LDPC Code Rate Adaptation Methods for NAND Flash

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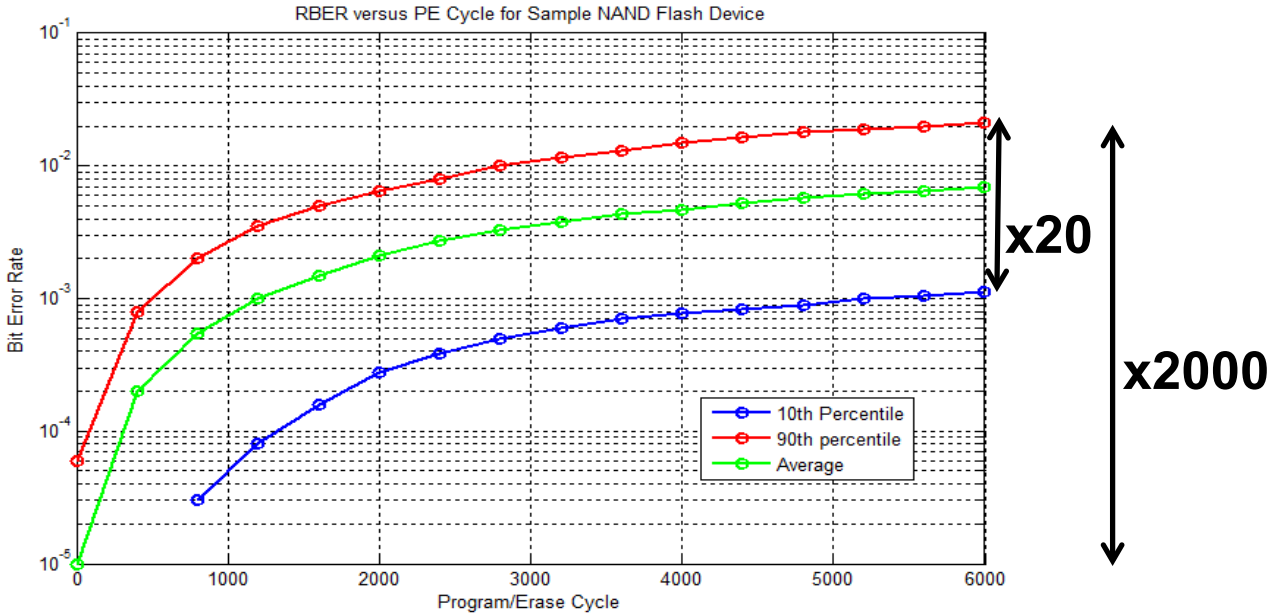
Outline

- NAND Flash Challenges
- Code Rate Selection Methods
  - Puncturing
  - Shortening
  - Custom code rates
- Performance Comparison
- Summary

NAND Flash Challenges

- Raw BER Factors
  - NAND type (QLC,TLC,MLC,SLC)
  - Vendor selection, spare size
  - Page-to-Page variations
  - PE cycle
  - Retention time
  - Product type (Enterprise or Commercial)
  - Future NAND technology disruptions
- Multiple BER regimes within a single Controller

