Apacer

Power Failure Management

White Paper

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Version 1.1

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Table of Contents

1. Introduction

Solid State Drives (SSD) have generally been recognized as far more reliable and faster in data transmission than traditional hard disk drives (HDD). Without the mechanical components and magnetic parts, the NAND flash based SSD memory devices can take on higher levels of shock, vibration, and wider range of ambient temperature. At the same time, less heat is generated during operation, making SSDs the more stable storage device for various applications in industrial, military, enterprise, communication network, consumer electronics and embedded purposes.

NAND flash storage devices, like other electronic devices, are vulnerable to power failure issues such as voltage disruptions, power supply fluctuations and surges. As flash memory is non-volatile, data, once stored, will not be affected even when power fails. However, during a flash memory operation, the flash memory can be left in an incomplete state in the event of power loss. Power instability can expose NAND flash memory to the risk of data loss caused by firmware damage, mapping table damage, or page/block corruption during an unexpected power down. To prevent data loss or drive corruption from events like these, it is necessary to develop a power-down recovery mechanism enabling the flash storage device to check for uncompleted operations upon power up, finish or correct them if possible.

Since memory devices are designed to work as the safety deposit for important data, Apacer's Power Failure Management (PFM) becomes essential for NAND flash memory to ensure data integrity during a sudden power down under all conditions.

2. Power Failure Management

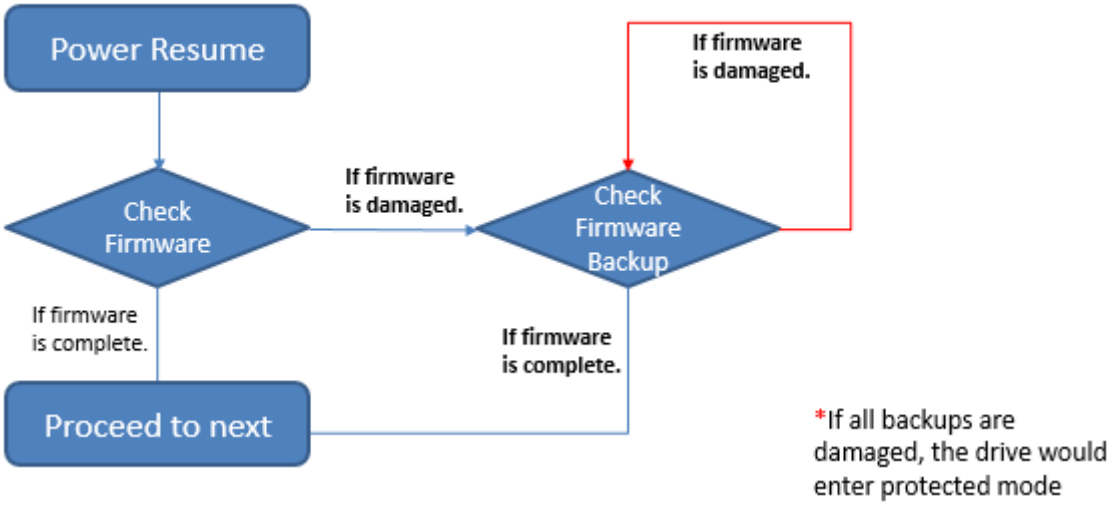
SSDs may be physically robust compared to HDDs, but they are similarly vulnerable to abnormal power failure. If an SSD read or write operation is interrupted due to an unexpected loss of power, there can be inconsistencies in the data; it may not load successfully, and an ECC (Error Correcting Code) failure can occur, leading to data loss.

To secure data integrity on an SSD during a power failure, Apacer has developed a power-loss data protection mechanism which incorporates the following three layers of power failure protection against data loss in the order of technological level:

Security Level	Layer	Description of Power Failure Protection
Less Secured ↓ **More Secured**	I	Multiple firmware backups for firmware protection
	II	Mapping table constantly updated to ensure mapping table protection
	III	Last-minute data written to NAND flash for last write protection

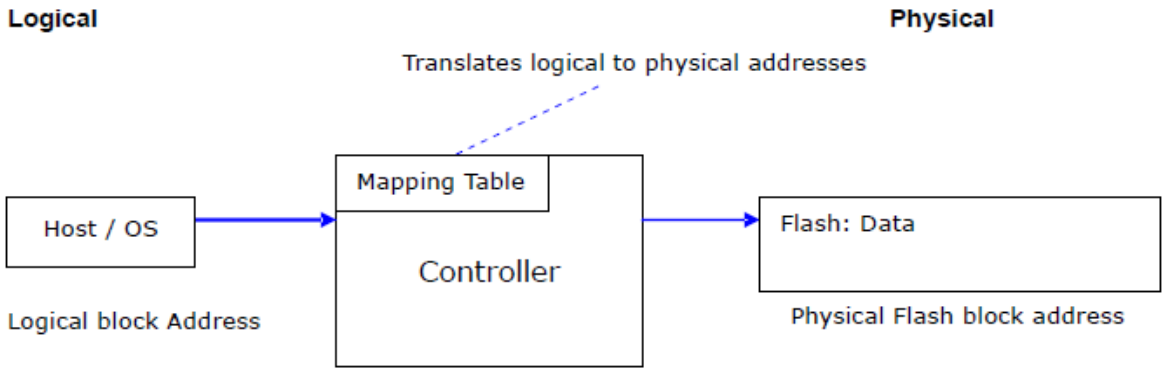
2.1 Layer I – Firmware Protection

In the event of an unexpected power outage, firmware in SSDs is exposed to the risk of being corrupted, which can cause the drives to enter boot code stage. To prevent firmware from being damaged, Apacer's underlying layer of protection mechanism allows the drive to back up multiple firmware versions. Once the primary firmware is corrupted, other backup version will take over to keep the drive working properly.

