KIOXIA

Technical Brief

Managed Flash Background Operations Series

Part 2: Understanding Bad Block Management in NAND Flash Memory

NAND flash memory is a cost-effective data storage technology that provides scalable capacity and performance. Bad block management is designed in NAND flash memory to manage and replace cell blocks that fail over time. This brief highlights the capabilities of bad block management and is the second brief in the Managed Flash Background Operations series.

Bad Block Management Overview

When an e-MMC[1] or UFS[2] device is used over time, bad blocks can develop due to increased Write/Erase cycles that can stress the NAND flash memory cells. As cells wear, bad blocks can negatively impact applications and storage devices in the field, and need to be properly managed for efficient flash-based storage operation.

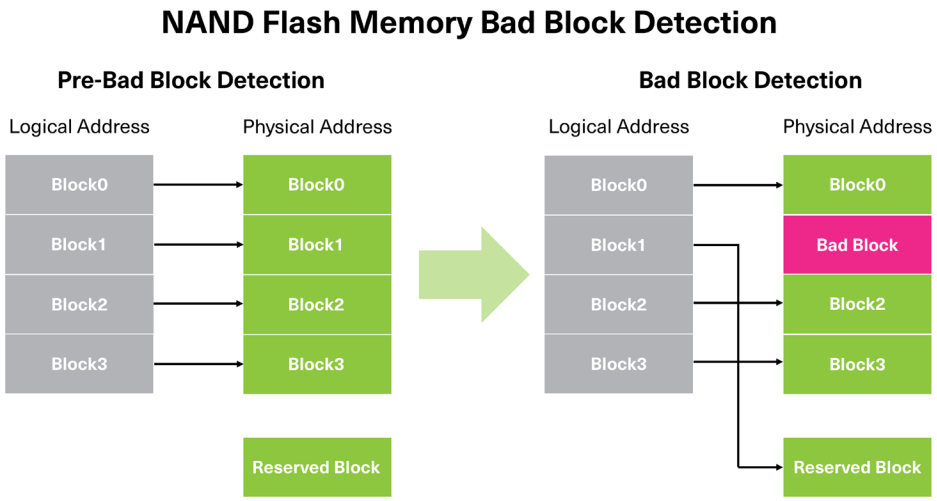
Bad blocks are common in two classes of storage devices: (1) **raw NAND** (or NAND); and (2) **managed flash**. Managed flash devices include e-MMC and UFS and combine raw NAND and an intelligent controller in one integrated package, enabling memory management to be performed internally.

- ***For raw NAND devices***, users are directly responsible for managing bad blocks at the host processor level.
- ***For managed flash devices***, users can offload the bad block management functionality from the host processor to the devices directly. This offload capability reduces user intervention of bad block management and is a major advantage of managed flash device technology versus raw NAND. Managed flash will detect any bad block during write operations to the NAND flash memory cell, and if an error occurs, will mark the block as bad and retire it. A reserved block will be assigned to replace the bad block.

When NAND flash memory ships from a supplier, it is likely that those devices will include bad blocks because bad blocks are an inherent part of the wafer manufacturing process - particularly as process nodes shrink. While it is possible to screen dies with bad blocks, it will come at a higher cost because the yield (or good die per wafer) will decrease. In order to maximize yields for the mass market, most large-scale NAND flash memory vendors will include bad blocks at the time of shipment. These initial bad blocks will be flagged for identification in the case of raw NAND, or not used in the case of managed flash. This allows NAND flash memory to be cost-competitive to meet the market demand.

Bad Block Management Functionality

During final die testing by NAND flash memory suppliers prior to customer shipments, initial bad blocks are detected, marked and won't be used. There may also be instances when write operations or other operations in the field have failed multiple times resulting in bad blocks which are also marked and not used. When a bad block is detected, a reserved block may be used as a replacement and managed by a logical to physical table through the host processor or the managed flash device controller (Figure 1).



How it works:

#1: Controller detects Block1 as a bad block

#2: Controller marks Block1 as a bad block (in red) and will not be used

#3: Controller uses a reserved block as a Block1 replacement

Figure 1 depicts a detected bad block in NAND Flash Memory

Bad Block Management Related Registers for e-MMC and UFS Devices

The bad block management process generates registers for both e-MMC and UFS devices as follows:

For e-MMC Managed Flash Devices:

Included within e-MMC devices is a Device Specific Data Register[3], or Extended Card Specific Data (CSD) Register, that provides indications about the device's life expectancy and is based on an average of reserved flash memory cell blocks consumed. Therefore, if the number of bad blocks increases then the number of reserved blocks will decrease. The host can monitor bad block status through the Extended CSD Register and quickly identify the number of reserved blocks consumed to see if the register shows normal or warning usages. (Table 1).

Extended CSD Register:

CSD- slice	Size	Name	Value	Pre-EOL Info.	Description
267	1	PRE_EOL_INFO	0x00	Not Defined	
			0x01	Normal	Normal
			0x02	Warning	Consumed 80% of reserved blocks
			0x03	Urgent	
			Others	Reserved	

Table 1 is an example of data presented in an e-MMC managed flash Device Specific Data Register
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For UFS Managed Flash Devices:

Included within UFS devices is a Device Health Descriptor[4] that provides indications about the device's life expectancy reflected by average reserved blocks, similar to e-MMC devices (Table 2).

Device Health Descriptor:

Offset	Size	Name	Value	Pre-EOL Info.	Description
0x02	1	bPreEOLInfo	0x00	Not Defined	
			0x01	Normal	Normal
			0x02	Warning	Consumed 80% of reserved blocks.
			0x03	Critical	Consumed 90% of reserved blocks.
			Others	Reserved	

Table 2 is an example of data presented in a UFS managed flash Device Health Descriptor
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Summary

Bad block management is a very important background operation needed by e-MMC and UFS devices. This capability is managed by a built-in controller (without user intervention) that will retire any bad block and replace it with a reserved block. Controller management of bad blocks helps NAND flash memory suppliers maximize chip yields from a manufacturing perspective.

The next brief in the Managed Flash Background Operations Series explores wear leveling and presents ways in which managed flash controllers prolong cell wear out to optimize NAND flash memory reliability.

General information for KIOXIA memory products is available here.

FOOTNOTES:

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

[2] 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.

[3] The Device Specific Data Register is in accordance to JEDEC specification JESD84-851.

[4] The Device Health Descriptor is in accordance to JEDEC specification JESD220E.

TRADEMARKS:

DISCLAIMERS: