

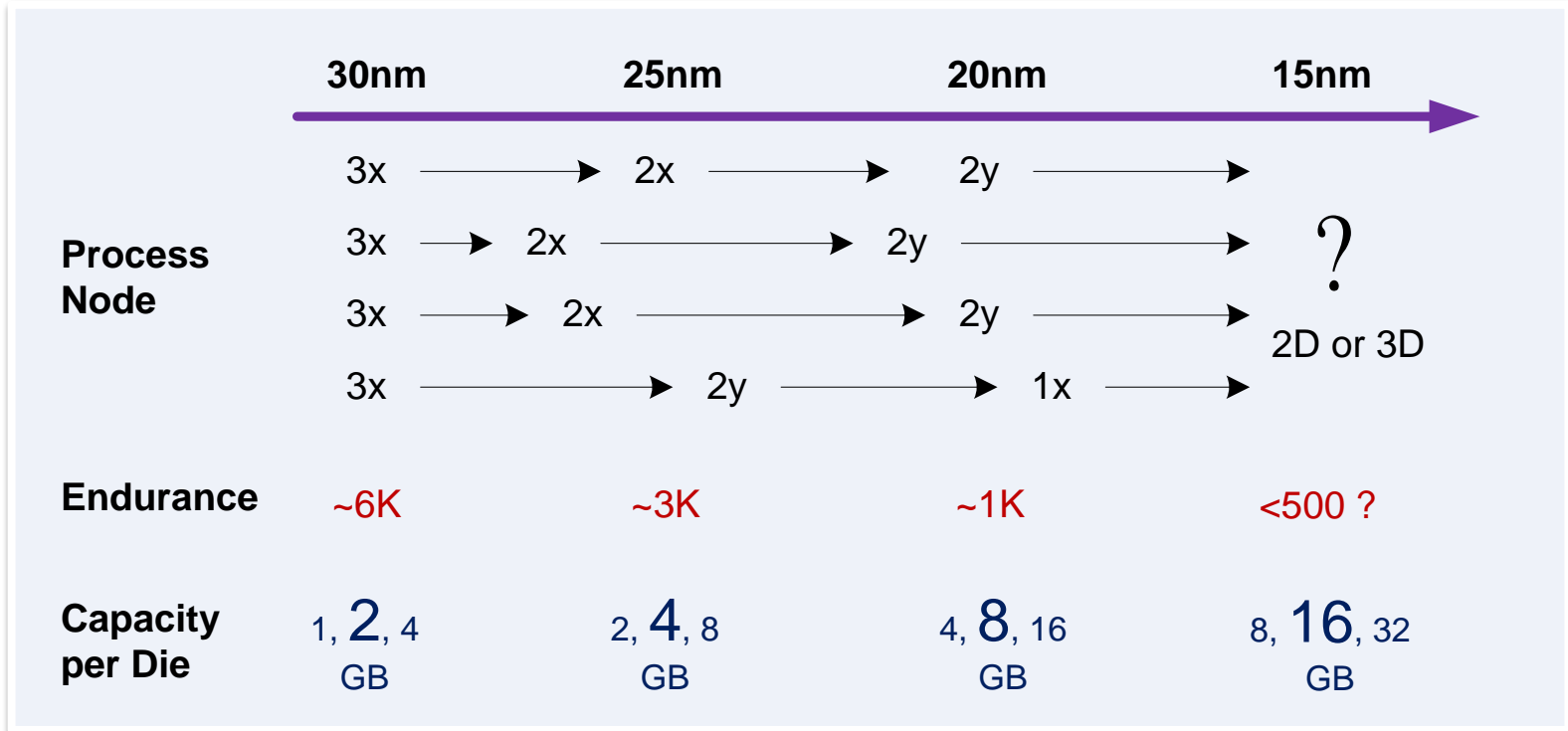
SSD Controller Technologies for TLC NAND

