



# Endurance Requirements for Next-Generation SLC NAND on Mobile Systems

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# Agenda

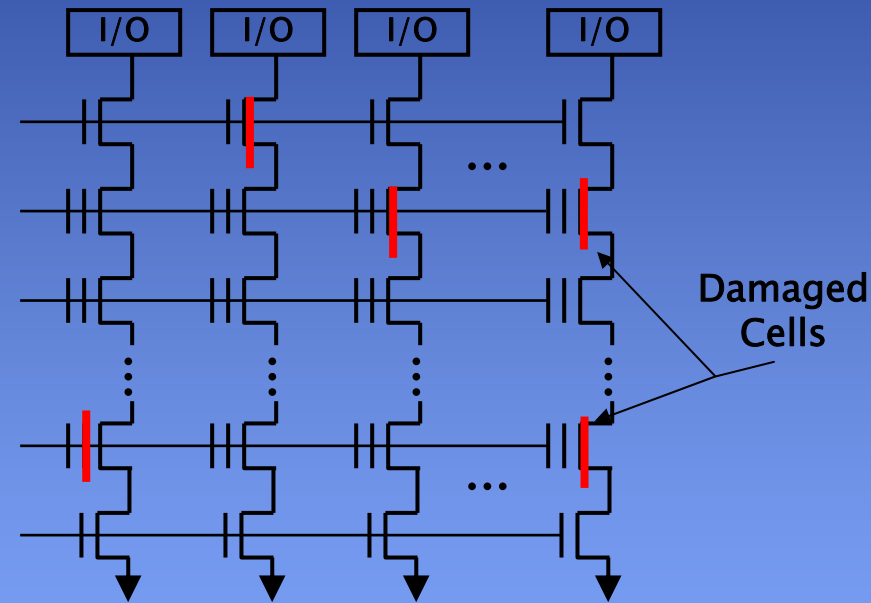
- Overview
- Program/erase cycling effects on NAND Flash
- How to minimize program/erase cycling effects
- Cycling of Flash devices in mobile systems
  - Usage models and their effects on NAND Flash
  - Usage models and how to predict the life of NAND Flash in a mobile system

## Overview

- In the mobile market, the SLC 100K endurance requirement has remained unchanged since the small-page NAND
- With the advancement in process nodes, it is becoming difficult to achieve 100,000 program/erase cycles
- As the densities/page sizes are increasing, should the requirement be same
- A look at SLC devices on mobile platforms to determine the usage conditions and effects on NAND cycling

# Program/Erase Cycling (Endurance)

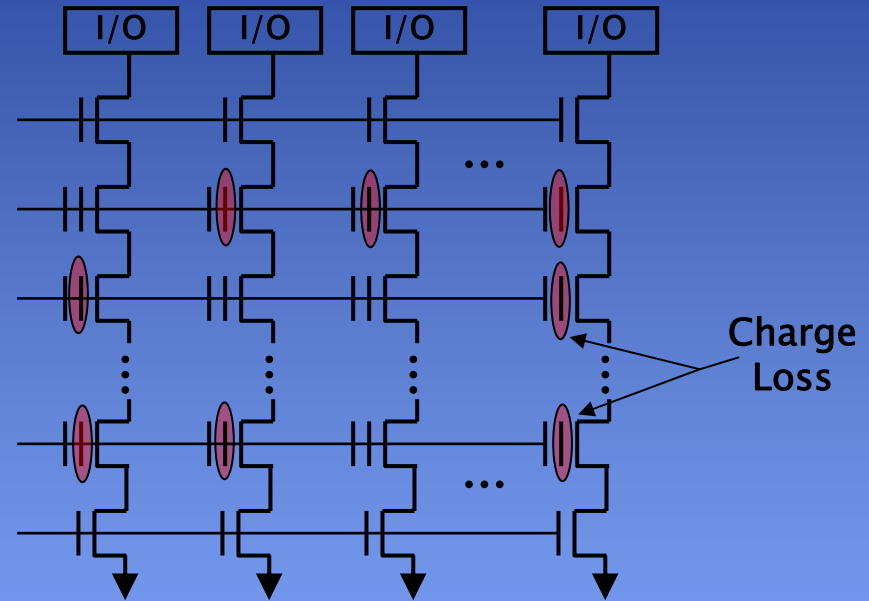
- Program/erase (high voltage stress) cycles cause charge to be trapped in the dielectric
- Causes a permanent shift in cell characteristics—not recovered by erase
- Observed as failed program or erase status
- Blocks that fail should be retired (marked as bad and no longer used)



Note: Circuit structures and voltages are representative only. Details vary by manufacturer and technology node.

