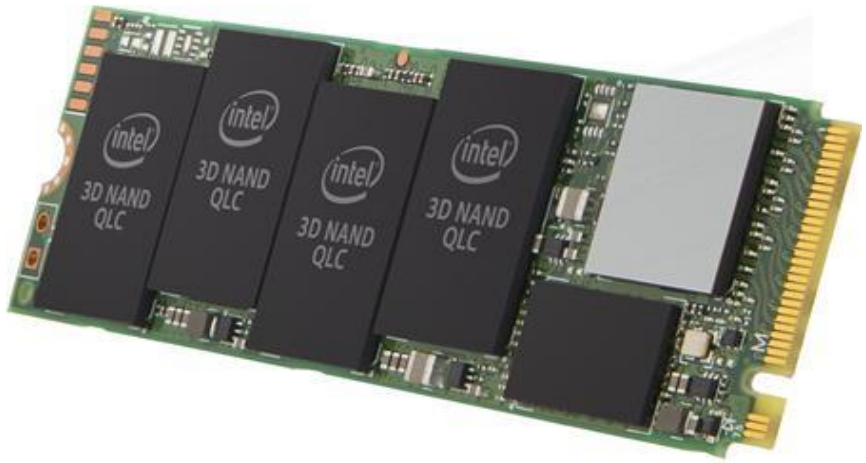
CSE360-Computer Interfacing
BRAC University
Solid State Drive (SSD)



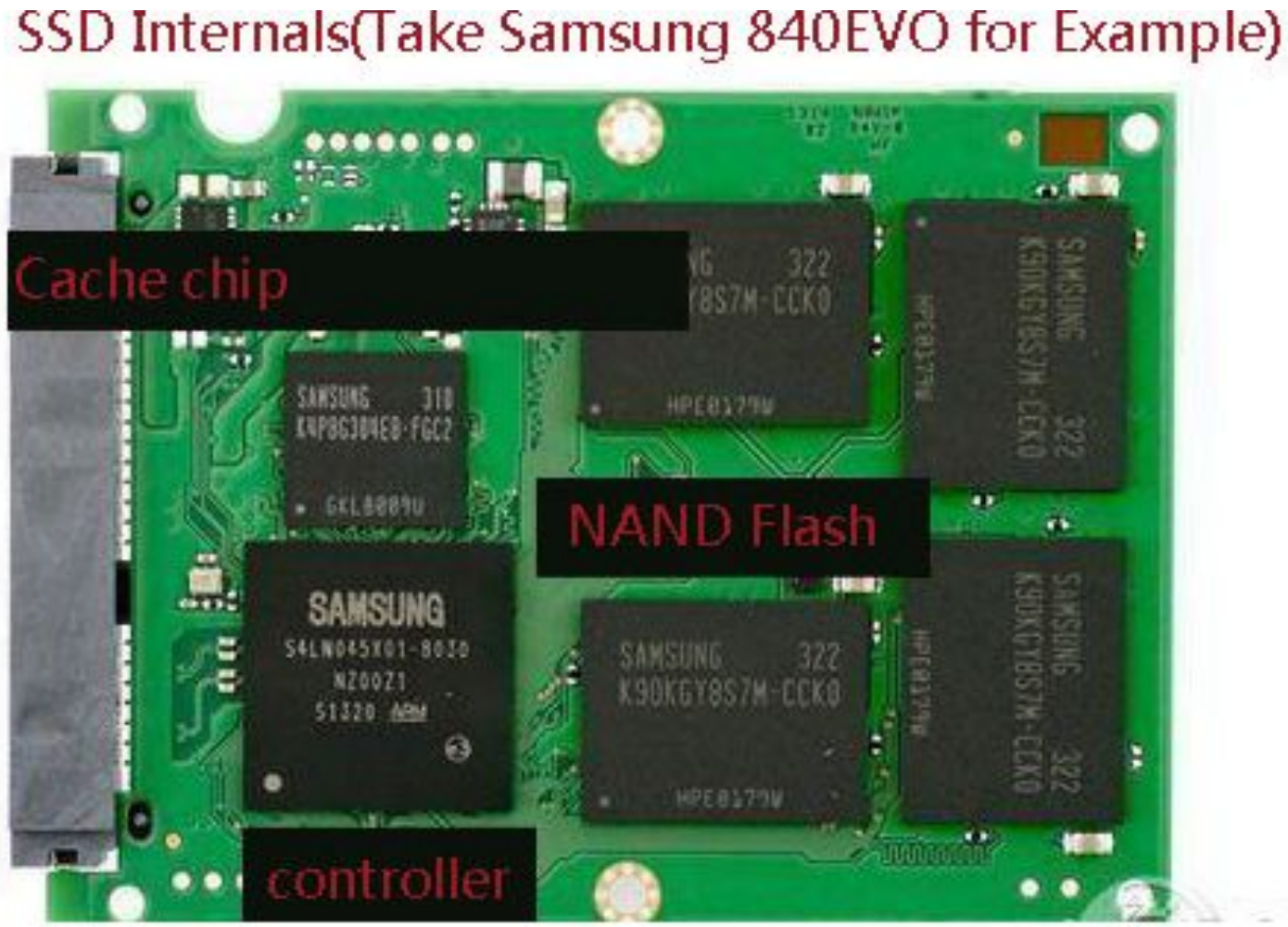
Solid State Drive

- An SSD is a Solid State Drive that is used to store data, files and applications, as well as to run computing devices.
- Solid state drives offer significant performance advantages over conventional hard disk drives (HDDs).
- SSDs do not have any moving mechanical components, which distinguishes them from traditional magnetic disks such as hard disk drives(HDDs).
- SSDs use microchips that retain data in non-volatile memory chips.
- SSD uses non volatile NAND Flash Memory , which enables it to retain data when the power is removed.