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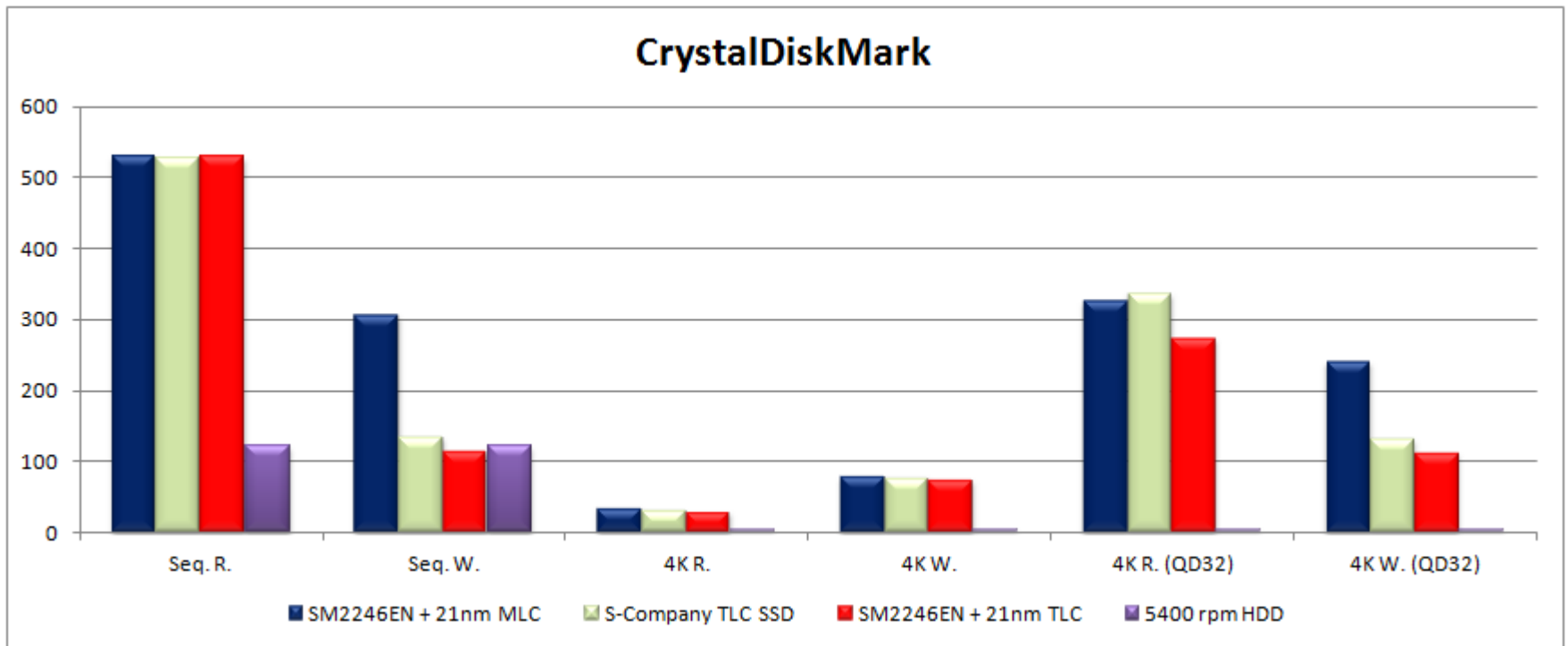
NAND Evolution and Effects

- New NAND Flash
 - Advanced smaller process nodes
 - Double capacity, but with half endurance capability