# Data Retention

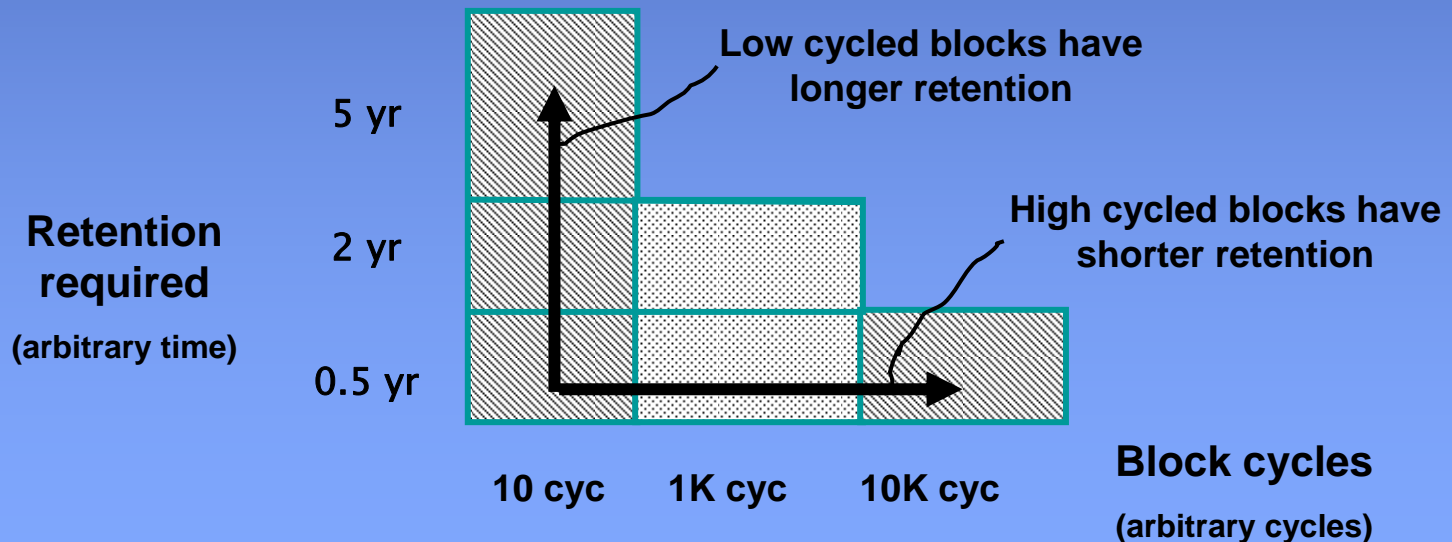
- Charge loss/gain occurs on the floating gate over time; device threshold voltage trends to a quiescent level
- Cell is undamaged; block can be reliably erased and reprogrammed



Note: Circuit structures and voltages are representative only. Details vary by manufacturer and technology node.

# Endurance and Data Retention

- There is a direct correlation in the number of cycles experienced by the NAND Flash and data retention

