



Flash Memory Summit



# Advanced data integrity assurance for QLC flash

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# Agenda

- QLC feature
- Read retry
- Advanced LDPC soft decoding
- RAID6 application
- Conclusion

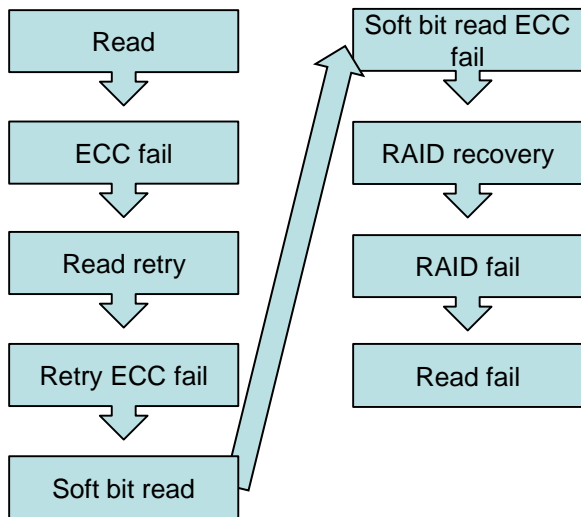


## QLC feature

- Large capacity, 1Tb/1.33Tb
- Low cost
- 100~1K PE cycles
- 2<sup>nd</sup> pass program
- Long program and read busy time
- pSLC is same



# Conventional read fail process flow

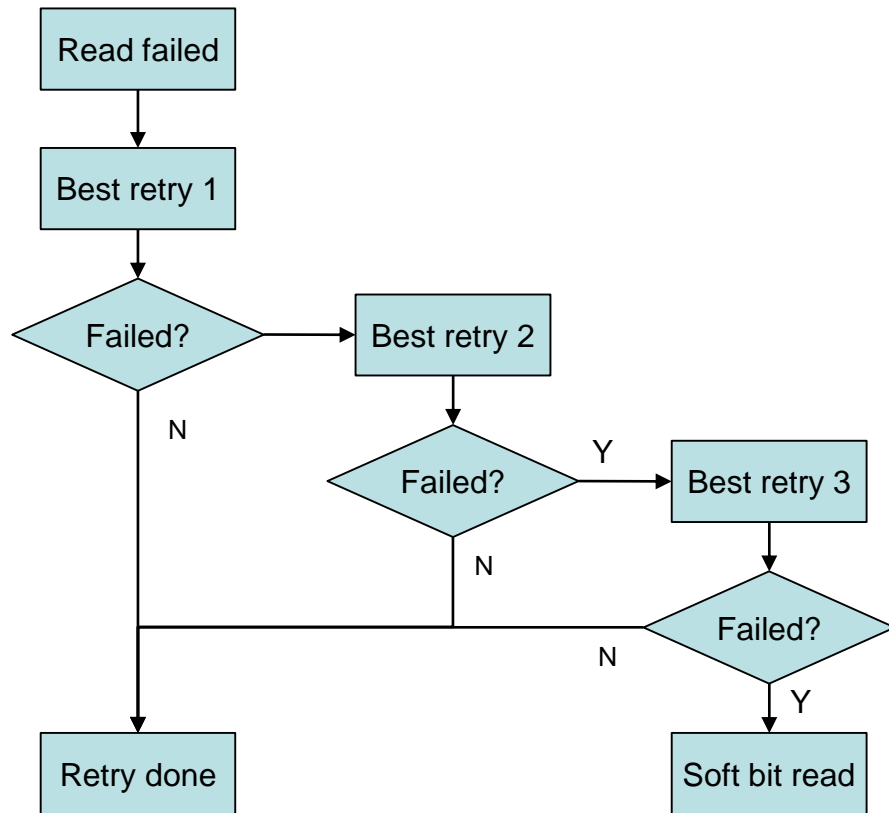


- Read retry strategy
  - Traverse all retry options
  - Smart read retry
  - Deep retry mode
- Soft bit strategy
  - One hard bit + one soft bit
  - Change LLR mapping value
- RAID
  - No RAID
  - Adopt RAID5