Performance – Throughput

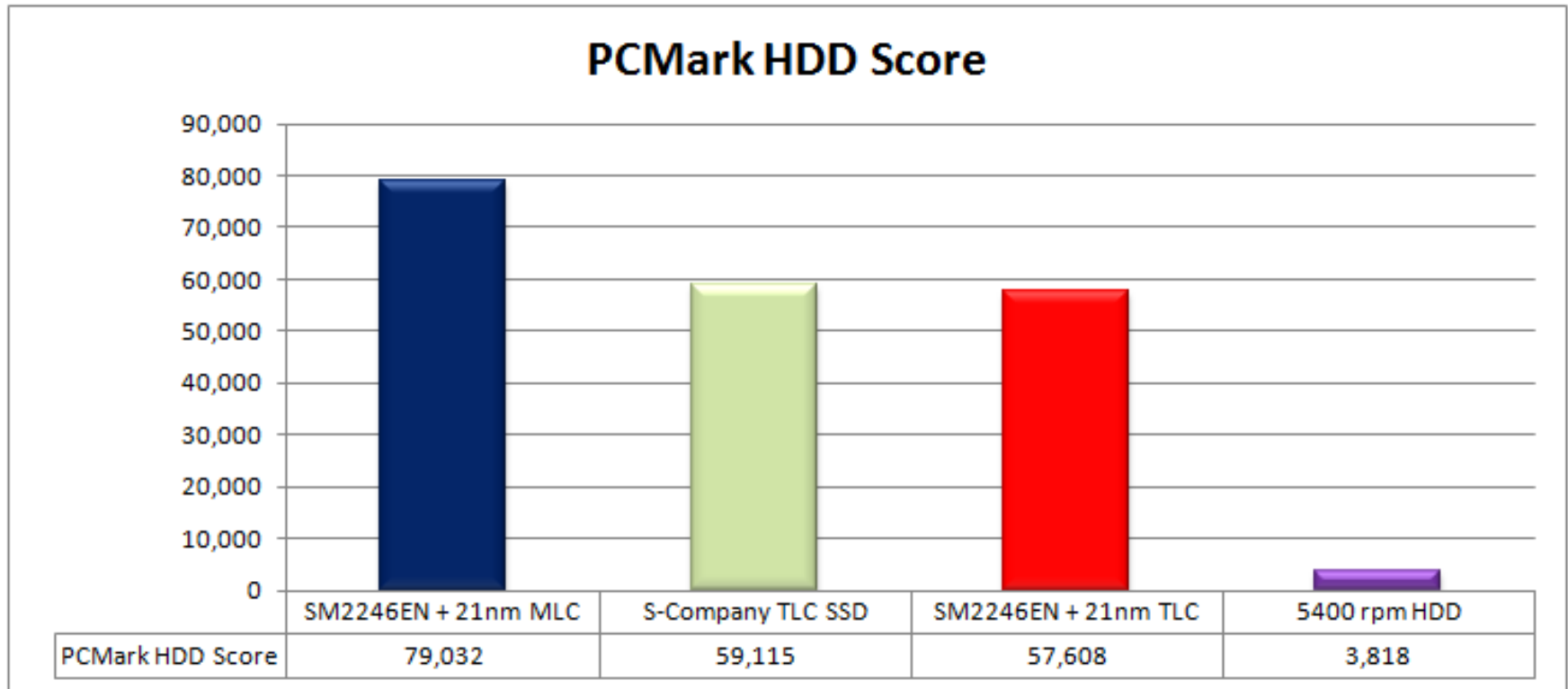
- 128GB TLC SSD vs MLC SSD vs HDD
- Read Performance: MLC = TLC = **4X** HDD!
- 4K Write Performance: MLC = 2X TLC; TLC = **120X** HDD



