An InnoDisk White Paper
August 2012

# Error Detection/Correction And Bad Block Management

## Early Detection of Factory-Marked Bad Blocks And Normal Operation Tracking Of Bad Blocks in Solid-State Drives (SSDs)

## Revision History

| Date | Version | Information |
|---|---|---|
| 2012.07.09 | 1.0 | First Release |

## Introduction

This white paper presents InnoDisk's procedure to detect, correct and manage initial factory-marked bad blocks (early bad blocks) in NAND Flash chips, and also bad blocks tracked during normal device operation (later bad blocks). An early detection and recovery is essential to managing a solid-state drive's (SSD) overall health and reliability.


SSDs are assembled using NAND Flash chips. The problem is that all NAND Flash chips have the potential to contain factory-marked bad blocks (early bad blocks). A procedure is needed to search for these early bad blocks (or later bad blocks) so that the bad blocks can be flagged in a table and marked as unusable.

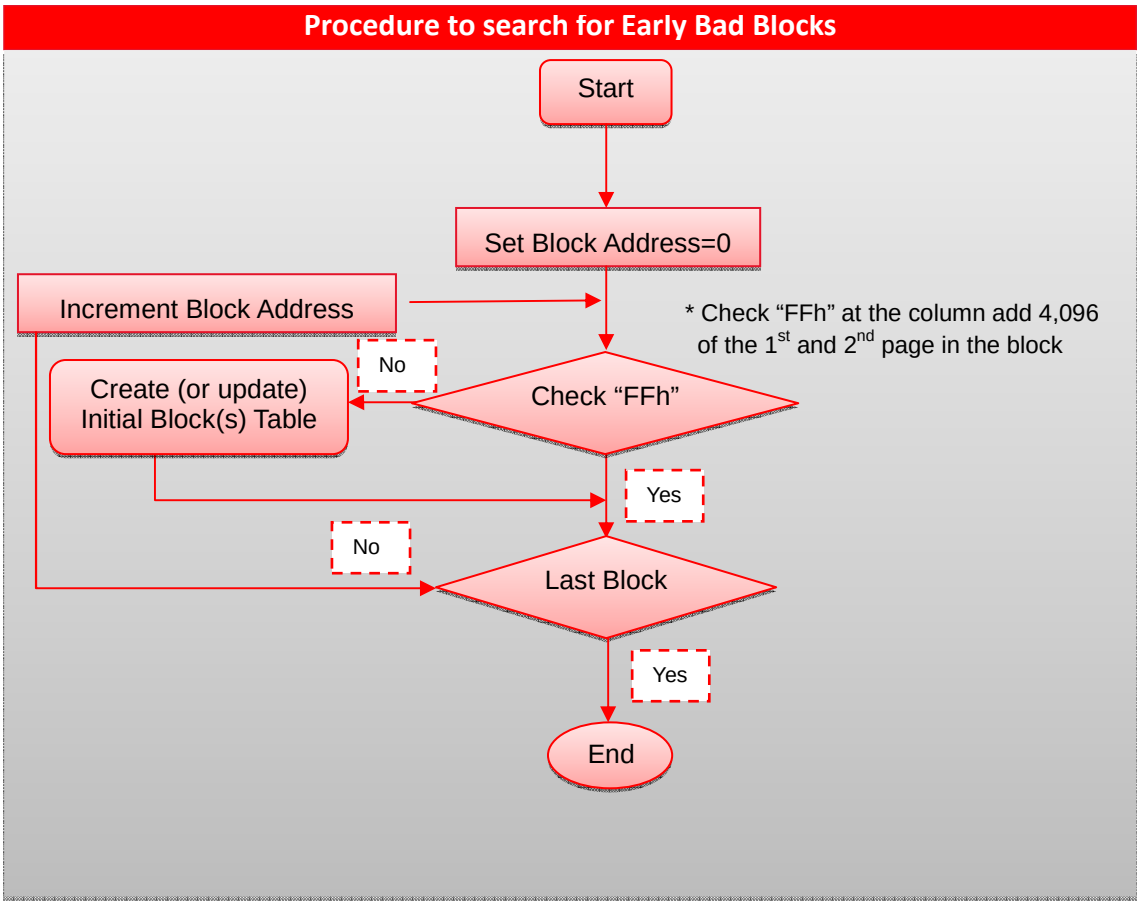
## How InnoDisk handles error detection/correction and bad block management

### Bad Block Management

There are two types of Bad Blocks in NAND Flash memory: Early Bad Blocks and Later Bad Blocks

**Early Bad Blocks (Initial Invalid Blocks in Figure 1)**

Early Bad blocks are written prior to shipping. These Bad Blocks are an unavoidable consequence of cost cutting measures during the production process and the inherent nature of Flash technology. The 6$^{th}$ byte in the spare region of the 1$^{st}$ or 2$^{nd}$ pages is checked to see if they contain an "FFh" (See Figure 1). If not, it is a factory-marked bad block and the "Initial Invalid Blocks" table in Figure 1 is updated with an entry for the bad block. This table is copied to a good block to prevent wiping during reboot. Figure 1 shows InnoDisk's procedure to search for factory-marked bad blocks (Early Bad Blocks).




