



# **Envoy Data Memory**

## **SSD CONTROLLER**

### **Technical Brief**

### **Garbage Collection**

## Introduction

Solid state drive (SSD) is basically a data storage electronic device made up of a controller, NAND flash, DDR (optional) and specific interface/protocol connector (e.g. PATA, SATA and PCIe NVMe ...). Unlike hard disk drive (HDDs), SSDs don't use mechanical parts to read, program and erase data. By precise control to millions of NAND flash memory cell, SSD controller is able to perform read, program and erase to build up a data storage system.

However, different from HDD, NAND flash memory cannot overwrite existing data. In order to approach an efficient data management in SSDs, garbage collection is processed to relocate free/used space and to reclaim those valid/invalid data.

GC is "Garbage Collection" in short, and it's a common technology adopted in all Solid State Drive (SSD) field. Generally speaking, this fundamental process can be implemented in many different ways that directly dominate the overall SSD performance and endurance.

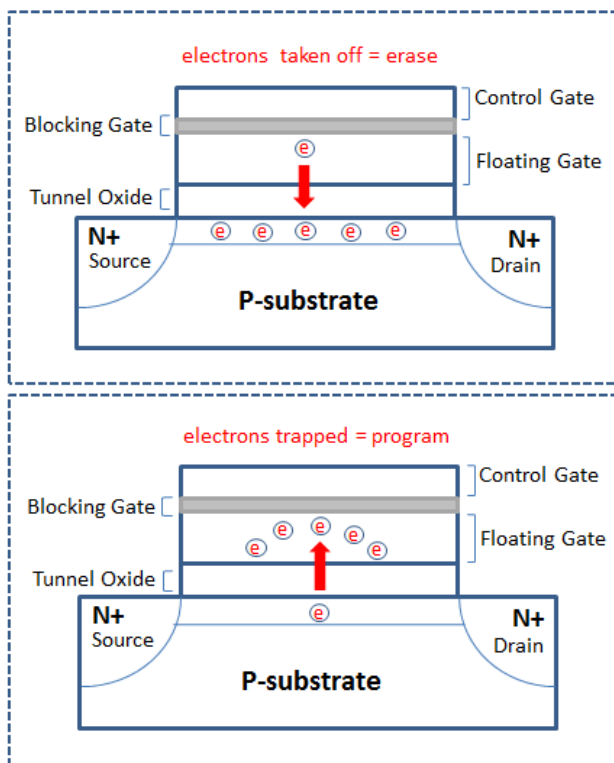


Fig.1 Erase and program in NAND Flash

A flash memory cell is essentially a MOSFET with a special floating gate that can retain and store data persistently. Each time the electrons trapped into the floating gate of transistor, the data is programmed. When the electrons are taken off, the data is removed (refer to Fig.1).

## How GC processes

Since SSDs cannot overwrite existing data in NAND memory cells, they must first erase old data before programming new data to the same location. In SSDs, GC is named for the process of relocating existing data to new locations.

In SSDs, GC is the name for the process of relocating existing data to new locations of free memory space and allowing the surrounding invalid data to be erased thoroughly. In figure 2, the example is illustrated to show how GC is processed.

Basically, a flash memory cell is composed of pages, and pages compose a block. Due to the intrinsic characteristic of NAND device physics, the flash cell allows data to be programmed on a page level but only erased on a block level. In fact, this inconsistency between program and erase is the major impact to SSD endurance.