* Based on Silicon Motion Internal Testing

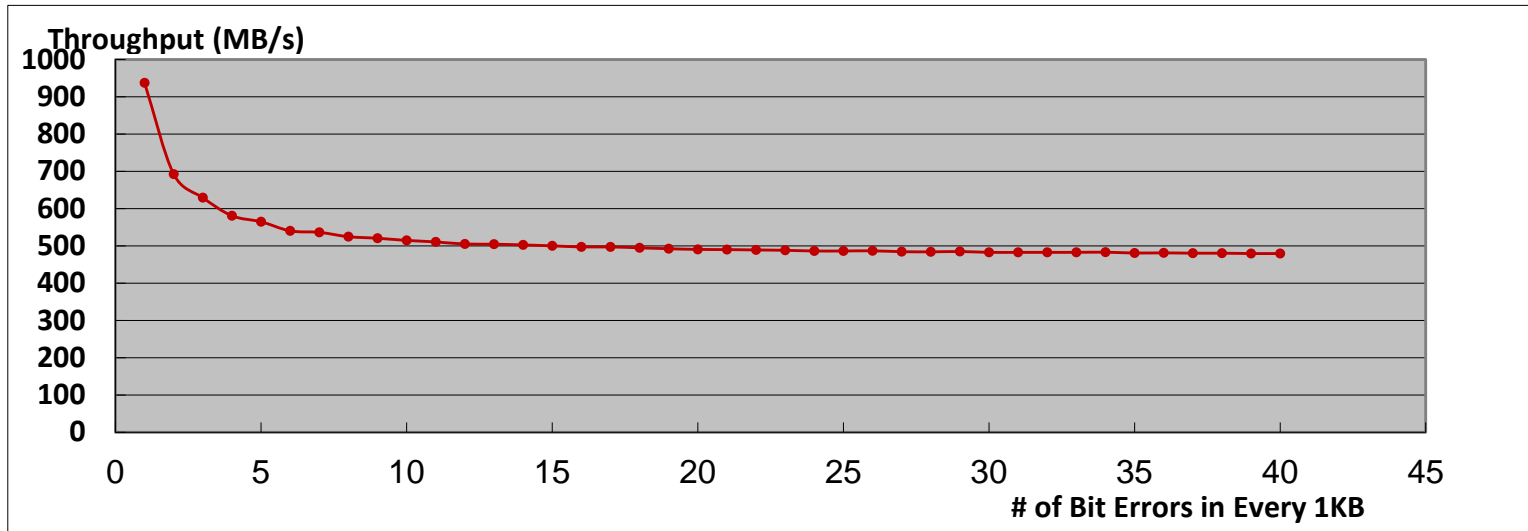
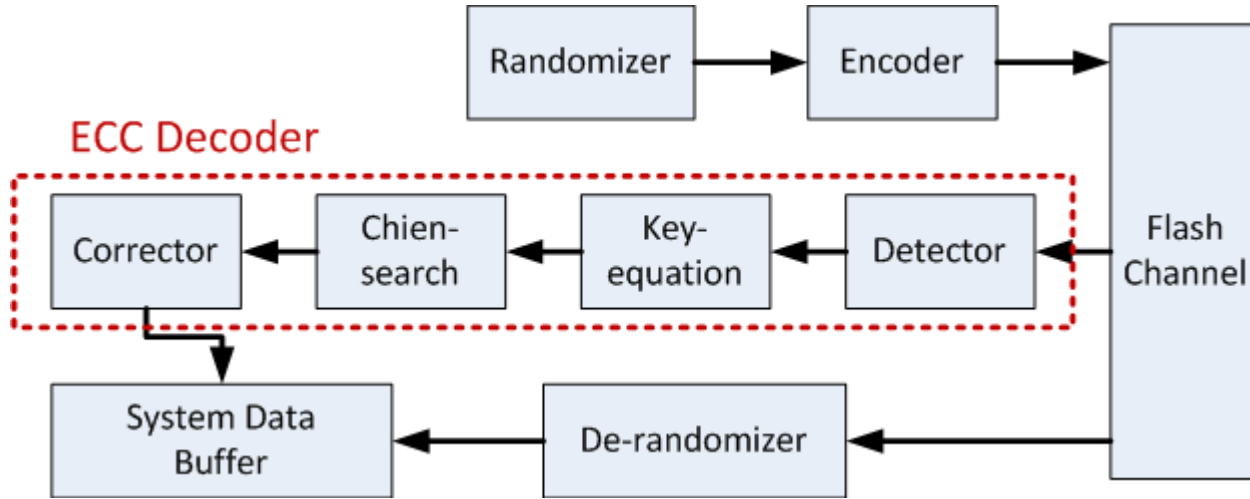
Performance – PCMark HDD Score

- TLC SSD is around 70% of MLC SSD (128GB)
- 128GB TLC SSD: **16X** HDD!!

