

Wear Leveling in NAND flash memories

This application note describes the Wear Leveling algorithm that Numonyx recommends to implement in the Flash Translation Layer (FTL) software for NAND flash memories.

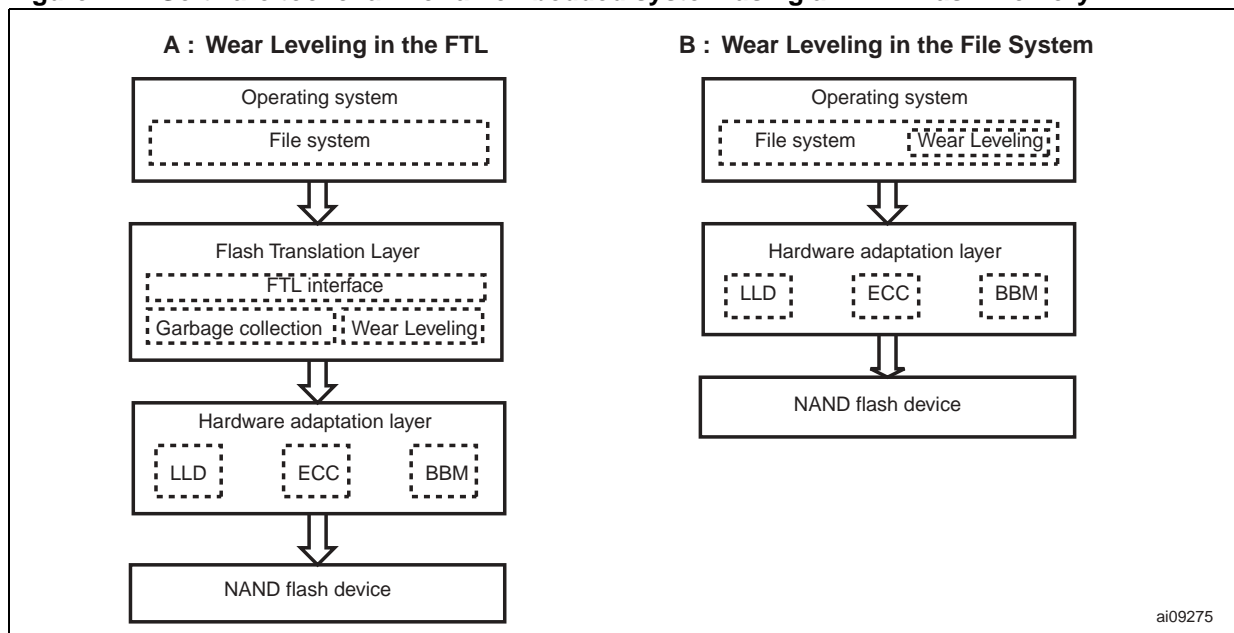
Introduction

In Numonyx single level cell and multilevel cell NAND flash memories each physical block can be programmed and erased reliably up to 100,000 and 10,000 times, respectively. For write-intensive applications, it is recommended to implement a Wear Leveling algorithm to monitor and spread the number of write cycles per block. In memories that do not use a Wear Leveling algorithm not all blocks get used at the same rate. The Wear Leveling algorithm ensures that equal use is made of all the available write cycles for each block.

Wear Leveling is implemented in the Flash Translation Layer which is the additional software layer between the file system and the NAND flash memory. The Flash Translation Layer allows operating systems to read and write to NAND flash memory devices in the same way as disk drives and provides the translation from virtual to physical addresses. Wear Leveling can also be implemented by the file system directly on the NAND flash (see [Figure 1](#)).

Refer to the datasheets for the full list of root part numbers and for further information on the devices (see [Section 4: References](#)).

Figure 1. Software tool chain for an embedded system using a NAND flash memory



1. LLD = Low Level Driver, ECC = Error Correction Code, BBM = Bad Block Management.

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1 How to increase the lifetime of a NAND flash memory

This section shows how the lifetime of a NAND flash can be increased by using Wear Leveling.

1.1 Lifetime without Wear Leveling

For systems that have a FAT (File Allocation Table) based file system, the FAT table is always stored in the same virtual blocks. Frequent FAT table updates are required during data write operations, which implies frequent erase cycles on the same physical blocks, hence a reduced NAND flash lifetime.

