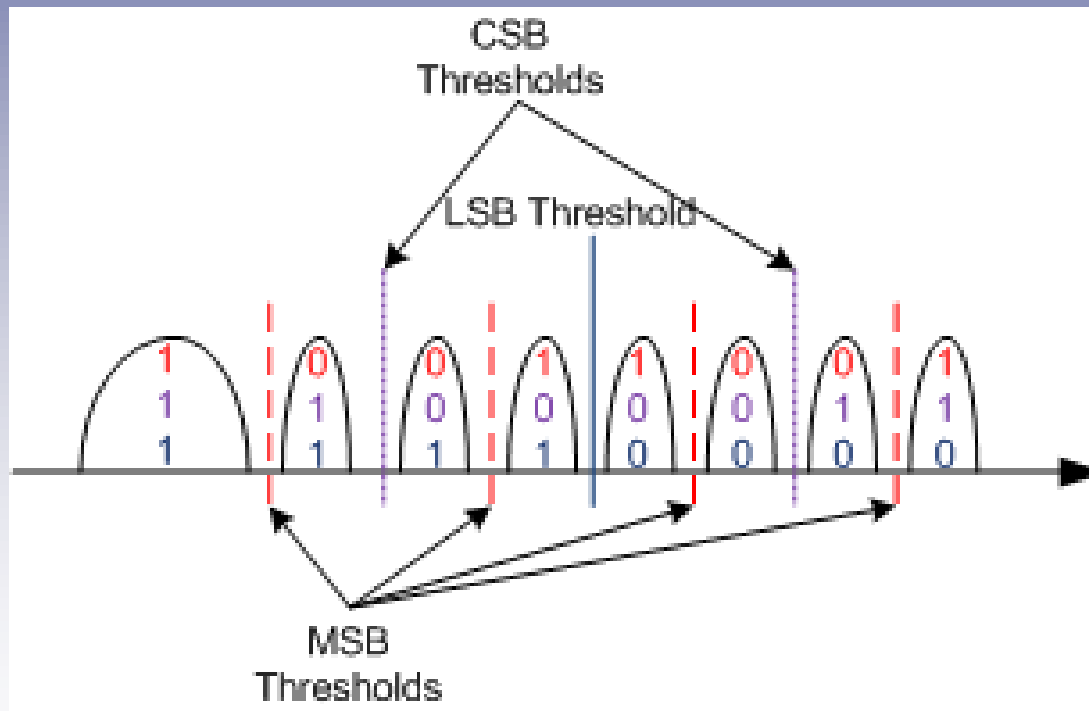
Overview of 3bpc Devices

- 8 Levels per cell
- Each cell contains 3 bits from 3 different pages



Overview of 3bpc Devices (2)

- Read threshold combinations

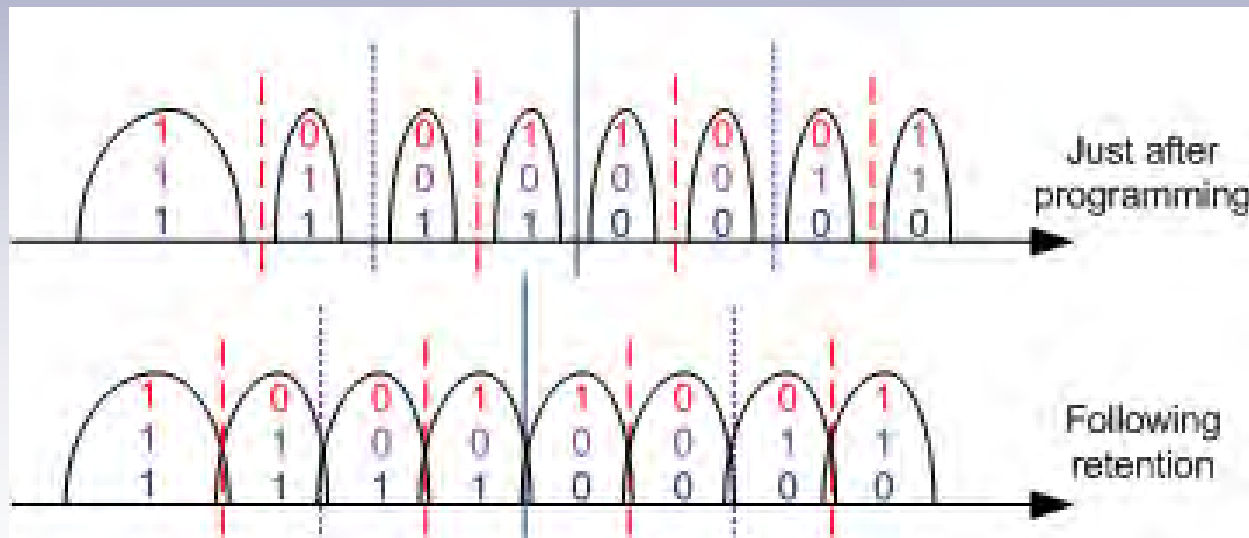


Overview of 3bpc Devices (3)

- Advance interface with Flash device allows controller to modify:
 - Program lobe positions
 - Read threshold positions
 - Other parameters
 - Allowing controller to control programming speed/accuracy
 - Even/Odd pages parameters
 - ...