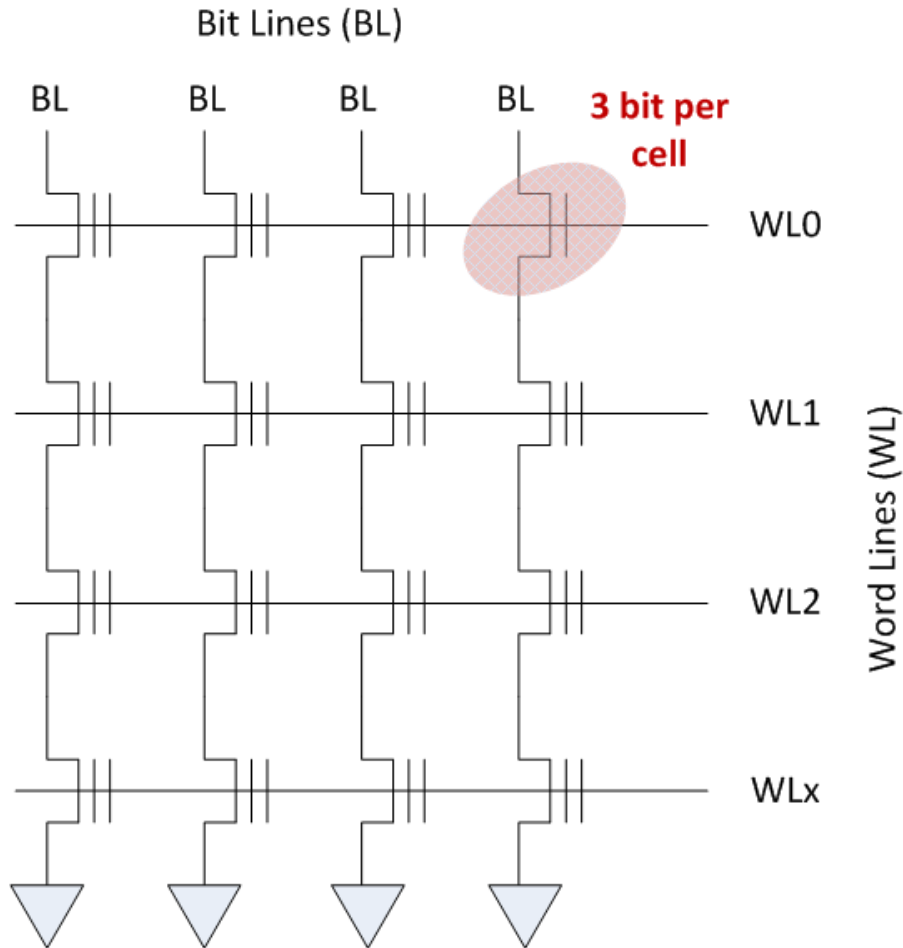


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Sustainable ECC Throughput



TLC Architecture – Program Disturbance

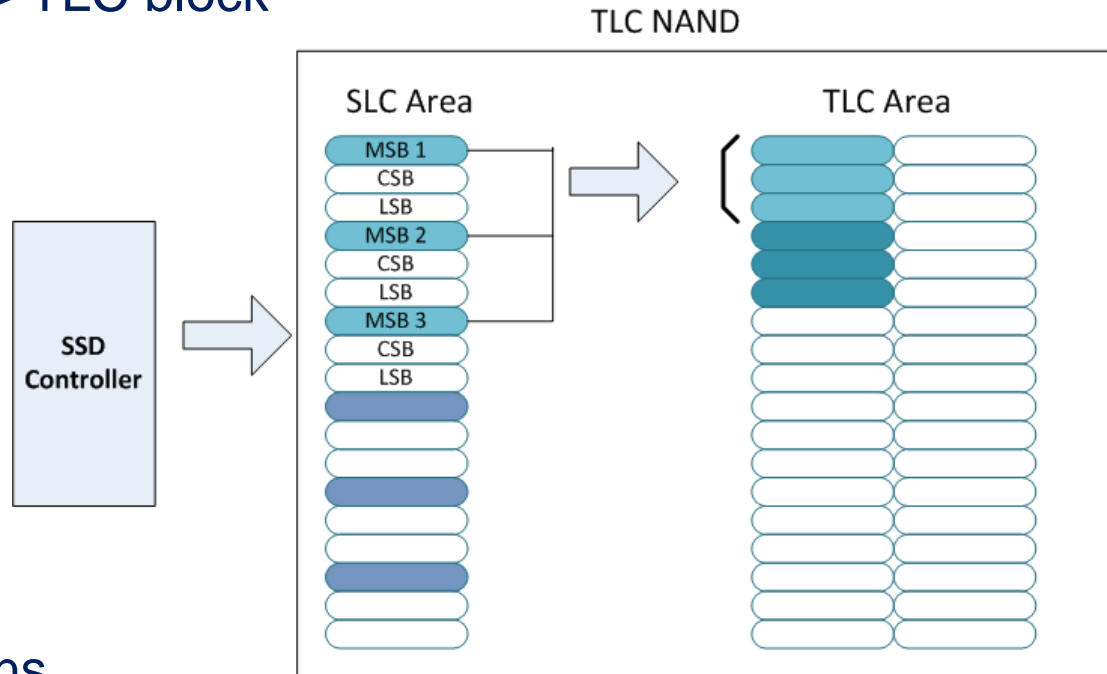


Program Disturbance

- Voltage state shifted when programming the adjacent WL
- 3 times in a special order
 - 0-1-0-2-3
- ECC errors occur if reading data before WL completely programmed.

