KIOXIA

Technical Brief

Tech Brief Series: Analyzing Managed Flash Device[1] Lifetime Reliability

Part 3: Improving Data Integrity with Refresh Functionality

The NAND flash memory used in a managed flash device, such as e-MMC[2] or UFS[3], has finite endurance capabilities which are usually rated in Program/Erase (P/E) cycles. It is crucial to accurately monitor and manage the amount of data written to NAND flash memory. One key consideration that users should monitor is the difference between the amount of data written from the host and the amount of data actually written to NAND flash memory. Typically, the amount of data written to NAND flash memory is larger than the data written from the host, resulting in a Write Amplification Factor (WAF) that is larger than 1. Further information is covered in Part 1 of this Tech Brief Series: The Fundamentals of TBW, WAF, and NAND Flash Memory Endurance. The total amount of data that a managed flash device is able to write in its lifetime is often specified by Terabytes[4] Written (TBW).

Finite endurance capabilities also means that each memory cell in NAND flash memory can only be written and erased a certain number of times before it begins to degrade, leading to potential data corruption. Over time, data stored in cells, even when write and erase operations are not active, can degrade due to charge leakage. ***This degradation depends on time and the ambient temperature.*** Data degradation not only increases the time it takes to read data, but can also cause the data to be completely unreadable.

In e-MMC and UFS devices, there is a capability called the refresh function which is critical for maintaining data integrity and consistent performance over the lifetime of NAND flash memory. This tech brief covers how a managed flash device controller performs the refresh function to prevent data corruption and improve data integrity. This is the third installment in the KIOXIA 'Analyzing Managed Flash Device Lifetime Reliability' series.

Refresh Functionality Overview

The refresh function requires the managed flash device controller to read data, and if needed, check and rewrite data periodically in its effort to prevent data corruption due to the wear characteristics of NAND flash memory (Figure 1).

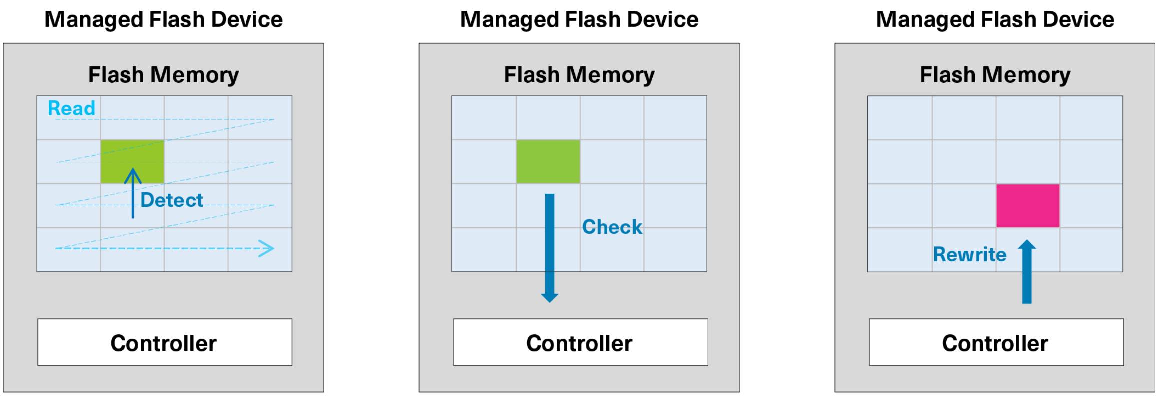

Figure 1 depicts the refresh process of a NAND flash memory cell within a managed flash device

The first action of the refresh process involves a scan through the memory space to detect blocks that have a risk of data corruption. The managed flash device controller can automatically flag these detected blocks during a read operation. The refresh function can be implemented by either software level drivers or at the managed flash device level to help maintain data integrity and deliver consistent performance over the lifetime of the NAND flash memory.

Note: The managed flash device manufacturer should be contacted regarding the availability of the refresh function and how it is implemented as this functionality can vary from each manufacturer.

Restoring Fatigued Data

Though the capabilities of the refresh function vary depending on the managed flash device, following a few simple steps below could help to restore fatigued data to its original state.

One recommended and reliable method requires users to perform read operations across the entire logical block intentionally (sequential and random read operations with varying chunk sizes can be used). By intentionally invoking read operations, the managed flash device controller can detect fatigued, and possibly corrupted data (Figure 2), and will move this data to healthier blocks.

Users can optimize the restoration of data frequency by performing read operations according to the data retention determined by the temperature environment used within the managed flash device. In conjunction, users can use actual device access patterns which define how the managed flash device accesses data. In general, high ambient temperatures tend to accelerate data loss. The optimal frequency for read operations to efficiently detect fatigued, and possibly corrupted blocks, depends on each use case and the temperature profile. For additional guidance, contact a local KIOXIA representative.

When a block that may cause data corruption is found, the managed flash device controller will rewrite the detected data to another block as a background process, avoiding performance degradation in the managed flash device.

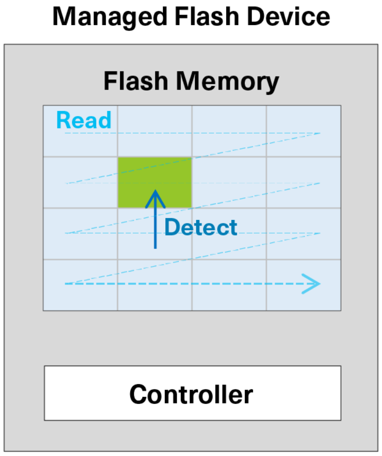

Figure 2 shows the read process of memory blocks in NAND flash memory

Summary

The refresh function in an e-MMC or UFS device is essential for maintaining the reliability and longevity of NAND flash memory. This function involves periodically reading, checking and rewriting data to prevent degradation, and to help ensure data integrity. This process is handled by the managed flash device controller and is designed to work seamlessly in the background to avoid impacting the device's overall performance as much as possible. By improving data integrity in NAND flash memory, refresh functionality helps to extend managed flash device life and maintain its performance over time.

The final installment in the 'Analyzing Managed Flash Device Lifetime Reliability' series will use concepts from the previous three parts. It will show how to perform a lifetime analysis on the NAND flash memory within a managed flash device to ensure that the storage design is reliable and robust.

General information for KIOXIA memory products is available here.

FOOTNOTES:

[1] A managed flash device combines raw NAND flash memory and an intelligent controller in one integrated package, enabling internal memory management.

[2] Embedded MultiMediaCard (e-MMC) is a specification developed by JEDEC for mobile applications. The current release is v5.1, published in February 2015.

[3] Universal Flash Storage (UFS) devices are based on the UFS specification, of which, the v4.0 specification is the current release issued by JEDEC and published in August 2022.

[4] Definition of capacity - KIOXIA Corporation defines a megabyte (MB) as 1,000,000 bytes, a gigabyte (GB) as 1,000,000,000 bytes, a terabyte (TB) as 1,000,000,000,000 bytes and a petabyte (PB) as 1,000,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1Gbit = 2^{30} bits = 1,073,741,824 bits, 1GB = 2^{30} bytes = 1,073,741,824 bytes, 1TB = 2^{40} bytes = 1,099,511,627,776 bytes and 1PB = 2^{40} bytes = 1,125,899,906,842,624 bytes and therefore shows less storage capacity. Available storage capacity (including examples of various media files) will vary based on file size, formatting, settings, software and operating system, and/or pre-installed software applications, or media content. Actual formatted capacity may vary.

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