Program Interference in MLC NAND Flash Memory: Characterization, Modeling, and Mitigation

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Flash Challenges: Reliability and Endurance

- **P/E cycles (provided)**
  - A few thousand

E. Grochowski et al., “Future technology challenges for NAND flash and HDD products”, Flash Memory Summit 2012
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![NAND Flash Memory Endurance Properties](image)

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NAND Flash Memory is Increasingly Noisy
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Our Goals:
NAND Flash Memory is Increasingly Noisy

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Model NAND Flash as a digital communication channel
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Model NAND Flash as a digital communication channel
Design efficient reliability mechanisms based on the model
NAND Flash Channel Model

Write (Tx Information) → Noisy NAND → Read (Rx Information)
NAND Flash Channel Model

Simplified NAND Flash channel model based on dominant errors
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- Erase operation
- Program page operation

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Additive White Gaussian Noise
NAND Flash Channel Model

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- Additive White Gaussian Noise
- Cell-to-Cell Interference
- Erase operation
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- Neighbor page program
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- Retention
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- Cell-to-Cell Interference
- Time Variant Retention
- Erase operation
- Program page operation

Write (Tx Information) → Noisy NAND → Read (Rx Information)
Basics of Program Interference

WL<0>  (n-1,j-1)  (n-1,j)  (n-1,j+1)
WL<1>  (n+1,j-1)  (n+1,j)  (n+1,j+1)
WL<2>  

Victim Cell  \((n,j)\)

MSB:6  LSB:0
LSB:3  MSB:4
LSB:1  MSB:2
LSB:0
Basics of Program Interference

![Diagram of memory cells and voltages](image)

- WL<0>, WL<1>, WL<2>
- (n,j), (n+1,j), (n+1,j-1), (n+1,j+1)
- ∆Vₓ, ∆Vᵧ, ∆Vₓᵧ
- MSB:0, MSB:1, MSB:2, MSB:3, MSB:4, MSB:6
- LSB:0, LSB:1, LSB:3

SAFARI DSSC Carnegie Mellon
Basics of Program Interference

What affects cell-to-cell program interference in Flash chips?
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What affects cell-to-cell program interference in Flash chips?
How to accurately model cell-to-cell program interference?
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How to accurately model cell-to-cell program interference?
How to improve flash reliability using the model?
Key Findings and Contributions

- **Methodology:** Extensive experimentation with real 2Y-nm MLC NAND Flash chips
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- Our new read reference voltage prediction technique can improve flash lifetime by 30%
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Today 1:40pm
CSA-2: Memory Systems Session

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