Reliability Challenges – Retention (1)

- Following Retention
 - Lobes shift
 - Lobes become wider
 - Dependence on cycle count



Reliability Challenges – Retention (2)

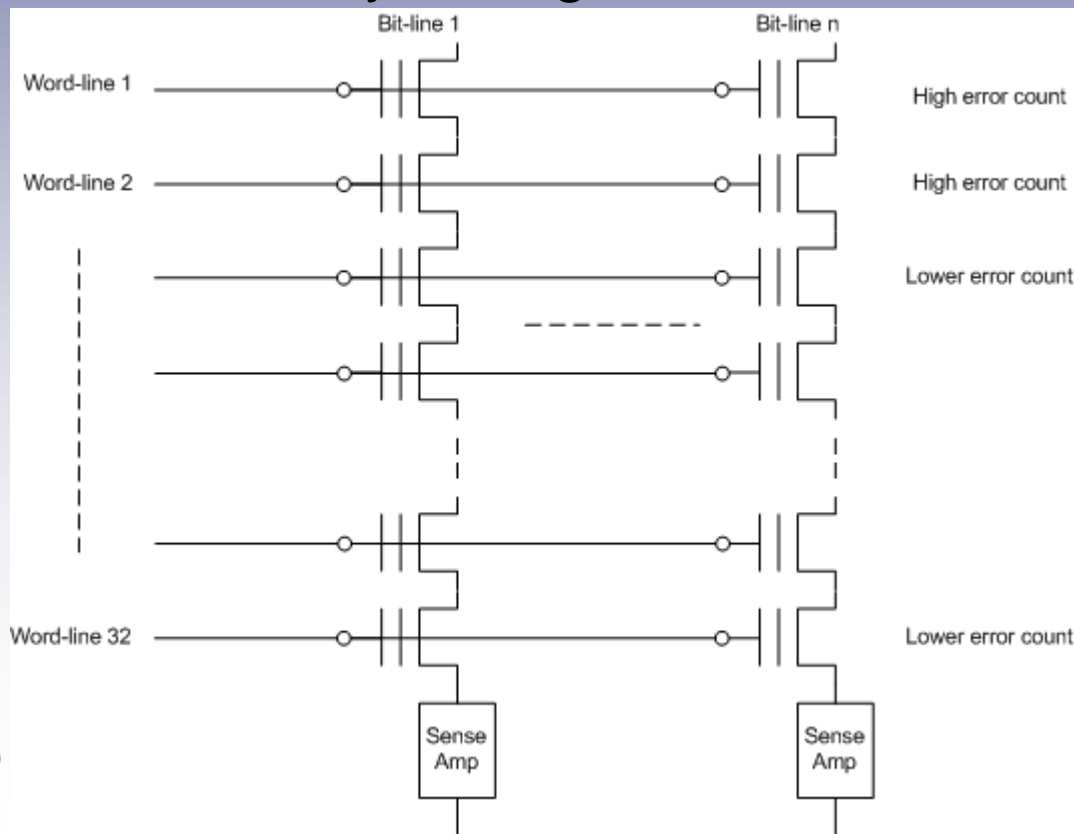
- Implications:
 - Using the same set of thresholds before and after retention is a bad idea
 - The expected error count after retention is expected to be much worse than in 2bpc and SLC devices

Reliability Challenges – Retention (3)

- Solution: DSP+ECC
 - Adaptive read threshold positioning
 - Adaptive programming
 - Blind read threshold positioning
 - Efficient threshold tracking
 - Manage history of thresholds
 - Obtaining soft information
 - Powerful ECC capable of performing both hard and soft decoding

