CTAN013: Wear Leveling – Static vs Dynamic

Covered Products: All PC Card, SSD, CF and DOM.

1. Introduction

NAND flash memory has a finite number of program/erase cycles due to a couple of defect causing mechanisms inherent in the program/erase operations. These mechanisms are:

- electrons trapped in the thin oxide layer that insulates the floating gate
- oxide breakdown due to hot carrier injection

Today's SLC NAND flash devices typically are guaranteed for 100,000 program/erase cycles. When this number is exceeded, the reliability of the cells starts to decrease and will eventually become unusable, requiring the entire block to be replaced by spare blocks.

2. Wear Leveling

As the number of available spare blocks in a flash storage device is limited, special flash management techniques are used to overcome and manage the flash wear out phenomenon. One such technique is wear leveling.

Wear leveling tries to even out the distribution of program/erase operations on all available blocks in the flash drive. This is done by writing all new or updated data to a free block and then erasing the block containing old data and making it available in the free block pool. The wear leveling operation is done in the background and completely transparent to the host system.

Two methods of wear leveling are used – static and dynamic.

3. Dynamic Wear Leveling

Dynamic wear leveling works on data blocks that are being written to dynamically. As mentioned earlier, all new data are written to free data blocks, i.e. blocks that do not contain user data. The flash drive controller selects the new free data block based on the number of program/erase cycles that the block already has. After the new data is written, the controller then updates its internal logical to physical mapping table to point to the new physical block location. The data block containing the old data is then erased and made available as a free block. Dynamic wear leveling addresses the issue of repeated writes to the same blocks by redirecting new writes to different physical blocks, thus avoiding premature wear out of the actively used blocks.

The important point to note here is that if a data block is not being written to, it will not be wear leveled by this dynamic wear leveling algorithm.

4. Static Wear Leveling

In contrast to dynamic wear leveling, static wear leveling wear levels all data blocks, including those that are not being written to. This is done in the background, completely transparent to the host system. Different vendors have different mechanisms for triggering a static wear level operating. For example, one such trigger could be the difference in program/erase counts between blocks in the static data pool and blocks in the free data pool.

5. Why Static Wear Leveling?

As we discussed in the previous paragraphs, dynamic wear leveling alone cannot guarantee that

all data blocks are wear-leveled evenly. There are situations where a flash drive may contain large number of blocks where data is written and remain unchanged for long periods of time, e.g. operating system files. Thus, while the active data blocks are being wear-leveled dynamically, the static blocks are never touched and remains inactive in the wear level process.

The net effect of doing dynamic wear leveling only is that the program/erase cycles that are available for sharing in the static data blocks are never made available for use to the dynamic data blocks. This effectively reduces the lifespan of the flash drive. This reduction in lifespan could be significant for those cases where the static data blocks is a significant percentage of the drive capacity.

Static wear leveling solves the uneven wear-level problem by including the static data blocks in the program/erase pool. While it is true that moving the static blocks around will increase the amount of program/erase operations on the rest of the data blocks and may cause some of these blocks to fail sooner, the gain in additional product lifespan more than compensates for the small increase in blocks being retired sooner.

6. Summary

In summary, the use of dynamic wear leveling alone is not sufficient to guarantee even wear of all data blocks in a flash drive. Static wear leveling must be included in the wear leveling algorithm in order for the flash drive to achieve even wear throughout the drive and provide the best endurance and product lifespan.

Cactus Technologies is able to deliver products with industry leading endurance and product lifespan by using static wear leveling in combination with dynamic wear leveling.

7. Version History

Version	***Date***	***Change***
1.00	Sept. 19,2008	Initial Version