Internal Components and Design

Major Components:

1. Outer Shell
2. NAND Flash
3. Controller
4. Firmware
5. DRAM Buffer



Outer Shell

- The outer shell could be of metal or plastic and it helps in absorbing most of the heat from inside the flash memory.
- Although, SSDs don’t contain any moving parts, they give off very little heat and emit no noise. This particular feature is vital in increased durability of an SSD.
- An SSD can withstand 10X more vibration than an HDD and up to 1500G of shock (compared to less than 70Gs for a typical HDD).
- SSDs exceed expectations in handling shock, vibration, and temperature extremes as well.

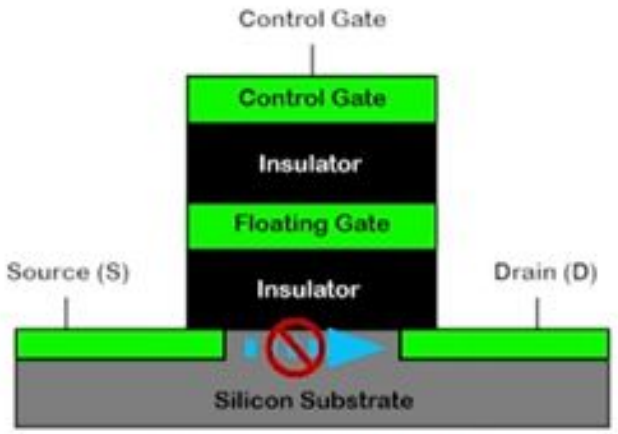
NAND Flash

- NAND Flash Memory is the key component of SSD.
- It is a specific type of EEPROM chip.
- It has a grid of columns and rows with a cell that has two transistors at each intersection as Control gate and Floating gate transistor.
- The principle of operation is based on MOSFETs.
- NAND flash memory is non-volatile that means it has ability to retain the data without a constant power supply.
- Lower cost compared to DRAM.
- Flash memory SSDs are slower than DRAM solution.
- NAND Flash components have structures called pages and blocks.

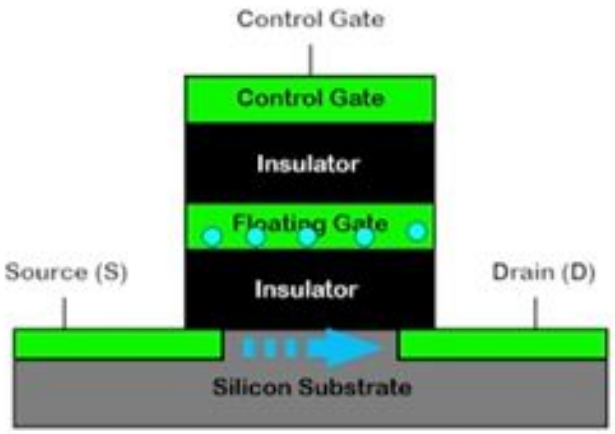
NAND Flash

- Groups of NAND flash cells are organized into pages and these pages are organized into blocks.
- Read and write operations can be performed on pages, but erase operations can only be performed at the block level.
- This means that when rewriting a page, the entire block must be erased first. This is because the act of erasing NAND flash requires a high amount of voltage.
- The SSD controller manages this process.