SLC as the Cache of TLC

- 3 SLC block -> TLC block



- Pros and Cons

1. Better data loss prevention when sudden power off
2. Write speed drops when SLC cache full
3. Smaller capacity

Endurance vs. Retention, BCH vs. LDPC

1KB BCH Protection

Endurance	600	1200	1800	2400	3000	3600
84 hrs	○	X	X	X	X	X
74 hrs	○	X	X	X	X	X
68 hrs	○	X	X	X	X	X
60 hrs	○	X	X	X	X	X
52 hrs	○	X	X	X	X	X
44 hrs	○	X	X	X	X	X
36 hrs	○	X	X	X	X	X
28 hrs	○	X	X	X	X	X
24 hrs	○	X	X	X	X	X
20 hrs	○	X	X	X	X	X
16 hrs	○	X	X	X	X	X
12 hrs	○	○	X	X	X	X
8 hrs	○	○	X	X	X	X
4 hrs	○	○	○	X	X	X
Endurance	○	○	○	○	○	○

1KB LDPC Protection

Endurance	600	1200	1800	2400	3000	3600
84 hrs	○	○	○	X	X	X
74 hrs	○	○	○	X	X	X
68 hrs	○	○	○	X	X	X
60 hrs	○	○	○	○	X	X
52 hrs	○	○	○	○	X	X
44 hrs	○	○	○	○	X	X
36 hrs	○	○	○	○	X	X
28 hrs	○	○	○	○	○	X
24 hrs	○	○	○	○	○	X
20 hrs	○	○	○	○	○	X
16 hrs	○	○	○	○	○	X
12 hrs	○	○	○	○	○	X
8 hrs	○	○	○	○	○	X
4 hrs	○	○	○	○	○	X
Endurance	○	○	○	○	○	○

- All data sectors are correctable
- At least one data sector is uncorrectable

Based on: 2ynm TLC, 120C baking

Life Span Estimation – JEDEC Workload

- According to JESD-218 standard
 - 49GB workload data on 128GB SSD
 - Data collected on standard laptop used for office productivity, storage of photos, music and Apps

Total # of Commands	39,923,531	%
# of Trims	2,498,963	6.26%
# of Writes	35,391,419	88.65%
# of Flush	2,033,149	5.09%
% of Sequential Writes		24.36%
% of Random Writes		75.64%
Total amount of trim data (GB)	764.92	
Total amount of write data (GB)	727.64	

Life Span Estimation

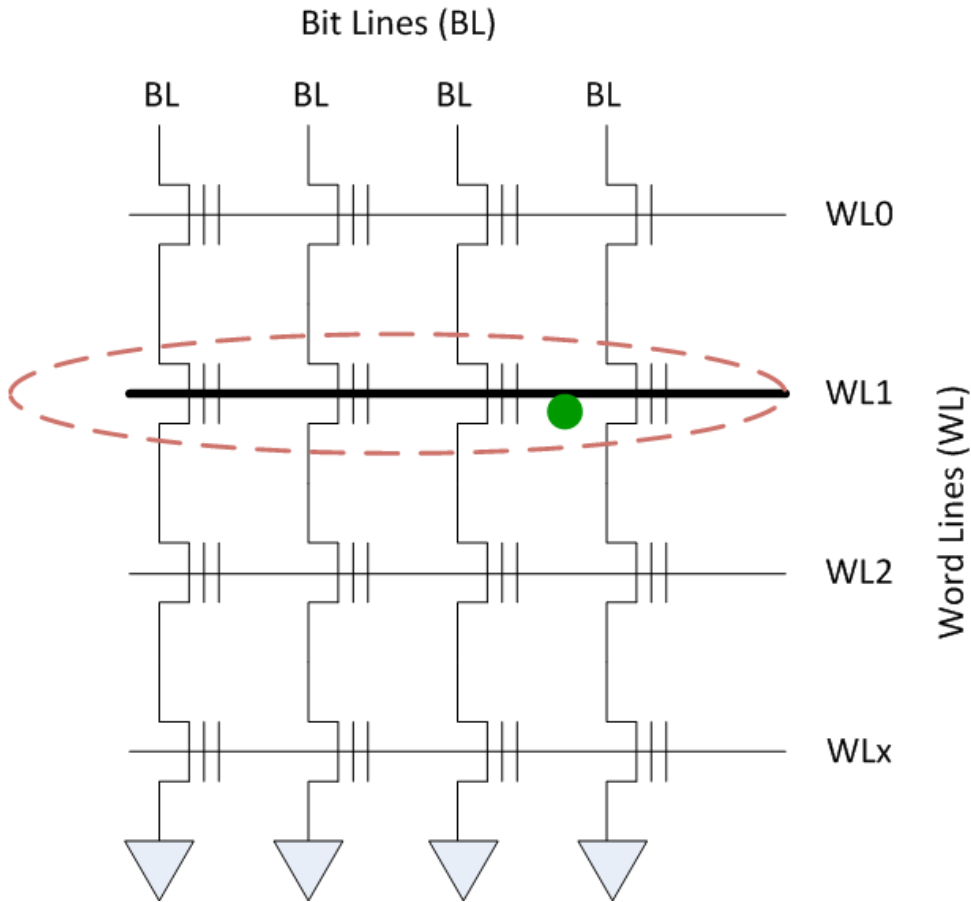
- Manage the data on 4KB basis
- WAF = 1.5 (based on Silicon Motion's Firmware Management)