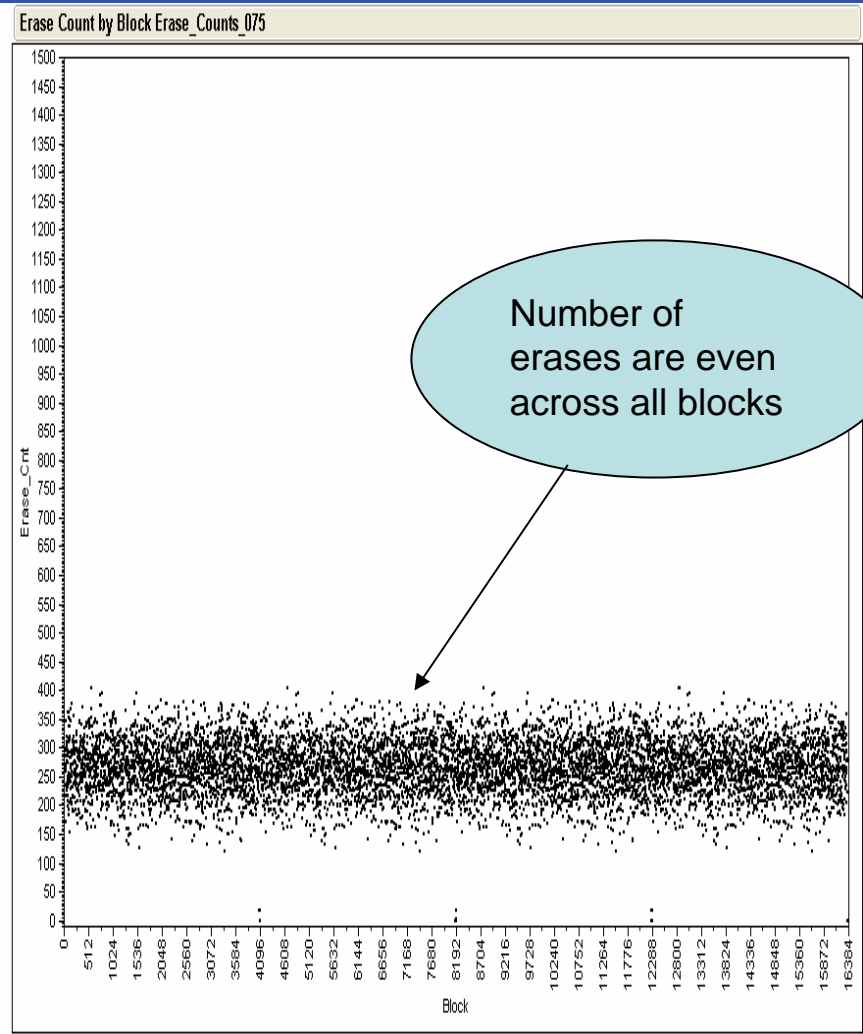




# Maximizing Endurance and Data Retention

- Robust wear-leveling mechanism
- Bad block management
- ECC

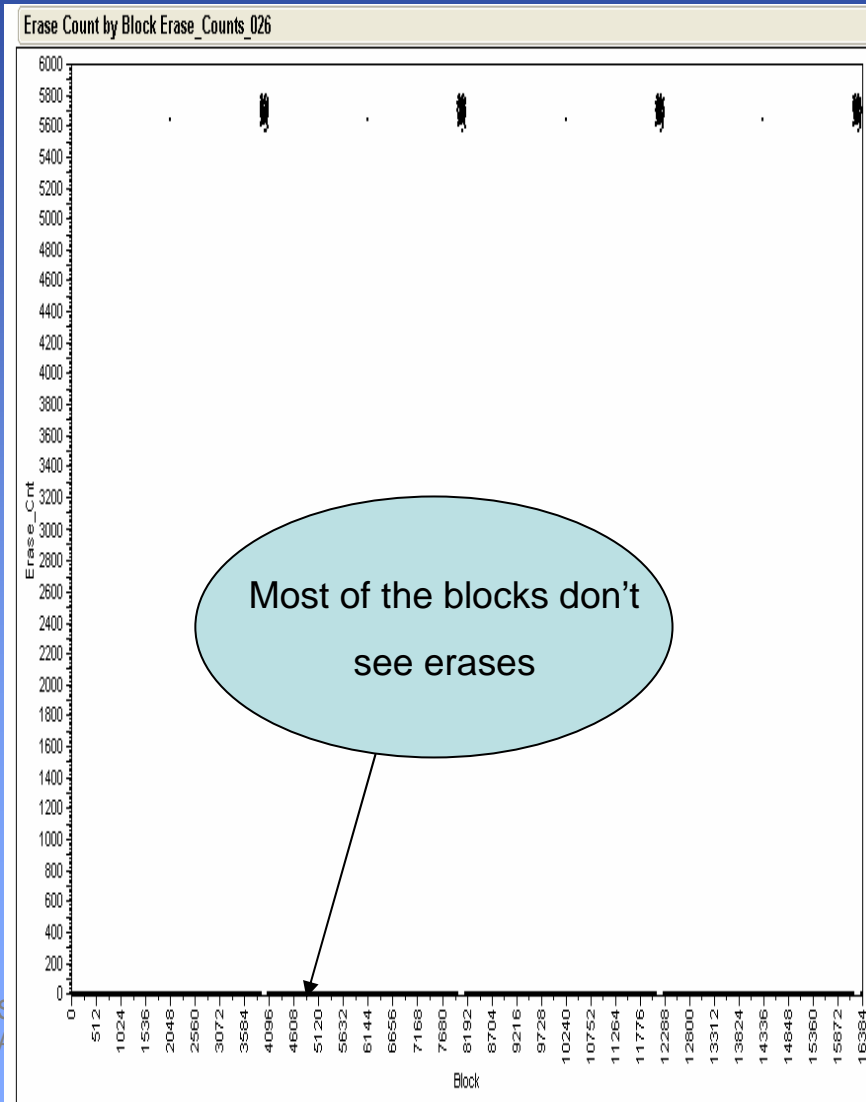
# Good Wear-Leveling



- Makes sure that each block gets approximately equal amounts of program/erase cycles
- Elongates the life expectancy of the NAND Flash device