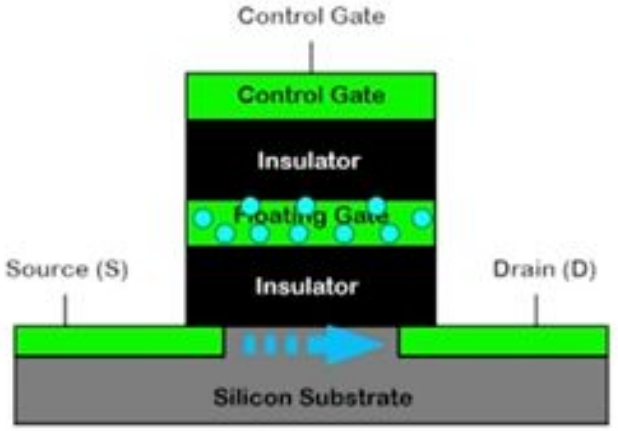
Charge States



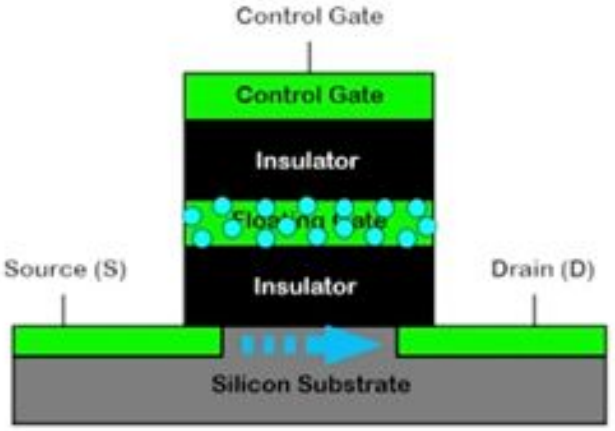
State 1 - No Charge



State 2 - Lightly Charged

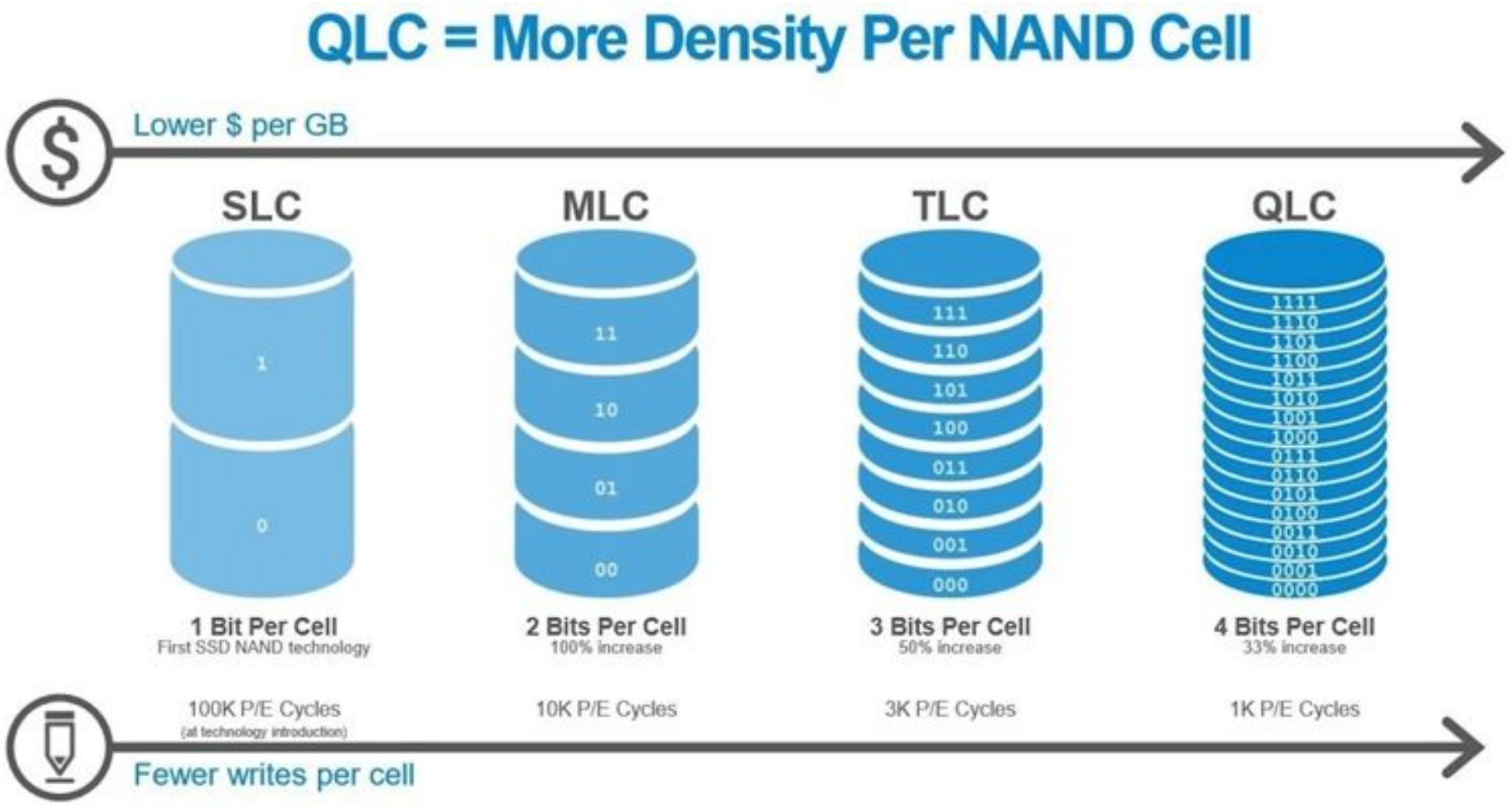


State 3 - Medium Charge



State 4 - Highly Charged

