The Innovator in Digital Media - Mtron

Reliability Issues in Flash Memory SSD Design

2008. 10. 20

Young Hyun Bae

MTRON Media Experts

Design Goal of Flash Memory SSD

- High Performance
  - High throughput and short access time
  - Consistent performance against fragmentation and aging
- High Reliability
  - Rugged storage in harsh environments
  - Reliable data retention on various component errors
- Long Endurance
  - Reasonable life-time with limited counts of program/erase cycle
- Low Power Consumption
  - Long battery time on mobile computing devices

Importance of Reliable Design

- User's Expectation for Solid State Drives
  - Rugged storage in any harsh environments
  - More reliable data storage than existing HDD
    - Extremely low user-level bit error rate is required.
  - Sufficiently long life-time as a reliable storage

- Unreliable peculiarities of NAND Flash Memory
  - Unexpected bit errors occur from disturbance problem and data retention problem.
  - Blocks have limited erase/program cycles and can be bad.
  - New technology introduces more unreliable characteristics.

Program Disturbance Problem

- Program Disturbance
  - Memory cells not being programmed in a block can be changed due to high voltage stress.
  - Bit errors can be increased at read operation.

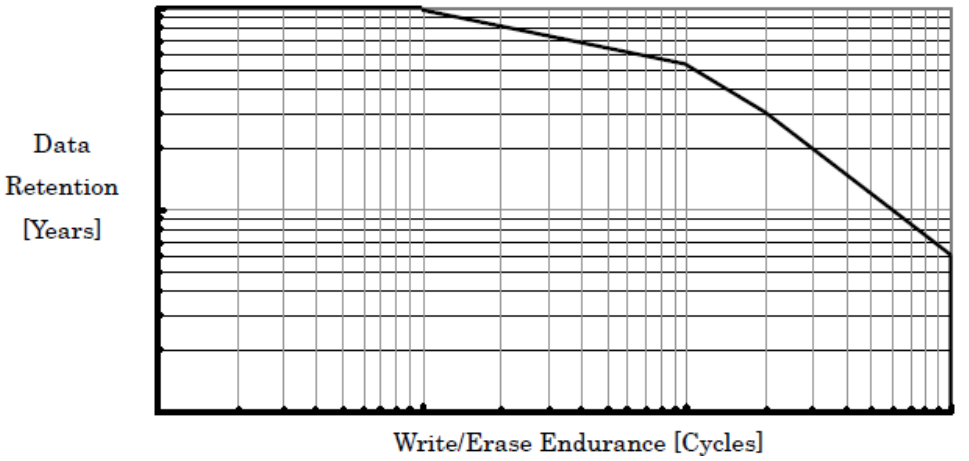
- Solutions to Program Disturbance Problem
  - Reducing program disturbance via restricted page program in a block
    - Sequential order page program
    - Single program on each page
  - Correcting bit errors using ECC mechanism

Read Disturbance Problem

- Read Disturbance
  - Memory cells not being read in a block can be changed due to high voltage stress.
  - Bit errors can be increased after large number of read operation.
- Solutions to Read Disturbance Problem
  - Moving data on some conditions
    - Threshold for read operation counts for a block (approximation using elapsed time after program)
    - Threshold for bit errors by ECC monitoring
  - Correcting bit errors using ECC mechanism

Data Retention Problem

- Data Retention
  - Data in memory may change after a certain amount of storage time.
  - The data retention time is dependent on program/erase cycles.



Source: Toshiba

- Solution to Data Retention
  - Refreshing data by moving on some conditions
    - Threshold for data retention period (program timestamp and elapsed time)
    - Threshold for bit errors by ECC monitoring

ECC (Error Correcting Code)

- The Essential Mechanism for Reliable SSD Design
  - ECC is the primary solution to recover bit errors due to various problems.
  - BCH is more suitable for managing bit errors on NAND flash memory.
  - New NAND technology needs higher ECC level.
- Considerations for ECC Implementation
  - Configurable ECC engine for various spare sizes