- Ensures more data can be stored before the bad block limits is reached



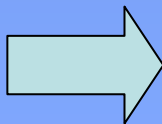
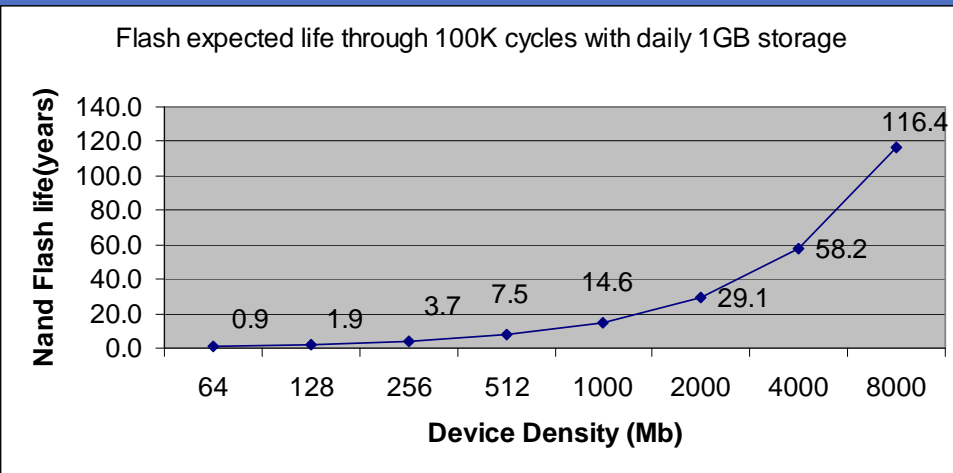
# Bad Wear-Leveling



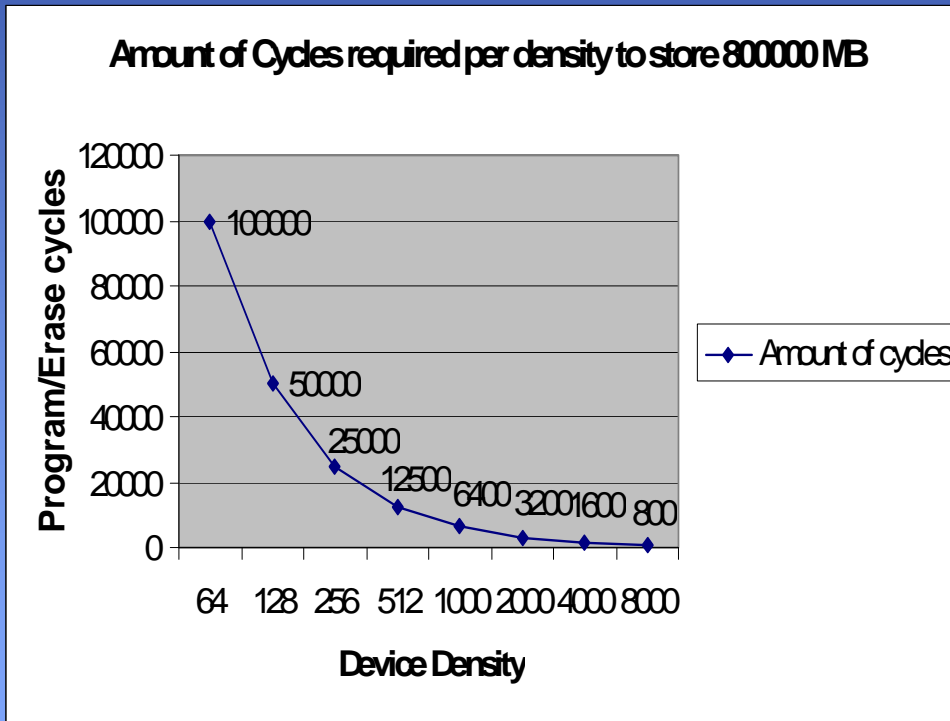
- Does not move around static data and only cycles the portion that is dynamic
- Shortens the life expectancy of NAND Flash device
- Stores less data before the bad block limit is reached