LDPC

	3K Endurance		1.5K Endurance		500 Endurance	
	49GB/day	20GB/day	49GB/day	20GB/day	49GB/day	20GB/day
128GB	14 yrs	35 yrs	7 yrs	17 yrs	2.4 yrs	5.8 yrs
256GB	28 yrs	70 yrs	14 yrs	35 yrs	4.8 yrs	11.7 yrs
512GB	57 yrs	140 yrs	28 yrs	70 yrs	9.5 yrs	23.4 yrs

> 5 years

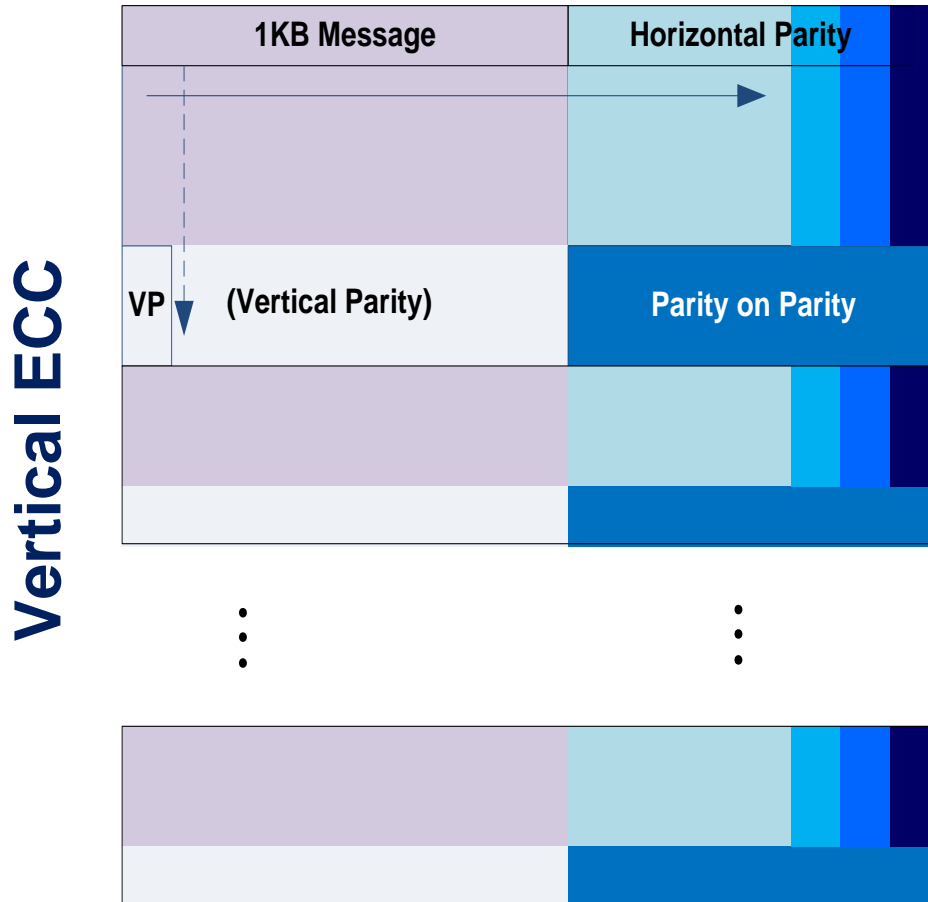
More Than Bit Errors



- Whole page data lost
- A particle on a Word Line to make WL thinner then broken
- Cannot be found by test patterns
- Long time burn in can screen some potential failure out