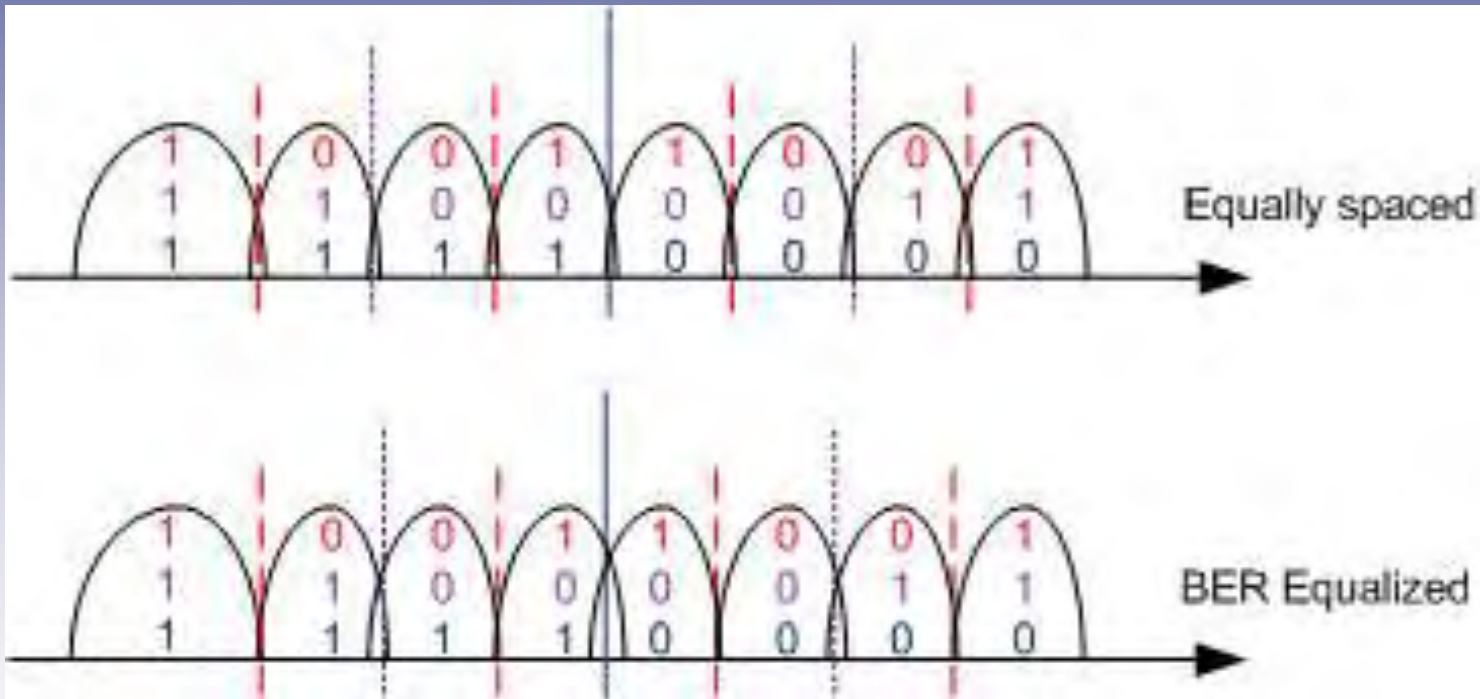
Reliability Challenges – Variations (1)

- Different regions within a Flash device exhibit different reliability
 - Error counts may change across word-lines



Reliability Challenges – Variations (2)