# Theoretical Expected Life of SLC NAND Flash

- Assumes cycling of 1GB daily until 100K cycles are reached
- Assumes that the wear-leveling is perfect
- Assumes that 15% of NAND Flash has static data and 85% dynamic
- Too good to be true



# Theoretical Expected Amount of Cycles



- Taking the smallest density, such as 64Mb, and multiplying this by 100K cycles, we get 800,000MB worth of data that can be cycled through 64Mb device
- We then take 800,000MB and see what would be the equivalent amount of cycles on larger density devices
- Assumes that the wear-leveling is perfect

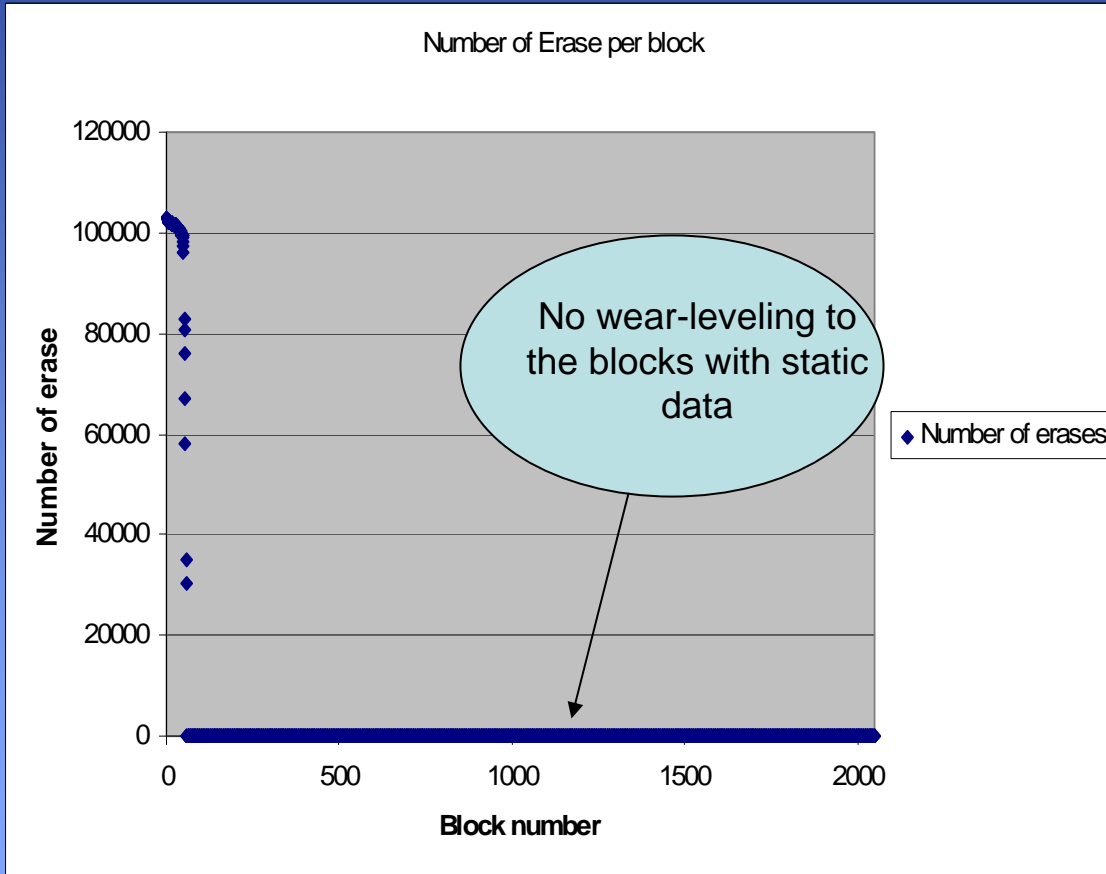
## System Information

- Lets examine some use cases on a mobile platform running with operating system 1 (OS1) with no wear-leveling and operating system 2 (OS2) with wear-leveling
- Both OSs use NAND Flash as a boot solution
- The file system resides inside the NAND Flash
- The wear-leveling also resides inside the file system