Page-to-Page Variation

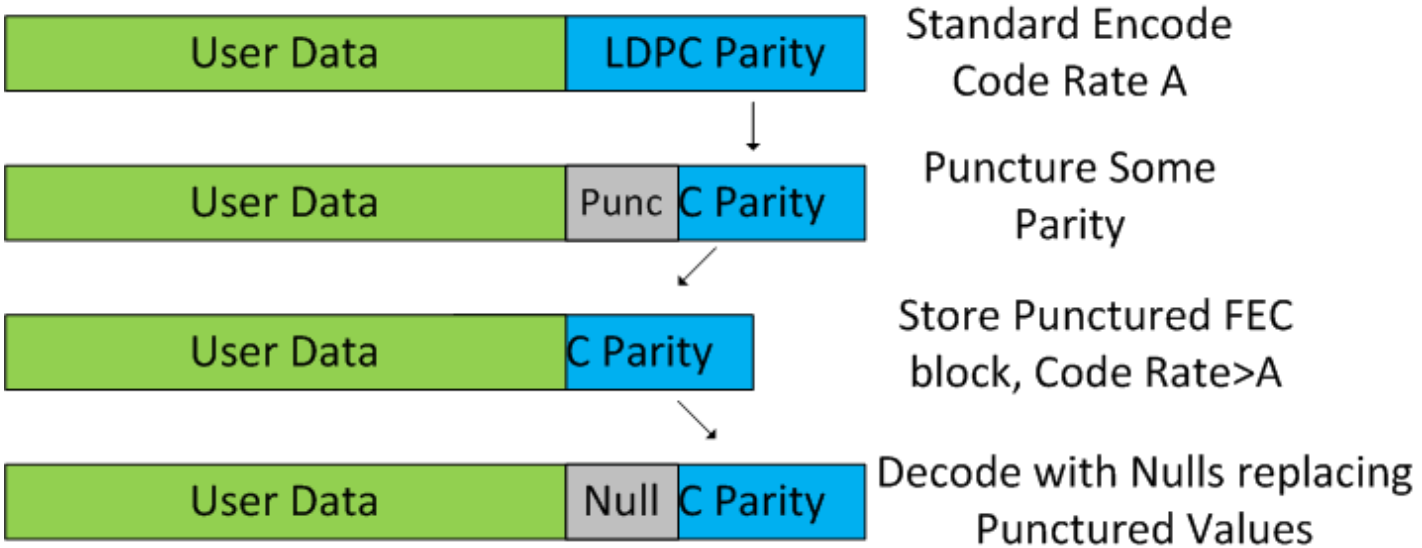


RBER of pages at same PE cycle - 20x difference
RBER over life-time - up to 2000x difference

Code Rate Selection

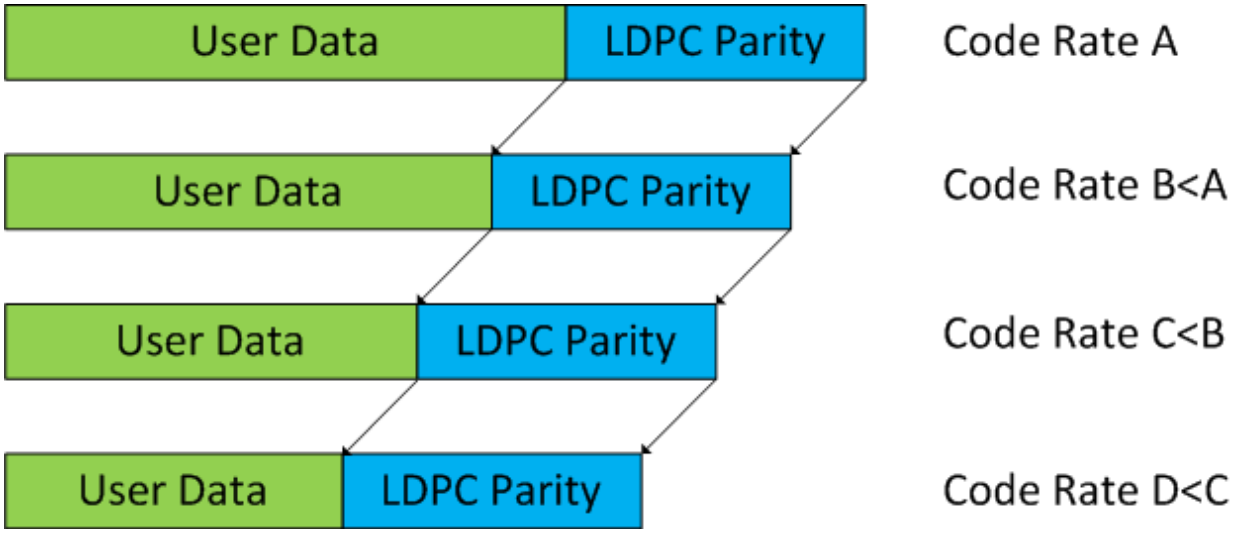
- Single low code rate protects all pages
  - Used parity is too large
  - Drive size is smaller, write-amplification is higher
- Single high code rate reduces parity overhead
  - Many pages fail as device ages
- Multiple code rate ECC solution required