The following example calculates how many times a FAT table (FAT32 and a cluster size of 2 Kbytes) is updated when writing a 10-Mbyte file to a NAND flash memory with a physical erase unit of 16 Kbytes (NAND small page device).

To write a file of 10 Mbytes, 5K entries in FAT and 5K clusters in the file system are required. This corresponds to 640 physical NAND flash blocks,

This means that the file can be written at the same location 20 times:

$$20 \times 5120 = 102400$$

which is greater than the maximum number of program/erase cycles.

The expected NAND flash lifetime can be calculated as follows:

$$\text{Expected lifetime} = \frac{\text{Size of NAND flash} \times \text{number of erase cycles} \times \text{FAT overhead}}{\text{bytes written per day}}$$

So, if the application writes at 3 Kbyte/s, the expected lifetime of the NAND blocks is:

$$\text{Expected lifetime} = \frac{10\text{Mbyte} \times 20 \times 0.7}{(3\text{Kbyte/s}) \times 24 \times 60 \times 60} = 0.55 \text{ days}$$

In a NAND flash, when virtual blocks are mapped to the same physical blocks, the lifetime of the device is significantly reduced, independently of its size.

1.2 Lifetime with Wear Leveling

Wear Leveling extends the lifetime of NAND flash devices because it ensures that even if an application writes to the same virtual blocks over and over again, the program/erase cycles will be distributed evenly over the NAND flash memory.

For example, the expected lifetime of a 64-Mbyte (512-Mbit) NAND flash device can be calculated as follows:

$$\text{Expected lifetime} = \frac{64\text{Mbyte} \times 100\text{Kcycles} \times 0.7}{(3\text{KBbyte/s}) \times 24 \times 60 \times 60} = 18,124 \text{ days (about 49.7 years)}$$

Where 0.7 is the file system overhead.

2 Wear Leveling algorithms

Wear leveling is associated with a Block Aging Table (BAT) to remember which blocks have been erased in a selected period of time.

There are two kinds of Wear Leveling that can be implemented in the FTL.

2.1 Dynamic Wear Leveling

When applying the Dynamic Wear Leveling, new data is programmed to the free blocks, among the ones used to store user data, that have had the fewest write/erase cycles.

2.2 Static Wear Leveling

In the Static Wear Leveling, even blocks storing long-lived data (for example, code) are involved and their content is copied to another block so that the original block can be used for more frequently-changed data.

The Static Wear Leveling is triggered when the difference between the maximum and the minimum number of write/erase cycles per block reaches a specific threshold. With this particular technique, the mean age of physical NAND blocks is maintained constant.

3 Conclusion

It is recommended to implement Wear Leveling as part of the software tool chain (either in the File Translation Layer or the File System) to increase the lifetime of the NAND flash in an embedded system.

In addition, it is recommended to implement garbage collection and bad block management algorithms while it is mandatory to implement error correction code algorithms.

To help integrate NAND flash memories in applications, Numonyx can provide a full range of software solutions: file system, sector manager, drivers, and code management. Contact the nearest Numonyx sales office or visit www.numonyx.com for more details.

4 References

The following documents, related to NAND flash memories, are available on www.numonyx.com

- NANDxxx-A, single level cell, small page, 528-byte/264-word page, 3 V supply voltage, NAND flash memory datasheets
- NAND01G-B2B_NAND02G-B2C, single level cell, large page, 2112-byte/1056-word page, 1.8 V/3 V supply voltage, NAND flash memory datasheets
- NANDxxGW3C2B, multilevel cell, large page, 2112-byte page, 3 V supply voltage, NAND flash memory datasheets
- AN1821 Garbage collection in NAND flash memories
- AN1823 Error correction code in single level cell NAND flash memories
- AN1819 Bad block management in NAND flash memories.

5 Revision history

Table 1. Document revision history

Date	Revision	Changes
11-May-2004	1.0	First issue.
12-Nov-2004	2.0	The document also applies to the NANDxxx-B devices. Product List table updated. Section : Introduction and Section 1 sections revised.
29-Jun-2006	3	Product list removed. Reference documents updated in Section 4: References .
22-Feb-2007	4	Section 1.1: Lifetime without Wear Leveling updated. Expected Lifetime updated in Section 1.2: Lifetime with Wear Leveling . Reference datasheets updated in Section 4: References .
15-Sep-2008	5	Applied Numonyx branding. Modified Section 2: Wear Leveling algorithms , Section 3: Conclusion and Section 4: References .

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