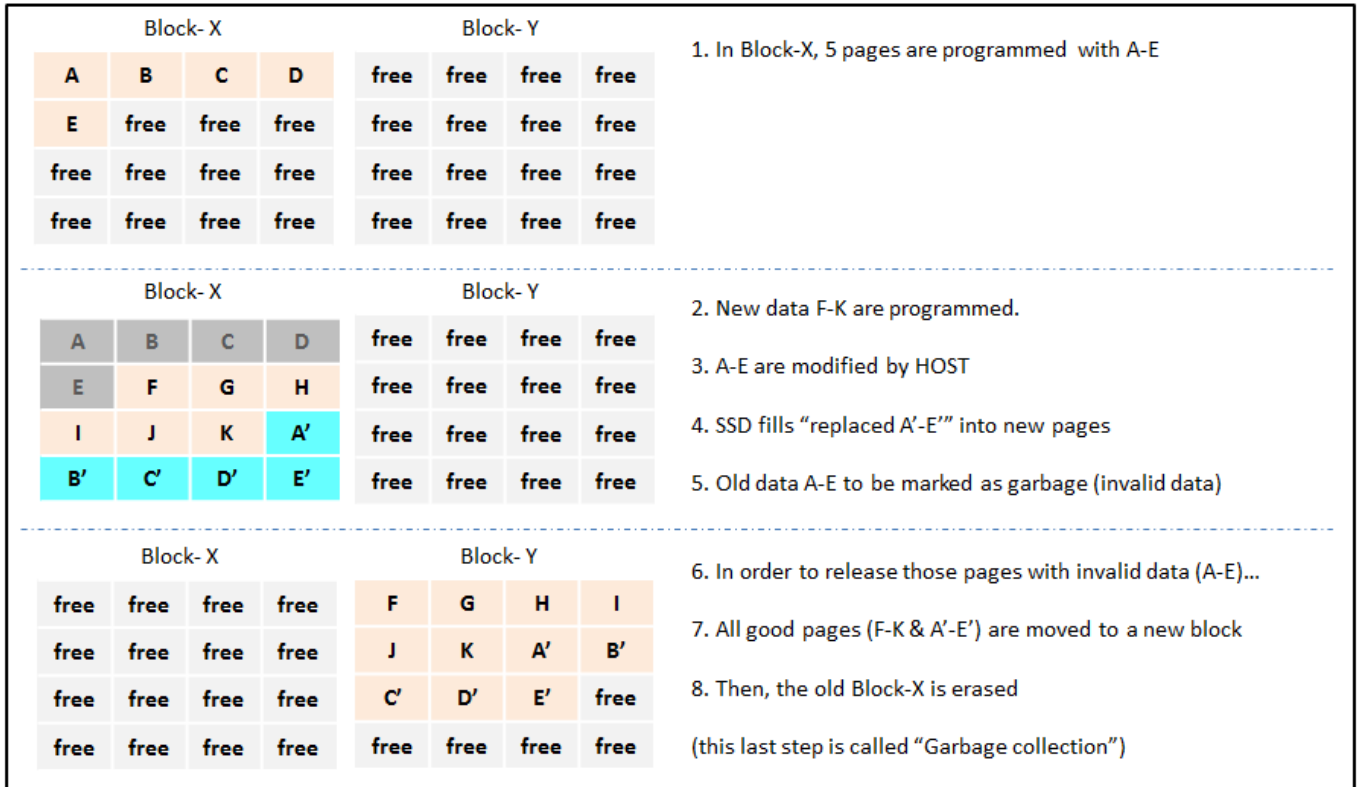


Fig.2 the illustration of Garbage Collection

Every time before claiming the space taken up by invalid data, all the valid data in pages from initial block must be copied and written into empty pages of a new block. Followed by that, the invalid data in the original block can be erased without concerns and ready for following new valid data to be written.

## Trim command

From Operating System (OS) awareness, it can only recognize the logical locations addressed in the mapping table of SSDs. The storage system returns the data from the physical locations while the OS requests for data from corresponding logical locations.

Microsoft proposed Trim command concept to

reduce unnecessary wearing on NAND. This command basically lets the OS give an immediate notice to SSD while a file is being deleted in the OS level. Followed by that, SSD is able to earlier tell whether the data is marked as a valid one or invalid one. The best benefit of Trim command is to assure the SSD be in real time to tightly follow what the OS is willing to execute. Consequently, redundant accessing to the NAND flash is efficiently reduced.