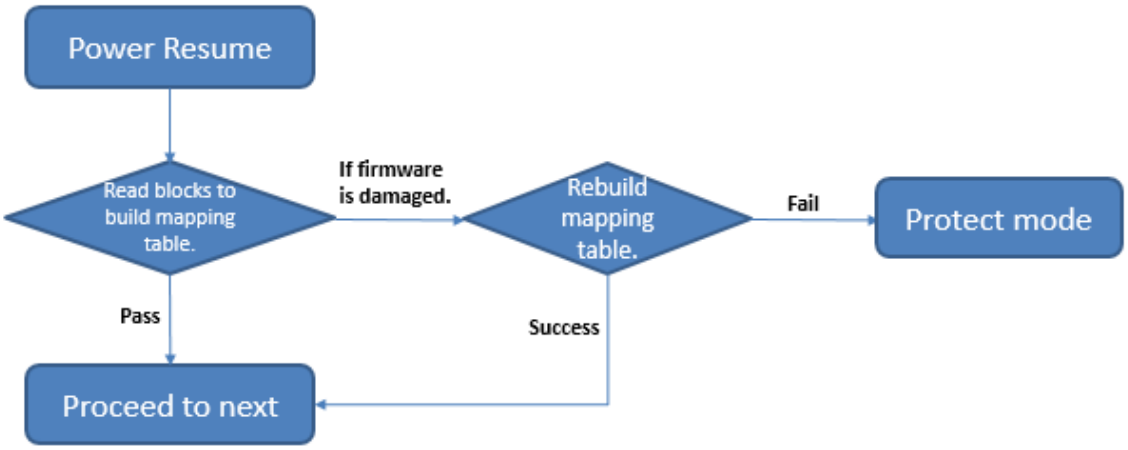


2.2 Layer II – Mapping Table Protection

A mapping table is a built-in block inside the controller that provides logic to physical address translation. While the data is under programming process, the controller is also recording the corresponding logical block address into its mapping table.

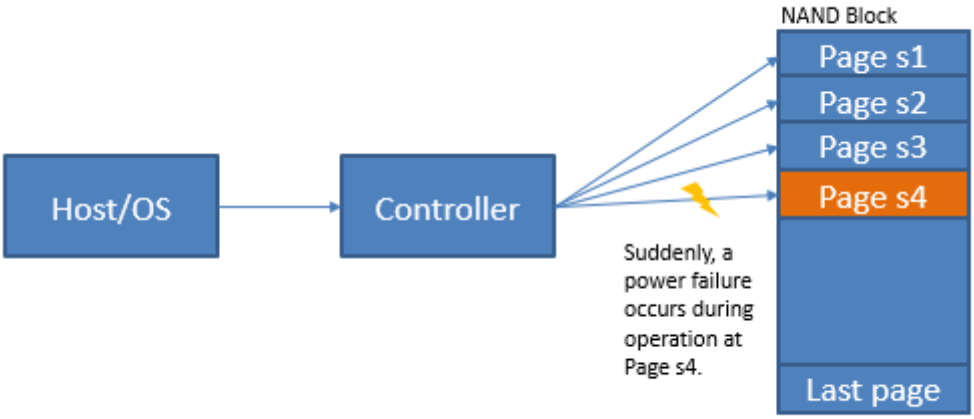


In an unexpected power outage, mapping information processed by a mapping table is at great risk. It is because mapping information of the mapping table is temporarily cached in the controller and becomes “solid” or “hardened” information once moved to flash memory. In other words, mapping information can be lost if a power failure occurs before it is flushed into the physical blocks. When power is down, the controller will read every NAND flash block in sequence and retrieve the logical address mapping to rebuild the mapping table as soon as the power supply is resumed. If the mapping table is not successfully rebuilt in the initial reading, the controller will keep reading block address information until the mapping table is recovered.



2.3 Layer III – Last Write Protection

NAND flash programming is usually divided into multiple write operations and each is written to a page of a block. As illustrated below, the write operation is carried out one page at a time in most NAND flash devices. If a sudden power failure occurs during the programming, the page with programming-in-progress data will be found invalid and with error. For instance, in the following illustration, the host is performing write operations to a NAND block. Suddenly, power goes off while page s4 is being programmed. Data written by the previous program operations on page s1, s2, and s3 can be retained because the data has already been written into the flash chips during programming operation. However, data in page s4 is invalid with error when the power resumes. The ECC in firmware will detect and correct the error in page s4 to ensure data integrity of the entire block.



3. Conclusion

Power loss protection is a critical element in data integrity. Since SSDs are often deployed in demanding environments, power disruptions may occur unexpectedly and potentially cause catastrophic damages to the data in the drive. When power fails during SSD operation, drives can be corrupted and data ruined, resulting in downtime as drives must be reformatted and operating systems reinstalled.

To ensure data integrity and the stability of data transmission in the event of power outage, Apacer develops Power Failure Management featuring multiple layers of protection, including firmware, mapping table and last write operation, to protect against data loss and corruption. Apacer has been dedicated to protecting data stored in SSDs. This gives storage devices significant robustness, even in the presence of uncertain power environments.

Revision History

Revision	Description	Date
1.0	Initial release	7/31/2020
1.1	Chart graphics updated	3/18/2021

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