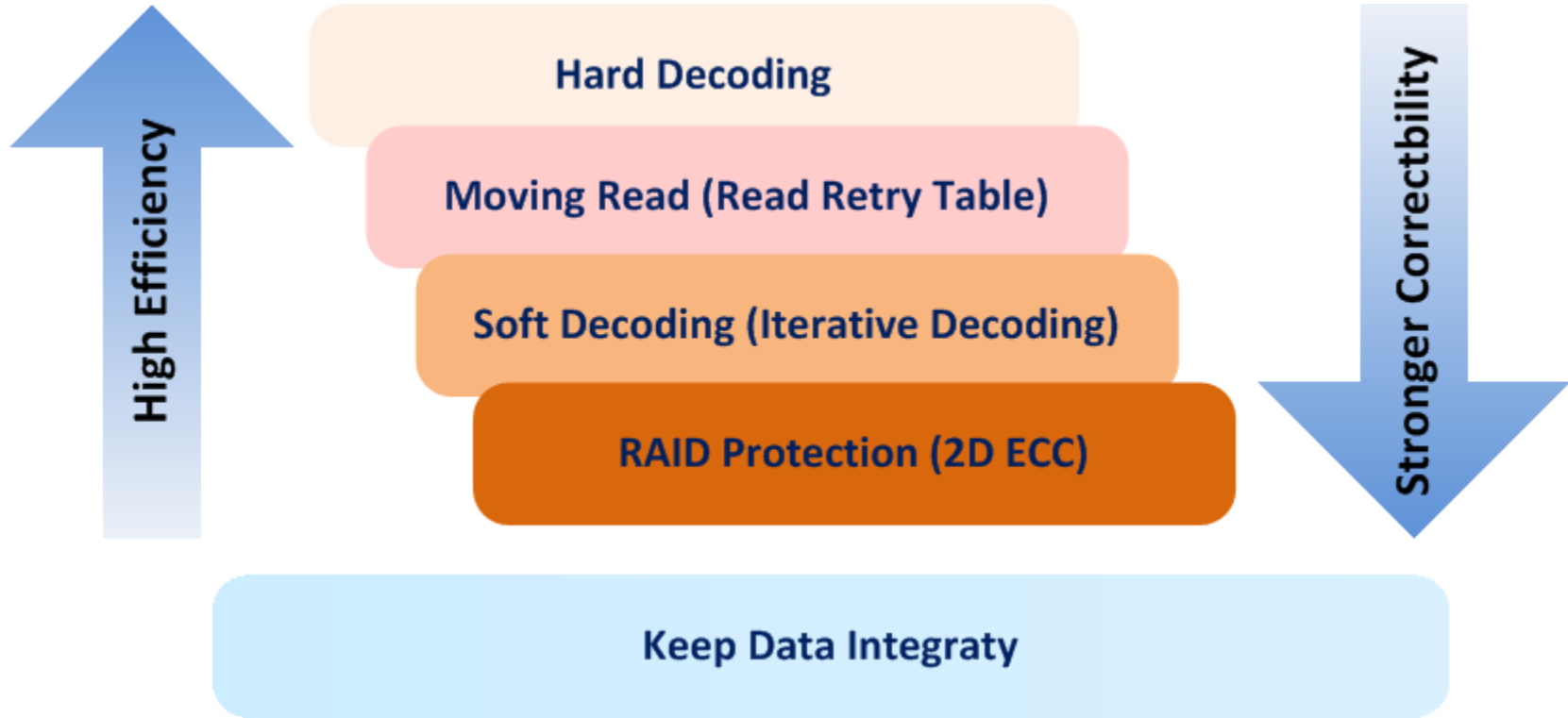
RAID-like Protection by 2-D ECC

Horizontal ECC: LDPC or BCH or RS



- Vertical ECC on a page base
- RAID5-Like
 - $(k, 1)$ by XOR,
- RAID6-Like
 - $(k, 2)$ by RS-code
 - $(2,2), (4,2), \dots, (253,2)$

Keeping Data Safe



Summary

- **TLC has the cost advantage for consumer SSD**
- **TLC SSD speed is much faster than hard drive**
 - **Read/write throughput and overall performance**
- **LDPC and different technologies extend the endurance and retention effectively, also secure the user data**
- **It will be coming soon**



THANK YOU!

Q & A

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Visit us at the booth 615

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