Trim command can produce three key benefits:

1. Lower write amplification: Early notice to mark invalid for those pages with useless data in SSD will contribute less data re-written. When more free space is available to write, it equals fewer write is required in SSD.

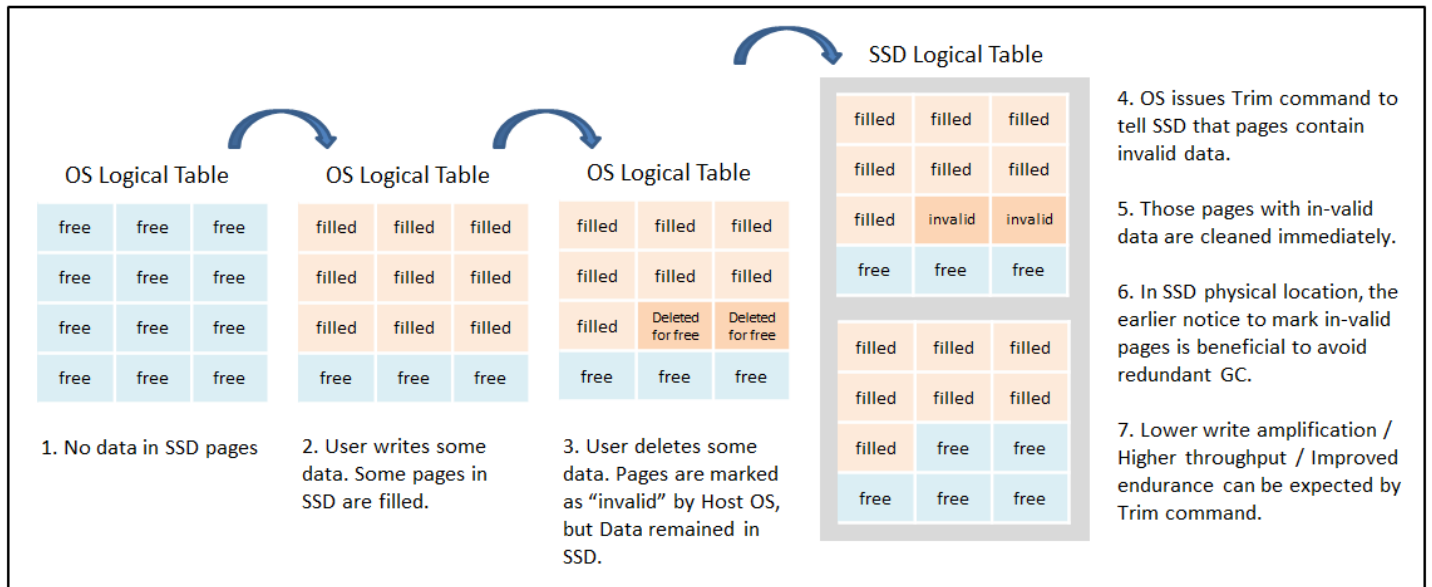


Fig.3 the illustration of Trim command

- High throughput: Drive runs faster as there is less data to move during GC with the Trim command. Throughput is bottlenecked by how fast an SSD can write to the flash memory. When GC is processing, the SSD has to stop some data transfer from Host. Therefore, it's beneficial to for SSD to know what page is with invalid data so the page doesn't have to be moved during GC.
- Improved endurance: By not re-writing invalid data, the drive is less writing to the NAND flash.

## Summary

Garbage Collection is the process reflecting how SSD functioning differently from HDD. Instead of overwriting existing data, SSDs perform GC when new data to be programed to those pages with invalid data. It causes additional wearing to NAND. However, one of the solutions to dismiss the concerns is OS issue Trim command to make SSD can always immediate follow the "file-deleting" from the user. Lower write amplification / higher throughput / improved endurance can be expected by Trim command issued to SSD.