Puncturing



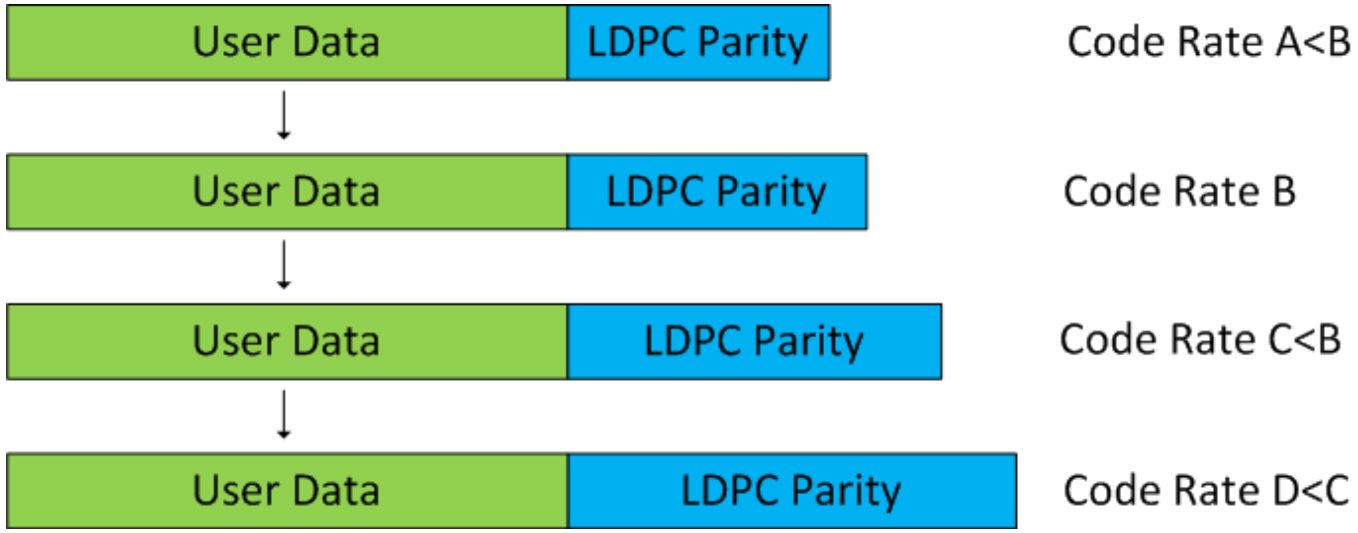
Remove some parity before writing to flash to increase code rate.

Shortening



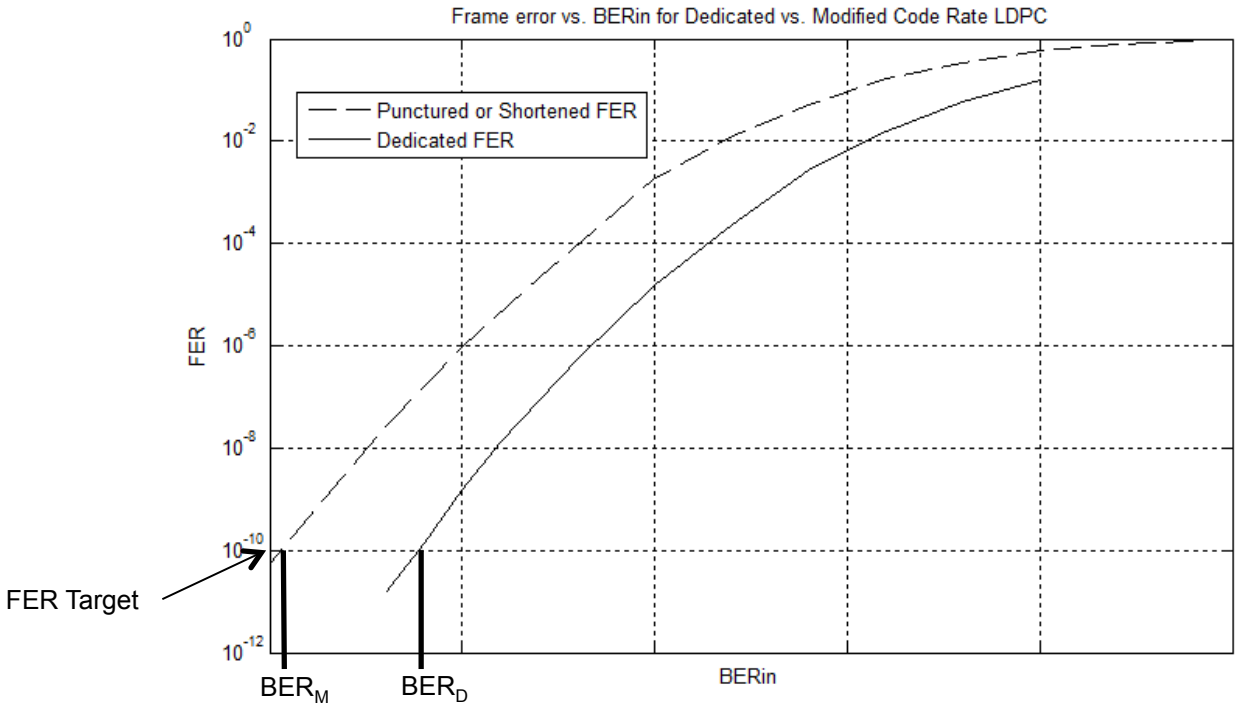
Leave parity fixed while decreasing data size to reduce code rate.