**Later Bad Blocks**

Throughout the lifespan of the Flash, multiple write/erase cycles eventually leads to Blocks being worn out. If the controller finds an un-recoverable error, the Block is discarded and added to the Bad Blocks table. Firmware maps Early Bad Blocks and Later Bad Blocks to ensure data is not unnecessarily being written to Bad Blocks.

## Error Detection and Correction

During normal operation, bits in Flash blocks can wear out during read/write operation, or experience rare phenomena such as "bit-flipping", where the bit is either reversed or marked as reversed. Therefore, error detection and correction must be implemented in SSDs to ensure data integrity and Flash reliabilty.

Error Detection Code (EDC) and Error Correction Code (ECC) are used to detect and correct errors. Single or multiple bit corrections are performed on data in Flash memory. An algorythm is used within the ECC engine of the Flash controller to compare ECC signatures. If two ECC signatures differ, the data is corrected by the controller before being provided to the host.

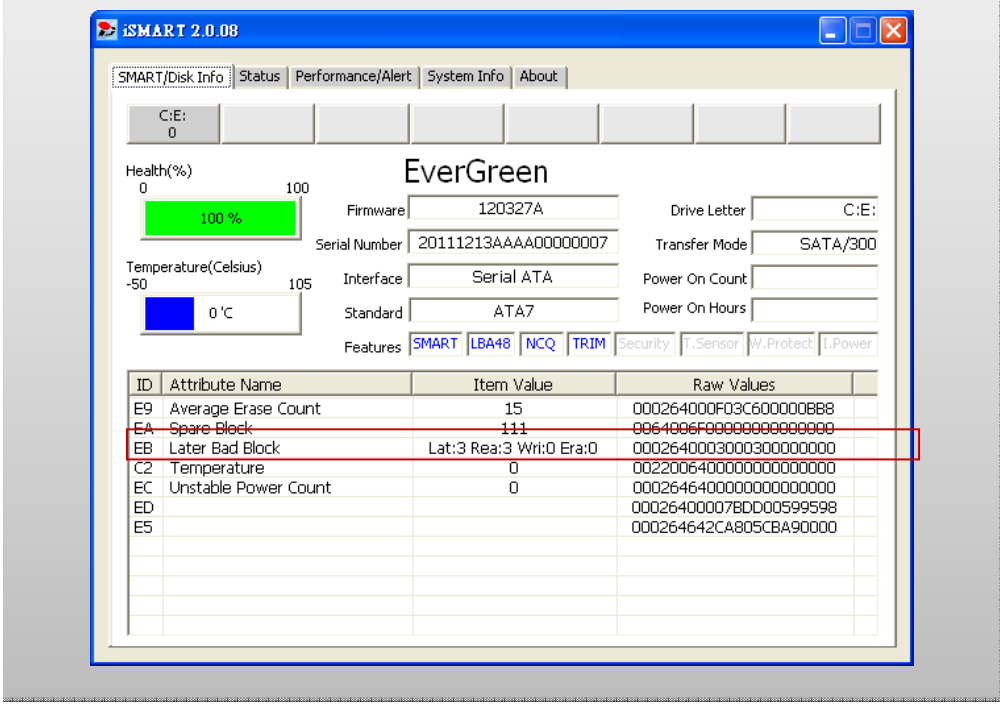
The SSD has the ability to recover error bits; for example, 40 bits per 1024 bytes in 25nm MLC Flash

memory. Once the error bit exceeds 40 bits, the SSD is unable to recover the error. Early detection is crucial in discovering which blocks are close to being worn out. i.e. the P/E cycle of the block is close to the physical limit, approximately 3000 times for 25 nm MLC Flash memory. We set a threshold in this example of 32 error bits. This marks the block as unusable before it reaches the 40 bit limit. This preemptive action reduces read/write errors in the blocks and avoids generating uncorrectable errors.

## Testing Data

The image below shows LaterBad Blocks detected by InnoDisk's iSmart software.

**Later Bad Blocks detected by InnoDisk's iSmart software.**




## Conclusion

Because good blocks can degrade and wear out over time, it is essential to track not only the initial, factory-marked bad blocks (early bad blocks) but also blocks that wear out during normal device operation (later bad blocks). The number of read/write error bits increases with P/E cycles, hence bad block replacement is needed to replace worn out blocks with good ones. Error detection/correction and bad block management is one of the core components of good SSD maintanence.

**All SSD series at InnoDisk support error detection/correction and bad block management**

## About us

InnoDisk is a worldwide leading provider of data storage and memory module solutions for industrial and mission-critical applications. Leveraging in-house engineering and R&D expertise with a keen insight on industry trends, InnoDisk's solid-state drive (SSD) technologies provide enhanced, vertically-integrated data storage solutions. Our advanced Flash-based data storage and DRAM memory solutions meet stringent aerospace and defense application requirements, and are also widely used in industrial applications and embedded systems. InnoDisk offers customized solutions, from unique form factors to special firmware designs, and our support team of hardware, software and firmware engineers is always ready to tailor the right solution to each customer's needs. InnoDisk continually strives to innovate and provide system integrators and end customers with the best service in the industry.

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