- Number of errors depends on page type

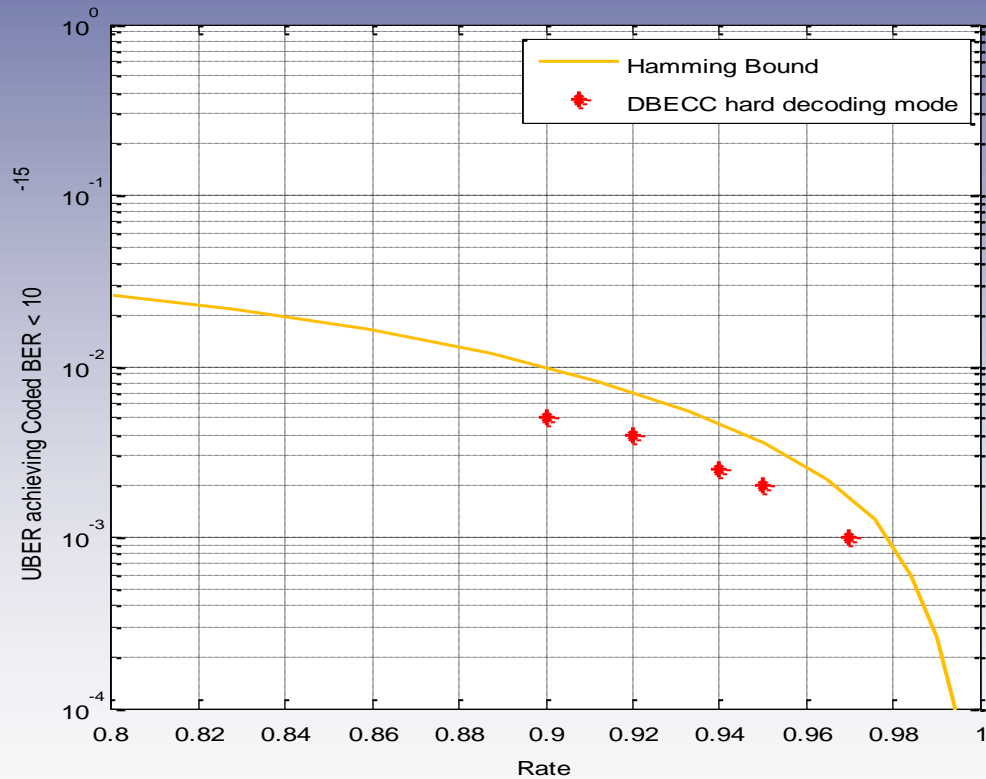


Reliability Challenges – Variations (3)

- Solutions for handling variations:
 - Powerful and lean Encoder / Decoder capable of variable coding rates
 - Encoding such as to average errors across different areas
 - Equalize BER
 - Optimize robustness variable code
 - Advanced memory management

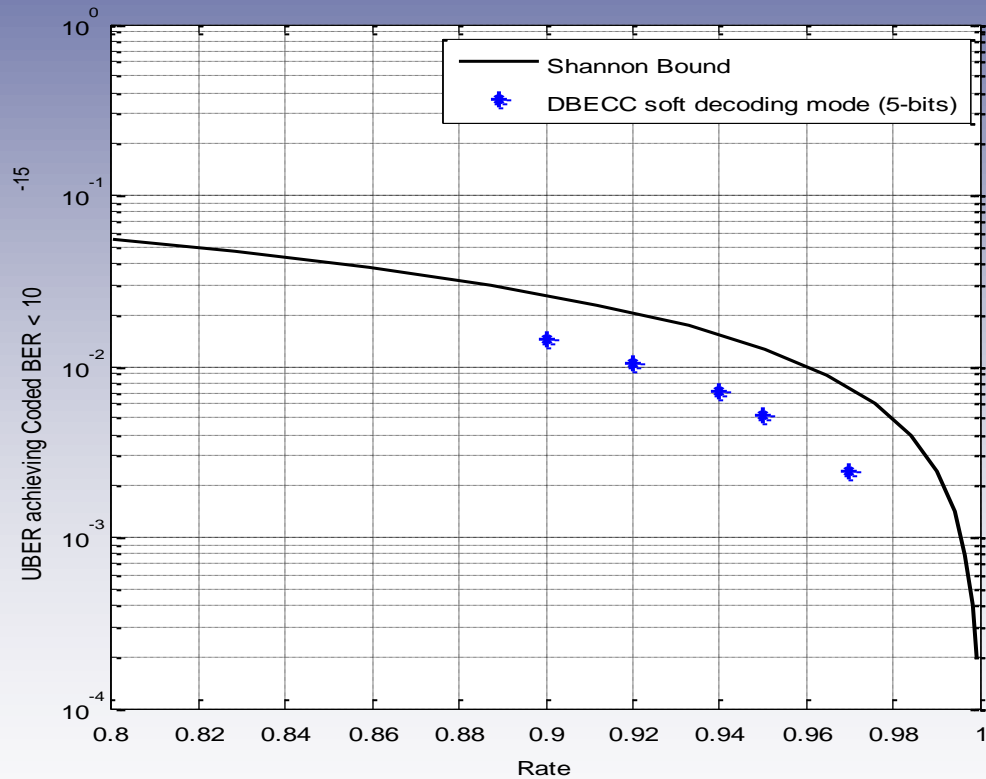
Example: DensBits' Coding System

- Hard Decoding



Example: DensBits' Coding System

- Soft Decoding



Memory Management Challenges (1)

- Large blocks and longer programming times
 - Long block copy times
 - Standard consumer products use management techniques which fail time-out limitations
 - Low IOP rates

- Solution
 - Advance, yet efficient memory management, on a par with that seen in SSDs
 - Accelerated and adaptive programming relying on advanced reliability solution

3bpc Controller: DensBits' DB3609

- DB3609
 - Supports 2 / 3bpc devices
 - SD / eMMC interface
 - Endurance + Retention with 3bpc devices: 10K cycles
 - Class 4 / 6

- www.densbits.com

Uncovered topics

- Cell Coupling
- Adaptive Programming
- Effective wear-leveling
- Managing variable rates
- Managing thresholds
- Power cycling in 3bpc
- ...

- Handling 3bpc devices with high reliability requires a fresh approach:

Management + DSP + ECC

- Unique and advanced design is required to meet power and cost requirements
- Obtaining 2bpc reliability and performance is possible



Thank You