Custom Code Rates



Leave data size alone and vary the amount of LDPC parity to select code rate.

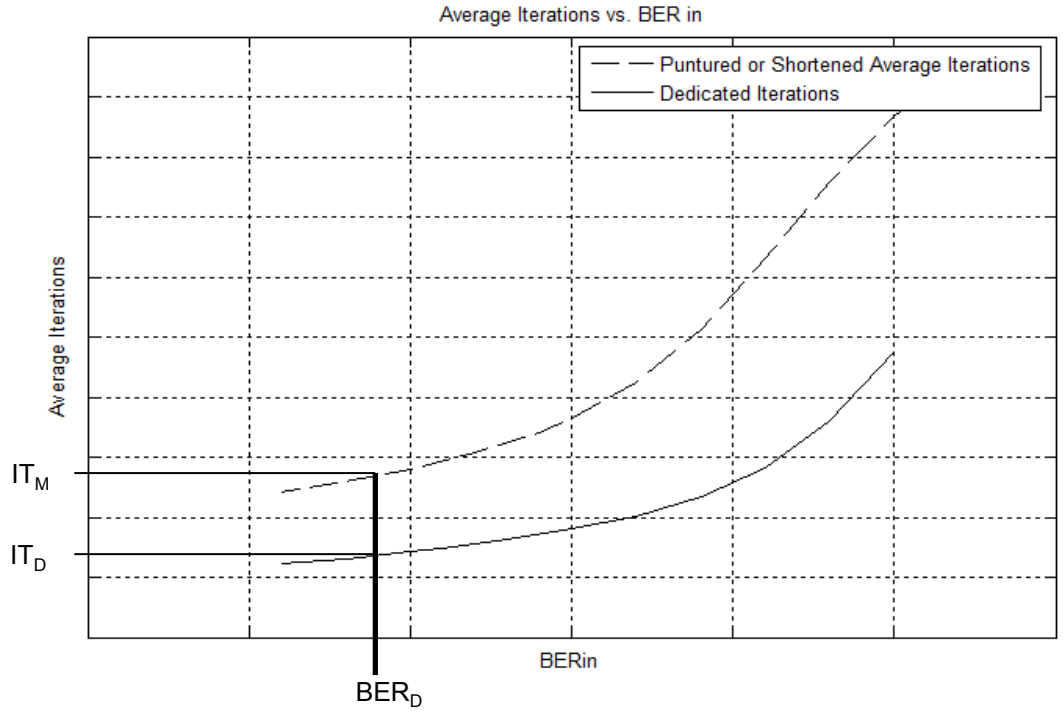
Performance Comparison (ECC)



Define
Relative Correction
Performance

$RCP = BER_D / BER_M$

Performance Comparison (Iterations)