NAND Cell Storage



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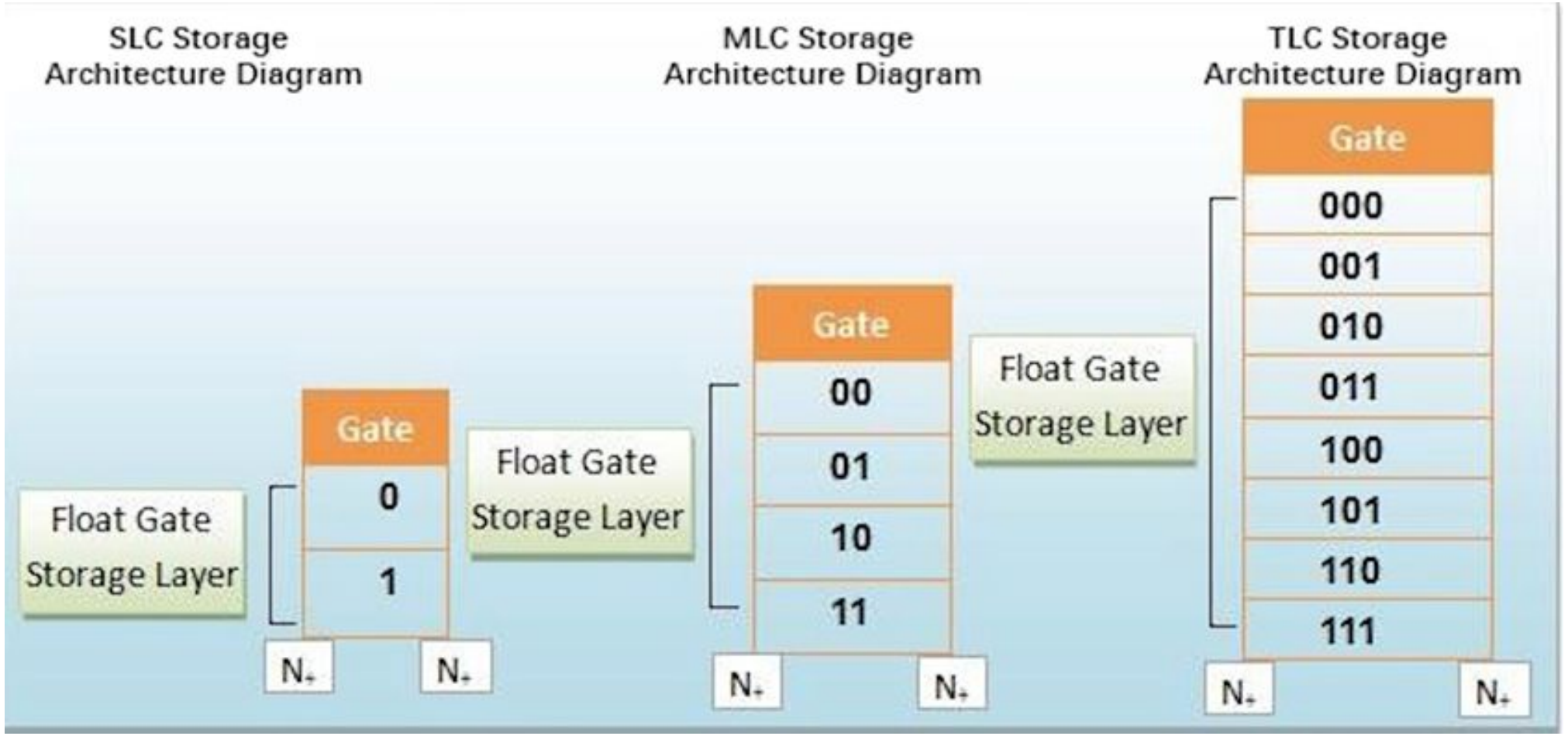
NAND Cell Storage



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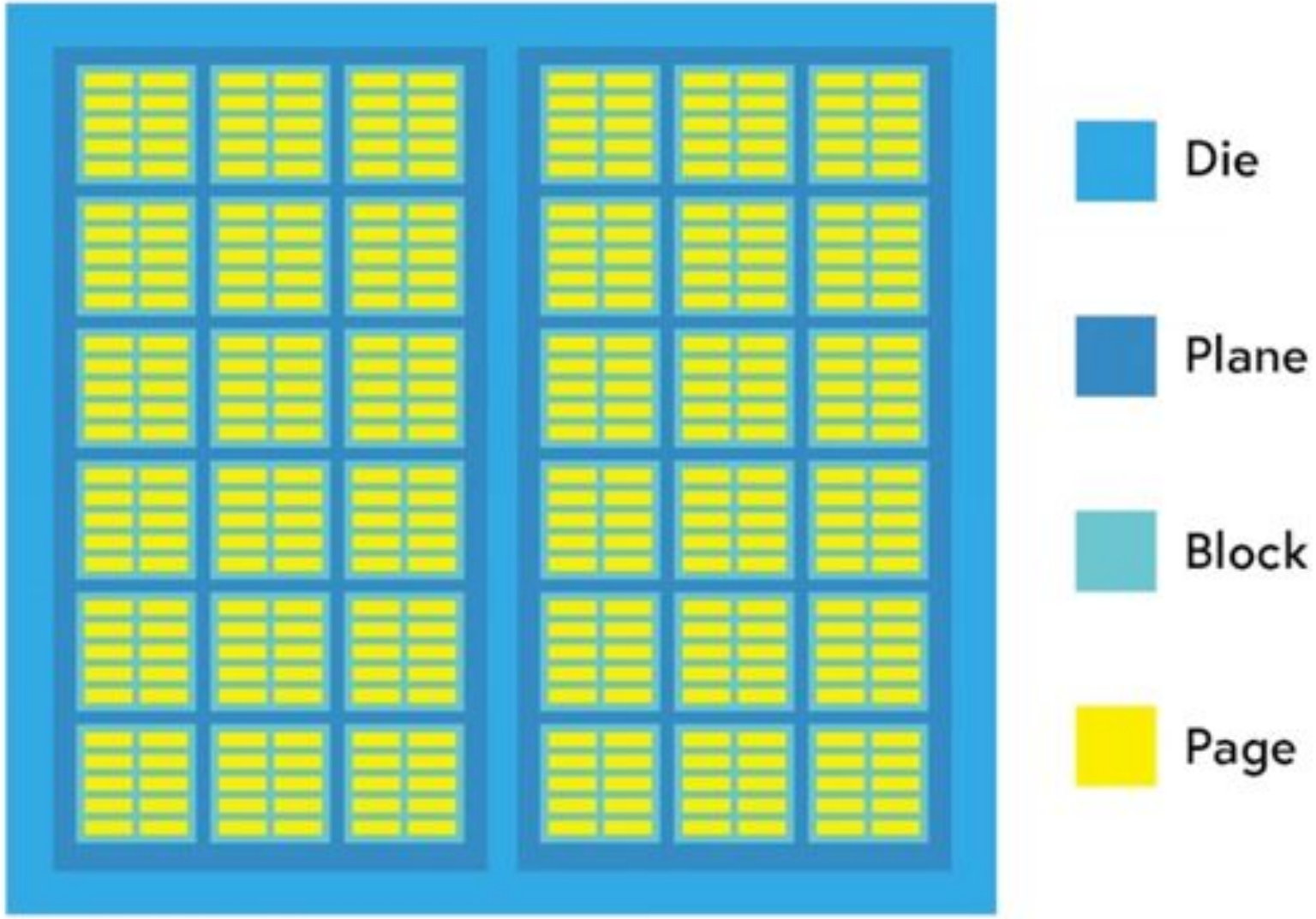
Performance Comparison