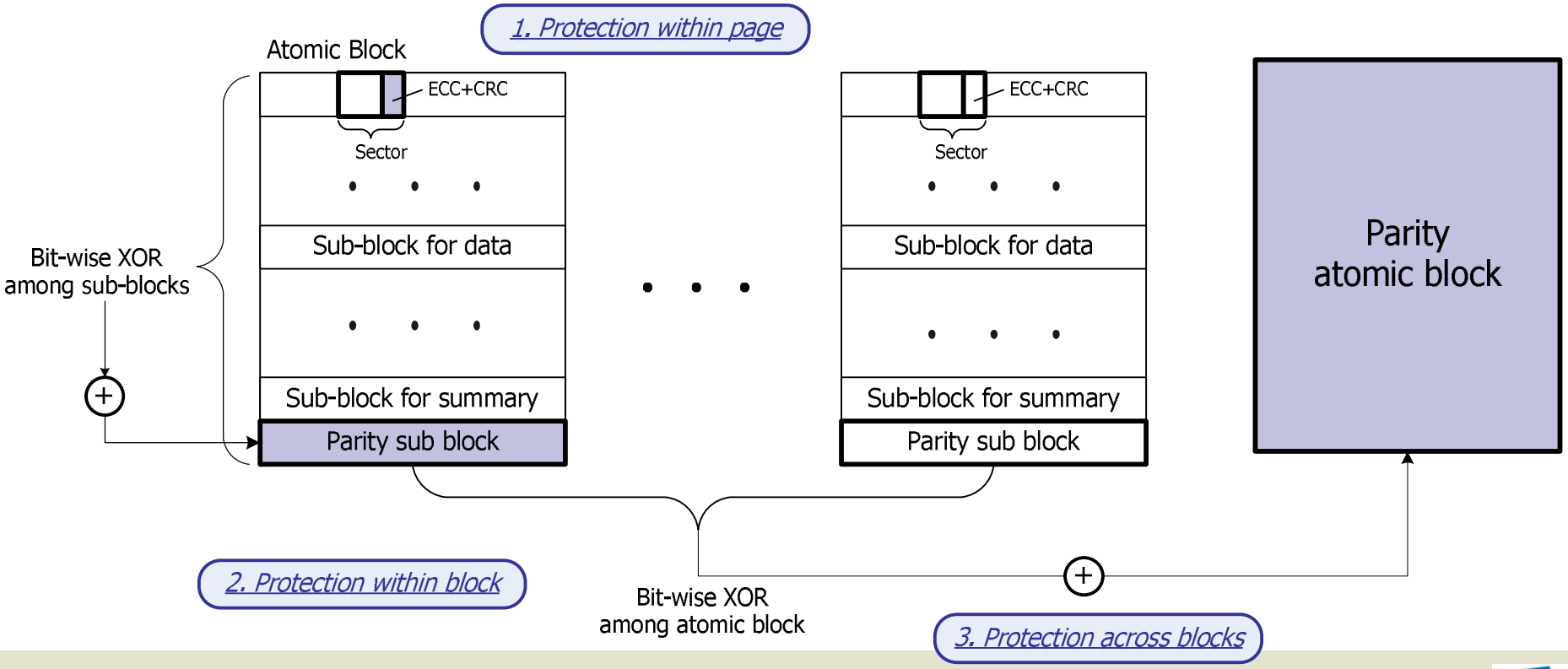
Correction Power	Spare Size (512B Sector)	Spare Size (520B Sector)
4 bits	7 Bytes	15 Bytes
8 bits	14 Bytes	22 Bytes
10 bits	17 Bytes	25 Bytes
12 bits	20 Bytes	*28 Bytes*
15 bits	25 Bytes	*33 Bytes*

Block Atomicity in Write Operation

- Whole block is programmed in atomic manner.
  - All pages in a block are programmed at a time.
  - Data in a block becomes valid via the last program for check-point.
  - Pages programmed before the check-point can be safely invalidated when sudden power failure occurs.
  - Each page is programmed by a single operation.
    - Program disturbance can be reduced.
- Paired Page Restriction of MLC NAND
  - Each page in a block are coupled with its paired page.
  - Sudden power failure during page program can cause bit errors in its paired page.
  - Block atomic program policy can resolve that problem.

Advanced Parity Scheme

- Parity Scheme for Advanced Error Recovery
  - Parity pages and parity blocks to handle unexpected errors
  - Pages constructing a parity come from different pages and blocks.
  - Parity density is configurable for more reliable operation.



Advanced Features for Reliable SSD

- Meta-data Redundancy
  - SSD is more robust with a redundant copy for FTL meta-data.
- Data Scrambling for MLC NAND
  - Newest MLC NAND requires randomized data patterns in a page and a block for safe program operation.
- Data Protection for DRAM
  - For more reliable SSD, data should be protected for all components in a SSD.
  - Conventional DRAM ECC increases the SSD reliability.
- Extreme Recoverability
  - Data stored in a SSD can be recovered with self-describing information in a atomic block.
  - The final recovery solution when SSD is damaged physically.

Thank You.