## Use Cases

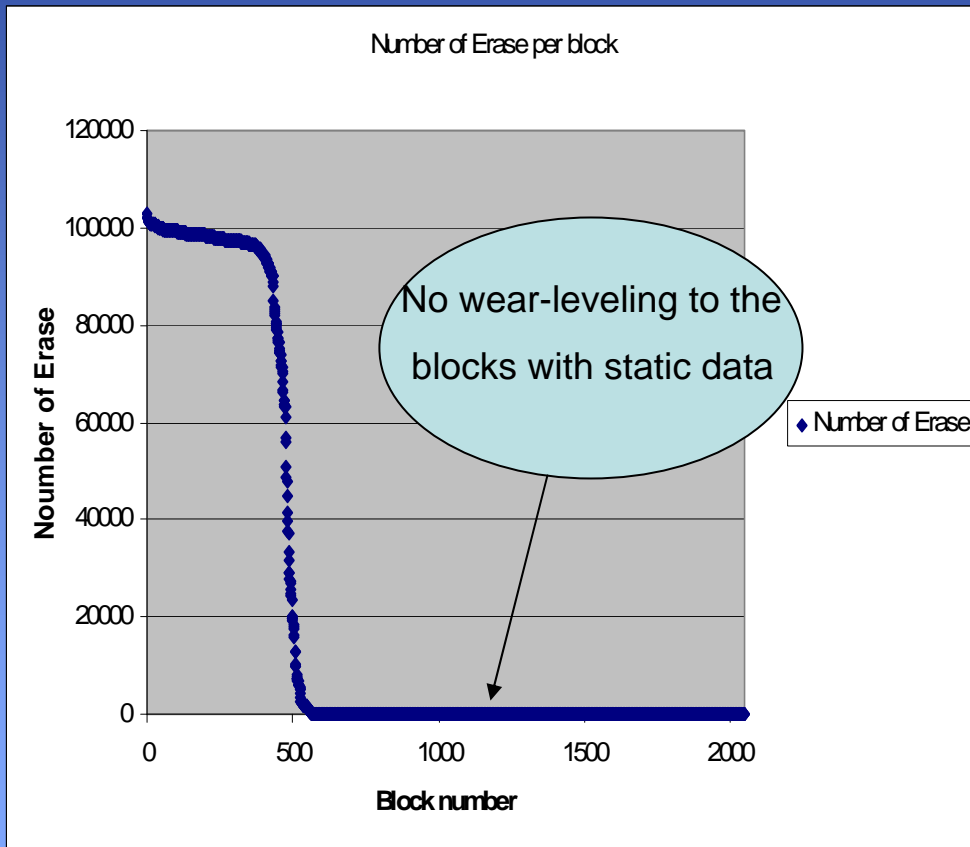
- All use cases assume 1GB of data is cycled daily through NAND Flash device
- 256MB device is used; the endurance spec on this device is 100,000 program/erase cycles
- The use cases keep certain portions of the NAND Flash with static data
- The system is booted, and a test application is run on top of OS
- This test application creates files of different sizes and deletes them to simulate program/erase on NAND Flash device