	SLC	MLC	TLC	HDD	RAM
P/E cycles	100k	10k	5k	*	*
Bits per cell	1	2	3	*	*
Seek latency (µs)	*	*	*	9000	*
Read latency (µs)	25	50	100	2000-7000	0.04-0.1
Write latency (µs)	250	900	1500	2000-7000	0.04-0.1
Erase latency (µs)	1500	3000	5000	*	*
Notes	* metric is not applicable for that type of memory				
Sources	P/E cycles [20] SLC/MLC latencies [1] TLC latencies [23] Hard disk drive latencies [18, 19, 25] RAM latencies [30, 52] L1 and L2 cache latencies [52]				

NAND Flash Die Layout



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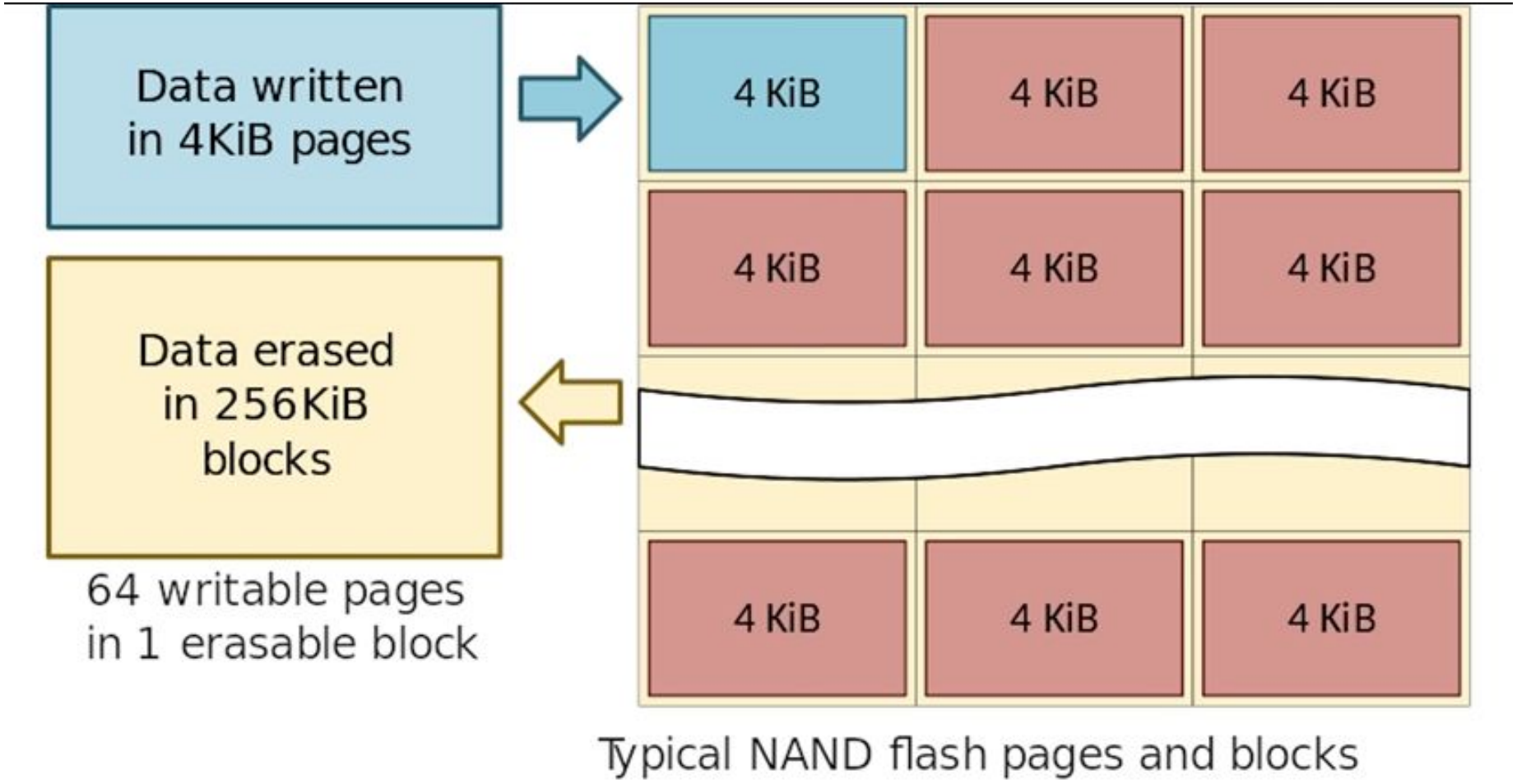
NAND Flash

- The only way for an SSD to update an existing page is to copy the contents of the entire block into memory, erase the block, and then write the contents of the old block + the updated page.
- If the drive is full and there are no empty pages available, the SSD must first scan for blocks that are marked for deletion but that haven't been deleted yet, erase them, and then write the data to the now-erased page.
- Garbage collection is a background process that allows a drive to mitigate the performance impact of the program/erase cycle by performing certain tasks in the background.