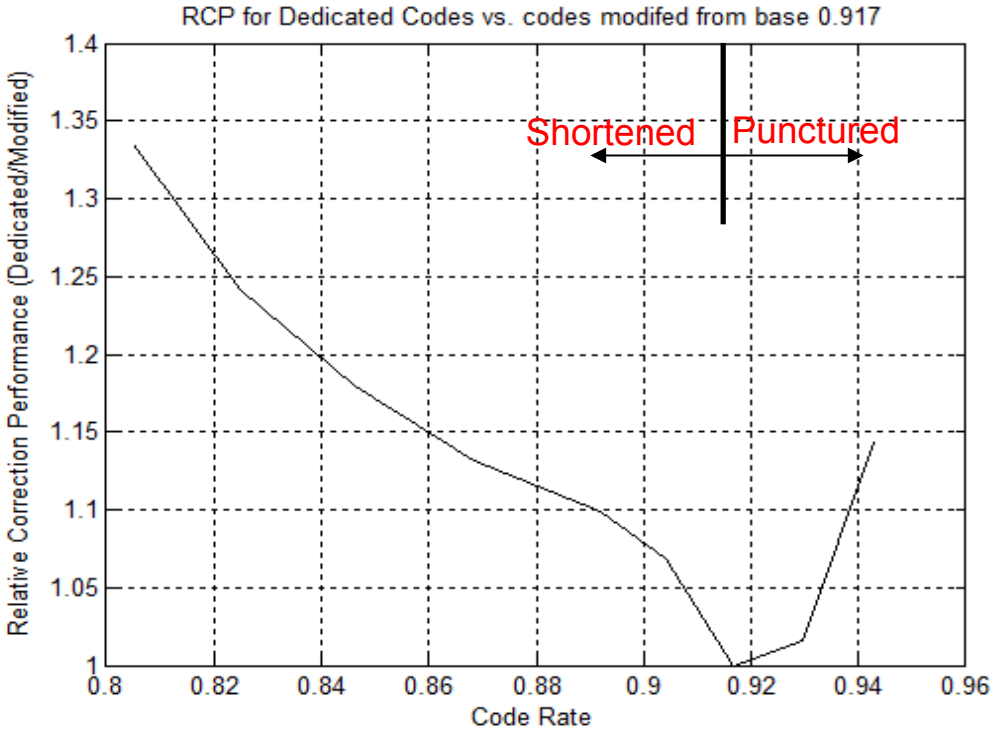
Define
Relative Iteration
Performance

RIP = IT_D / IT_M

Outline of Experiment

- Dedicated Codes
  - Design several custom codes between CR=0.8 and 0.95
- Modified Codes
  - Start with native code at CR=0.917
  - Match CR to dedicated codes
  - Use shortening to decrease CR and puncturing to increase CR
  - Compare RCP and RIP

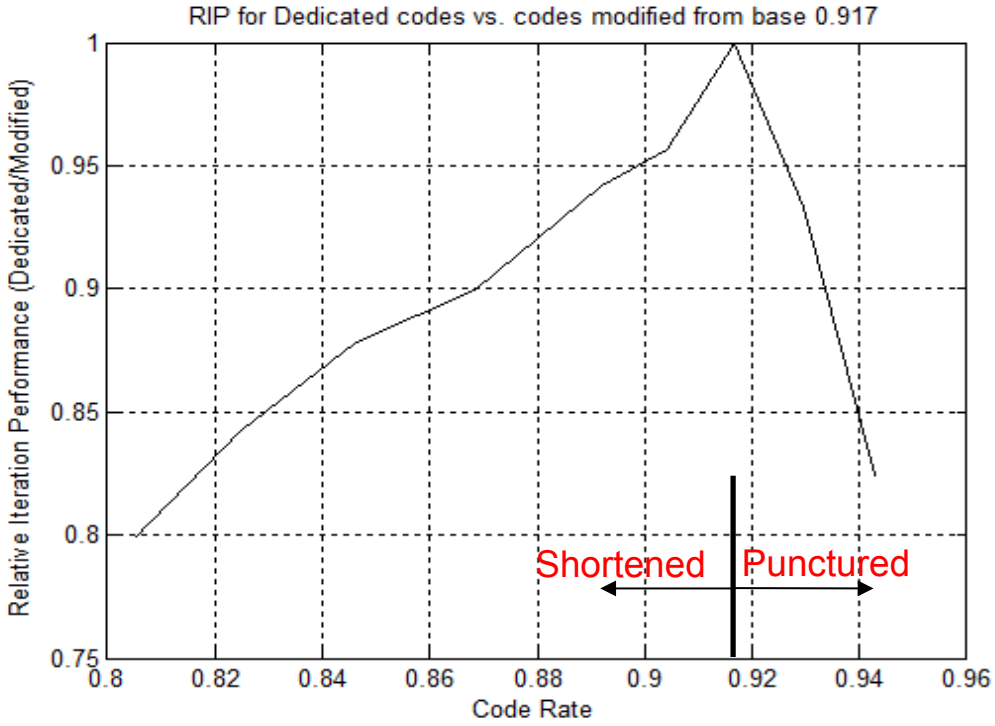
FER Results



Dedicated codes improve error correction performance by up to 30% compared to Modified codes.

Small Modifications to CR of +-0.01 do not significantly alter Error Correction Performance.

Average Iteration Results



Dedicated codes have up to 20% reduction in Average Iterations compared to modified codes.

Small Changes to CR of +-0.01 do not significantly alter Average Iterations.

Summary

- NAND Flash Devices require flexible code rate selection
- The further a code is moved from its native state the worse the error correction performance and the higher the power consumption
- Dedicated codes exhibit up to 30% better error correction performance and 20% better iteration performance compared to punctured or shortened codes.

Thank You!

- Questions