# Use Case 1 (OS1)



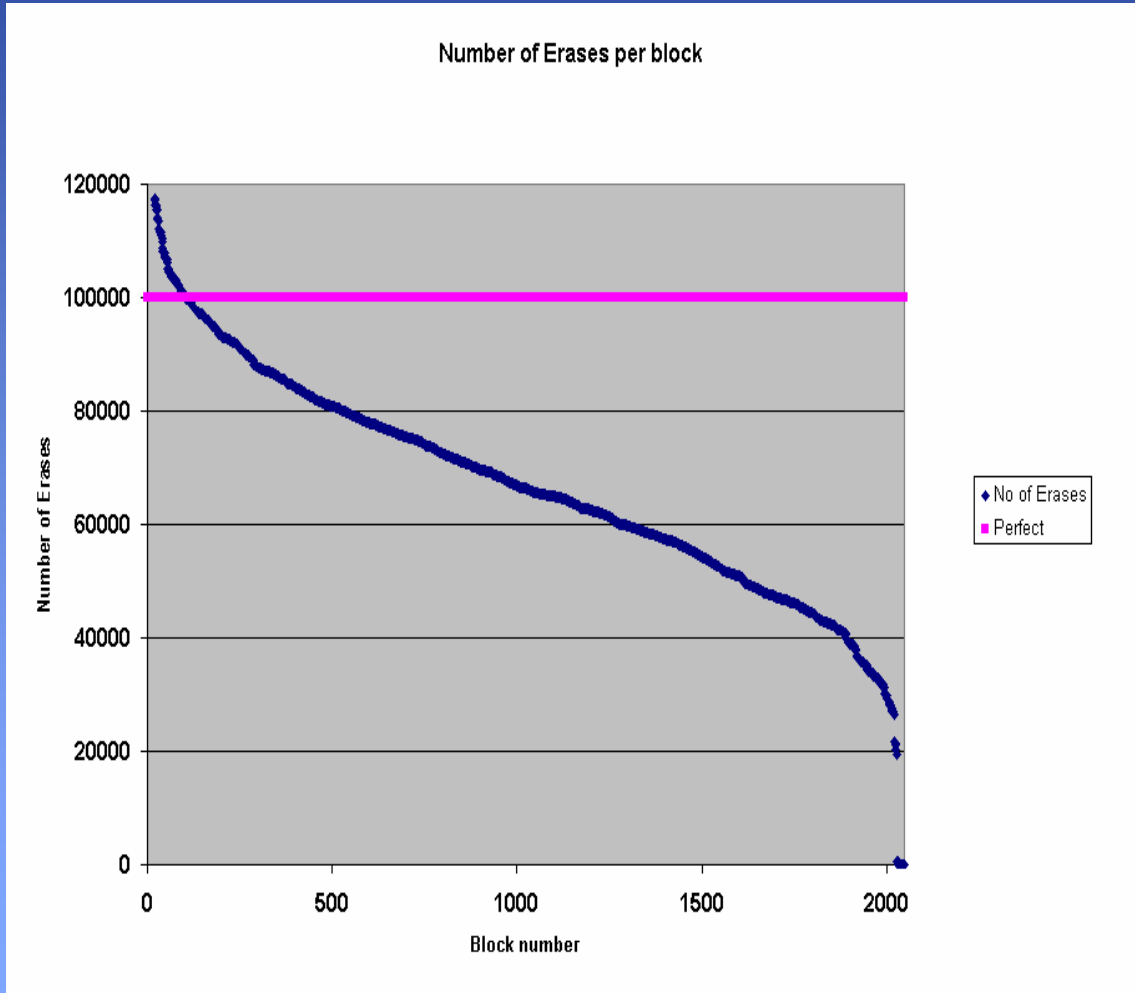
- 97% of NAND Flash filled with static data
- Test application creates random files with sizes ranging from 64KB to 1MB
- Bad; not all the good blocks are seeing equal amount of erases
- With this use case, the 256MB device will last 1.5 years, cycling 1GB daily

## Use Case 2 (OS1 To Be Collected)



- 70% of NAND Flash filled with static data
- Test application creates random files with sizes ranging from 64KB to 1MB
- Bad; not all the good blocks are seeing equal amount of erases
- With this use case, the 256MB device will last 3 years, cycling 1GB daily

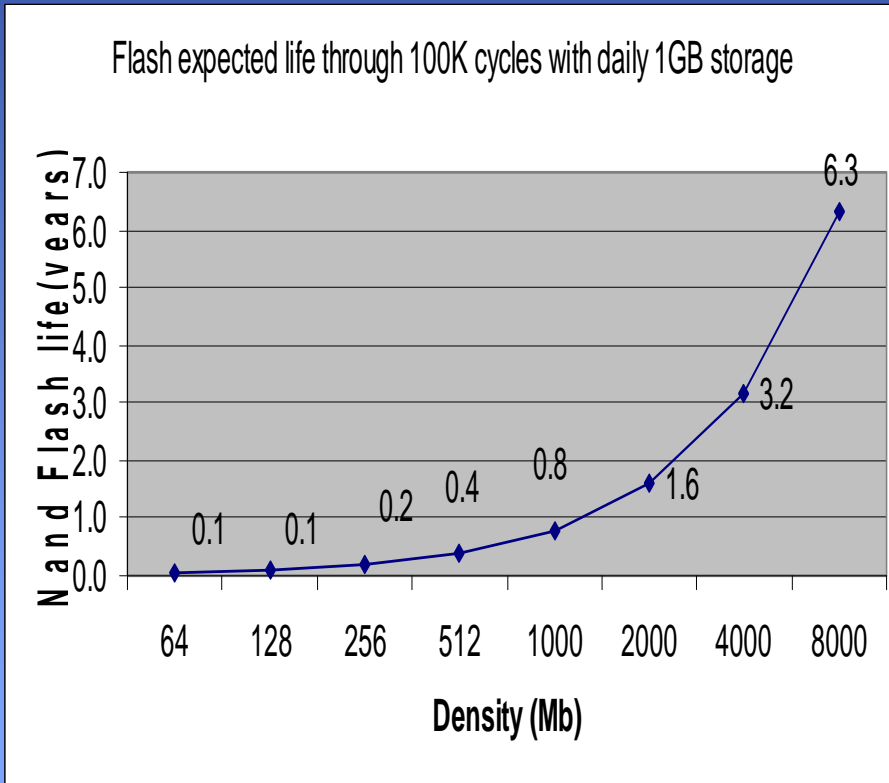
# Use Case 1 (OS2)