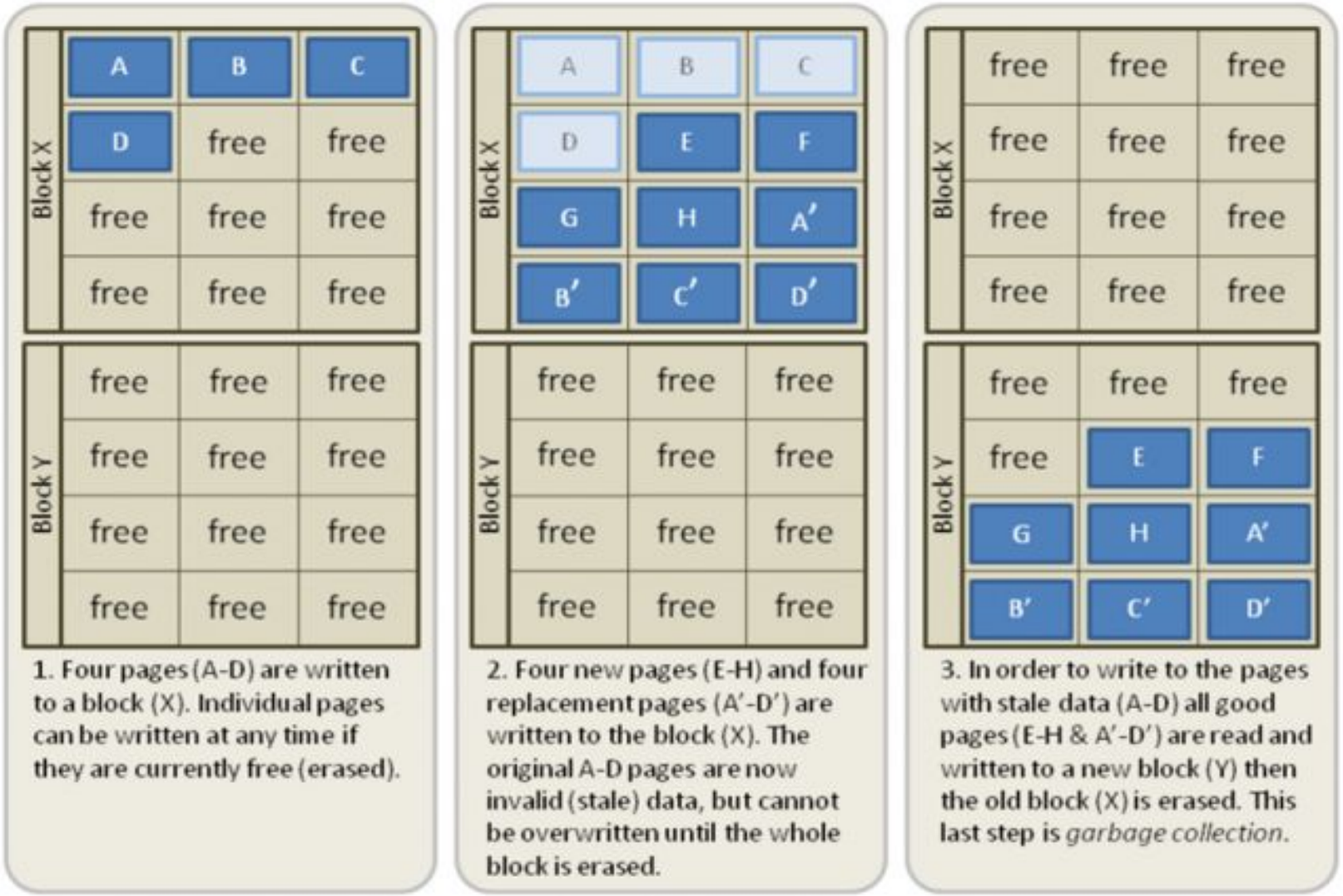
Data Read, Write and Erase



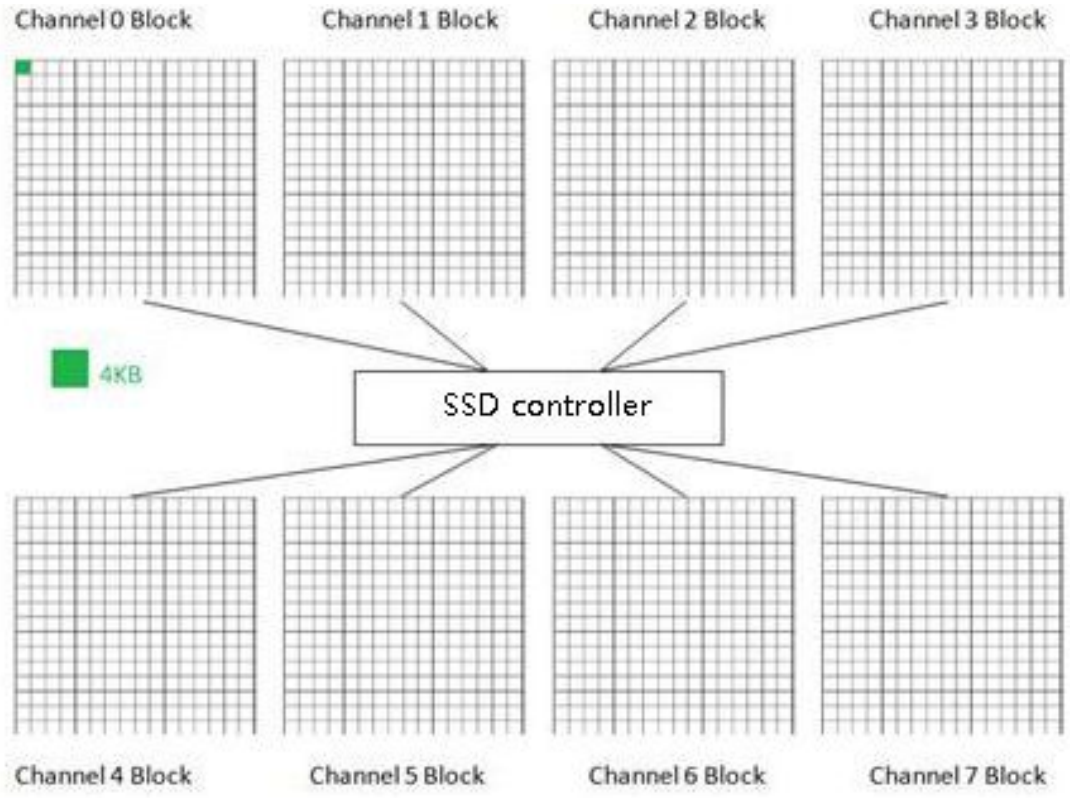
Some Important Concepts

1. Garbage Collection
2. TRIM Command
3. Wear Leveling
4. Write Amplification
5. Over-Provisioning

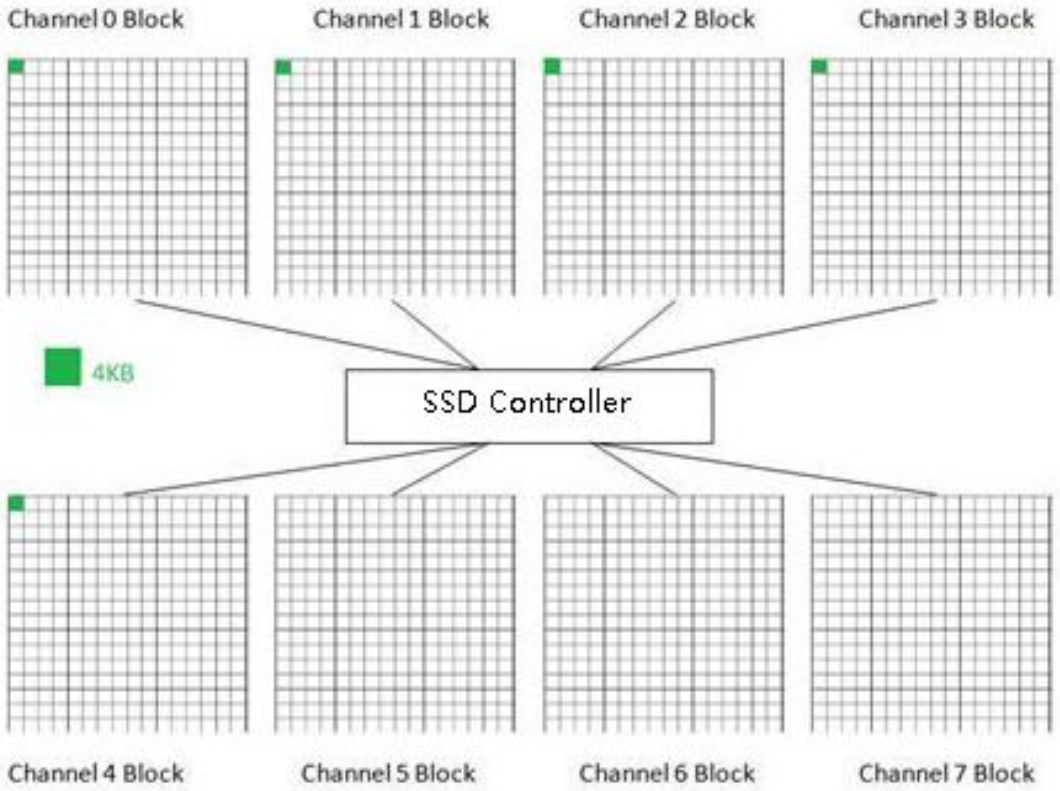
Garbage Collection



Wear Leveling

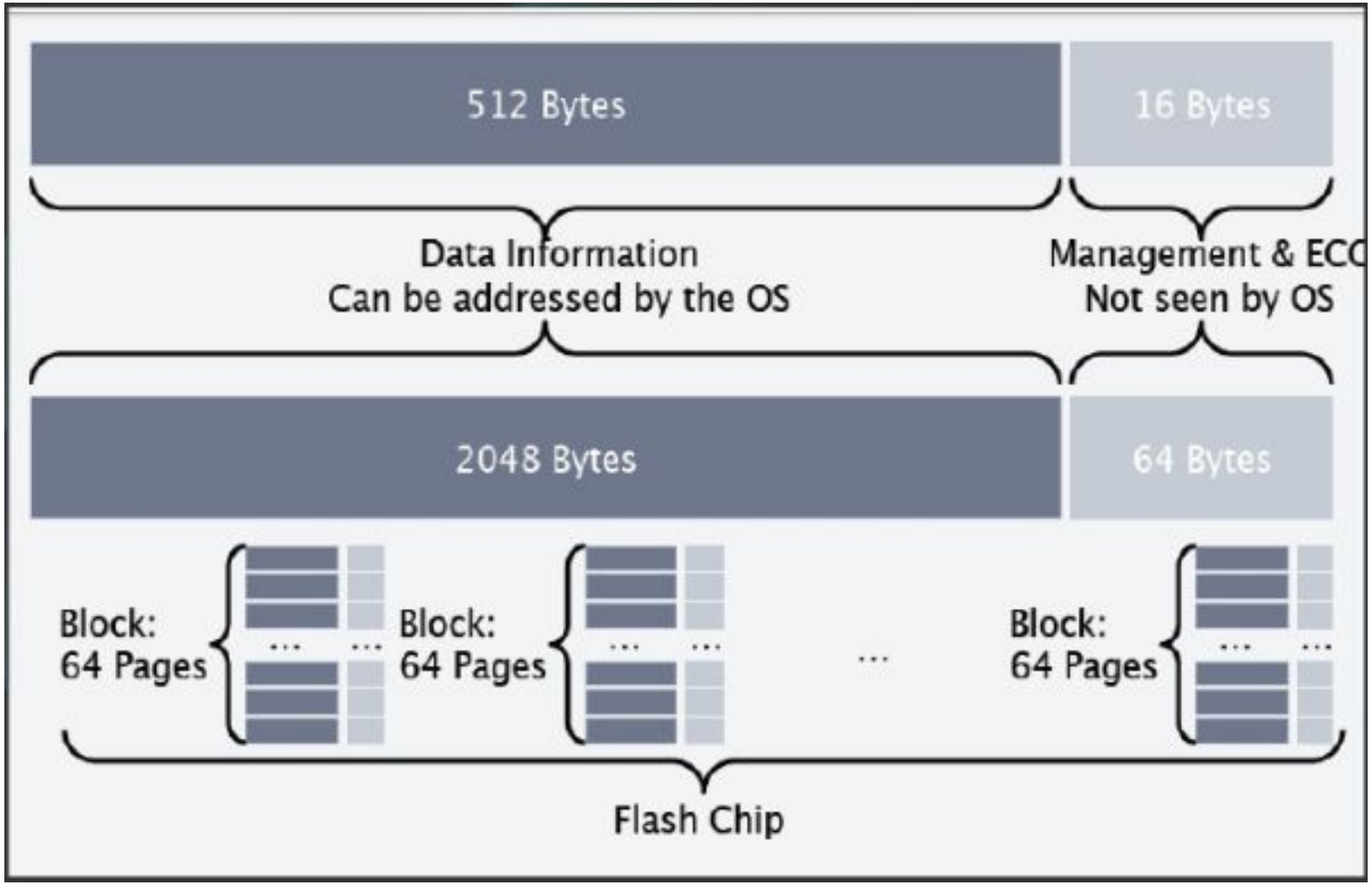


When HOST write 4KB of data:



HOST continues to write 16KB of data

Over-Provisioning



SSD Controller

- Flash controller includes the electronics that bridge the Flash memory components to the SSD input/output interfaces.
- The controller is an embedded processor that executes firmware-level software.
- Every SSD includes a controller i.e. an embedded processor that executes firmware-level code and is one of the most important factors of SSD performance.
- Functions:
  1. Error Correction(ECC).
  2. Bad block mapping.
  3. Read disturb management.
  4. Read and write caching.
  5. Encryption.

DRAM

- A bit of DRAM is included in every SSD for the process of buffering.
- Similar to hard drive's cache, data is stored on it for some time temporarily before it is being written to the device.
- It increases SSD performance to some level.

Advantages

- High performance-Significantly faster than a standard HDD.
- Faster seek time-Up to 60x faster than HDD.
- Higher reliability-No moving parts.
- Lower power-Lesser power consumption, cooler operation.
- Silent Operation-Ideal for post production environments.
- Light weight-Perfect for portable devices.
- Wider Operating Temp.

Disadvantage

- They are more expensive than traditional hard drives.
- They currently offer less storage space then traditional hard drives.
- Flash memory SSDs are slower than DRAM solution.

Applications

- Desktop Computers
- Laptops
- Ultra books
- HD Camcorder, CCTV Digital Video Recorder (DVR)
- Smart TV
- Set Top Boxes
- Mobile Phones
- Servers - SSD are used as cache at server side of Enterprises.

SSD vs HDD

2.5" SATA 3.3 Gbps SSD		2.5" SATA 3.8 Gbps HDD
Solid NAND Flash based	**Mechanism Type**	Magnetic Rotating platters
64GB	**Density**	80 GB
75gm	**Weight**	365gm
Read: 100MB/s Write: 80MB/s	**Performance**	Read: 59MB/s Write: 60MB/s
1W	**Active Power Consumption**	3.86W
10-2000Hz	**Operating Vibration**	22-350Hz
1500G/0.5ms	**Shock Resistance**	170G/).5ms
0 °C– 70°C	**Operating Temperature**	5°C– 55°C
None	**Acoustic Noise**	0.3 dB
MTBF > 2M hours	**Endurance**	MTBF < 0.7M hours

Thank You

For Your Attention