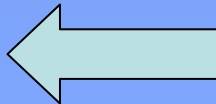
- 97% of NAND Flash filled with static data
- Test application creates 1 file with fixed size
- Better; a lot of blocks see even amount of erases
- With this use case, the 256MB device will last 7 years, cycling 1GB daily
- Erase-to-write ratio is 1.79



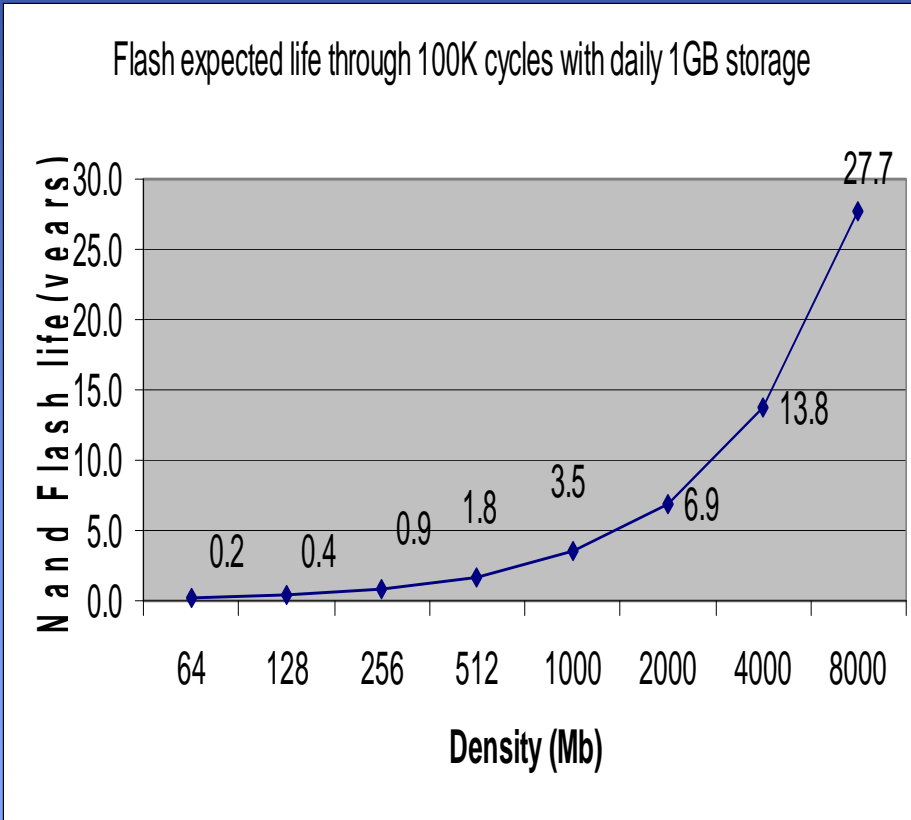
# Revised Expected Life of SLC NAND Flash (No Wear-Leveling)



- This model assumes cycling of 1GB daily until 100K cycles are reached
- 97% of NAND Flash has static data and 3% dynamic
- Erase-to-write ratio of 1.35



# Revised Expected Life of SLC NAND Flash (With Wear-Leveling)



- This model assumes cycling of 1GB daily until 100K cycles are reached
- 97% of NAND Flash has static data
- Erase-to-write ratio of 1.79

## Conclusion

- With wear-leveling and 1GB write daily, we get about 7 years on a 256MB device; is the 100K cycles really required
- On large page 1G, 2G, 4G SLC, the requirement should be reviewed
- From the initial data, 100K requirement looks like overkill