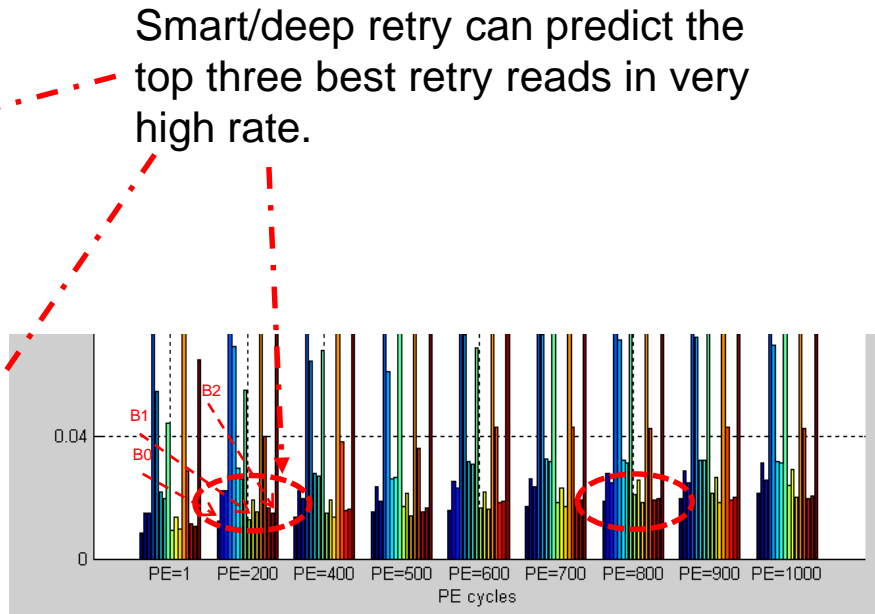
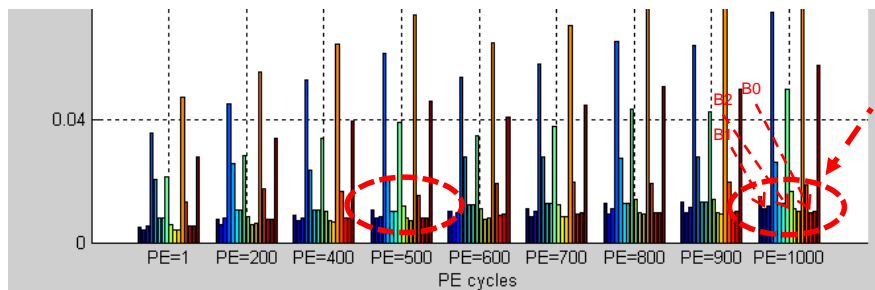
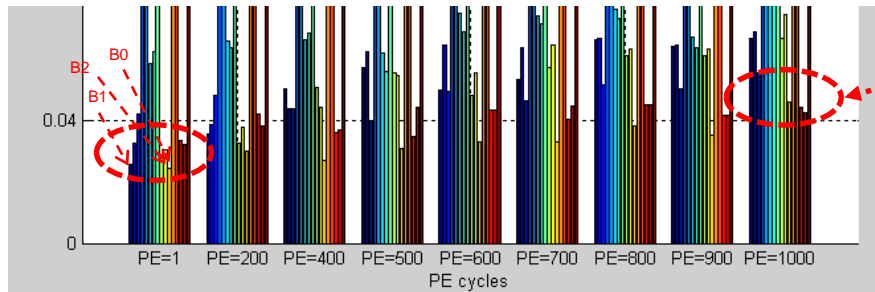
# Read retry

- Read retry options
  - MLC - ~10 options
  - TLC - ~20 options
  - QLC - ~40 options or even more
- Traverse all options is not reasonable
- Smart/deep retry first
  - 0/1 ratio
  - cell-to-cell interference
  - temperature
  - PE cycles and retention times
  - Bad cell
  - ...
- Move to soft bit after 3 smart retry reads failed





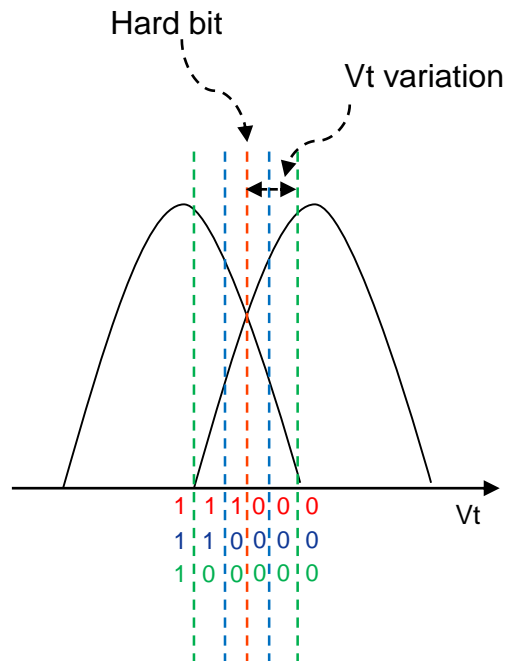
# Read retry





# Soft bit read

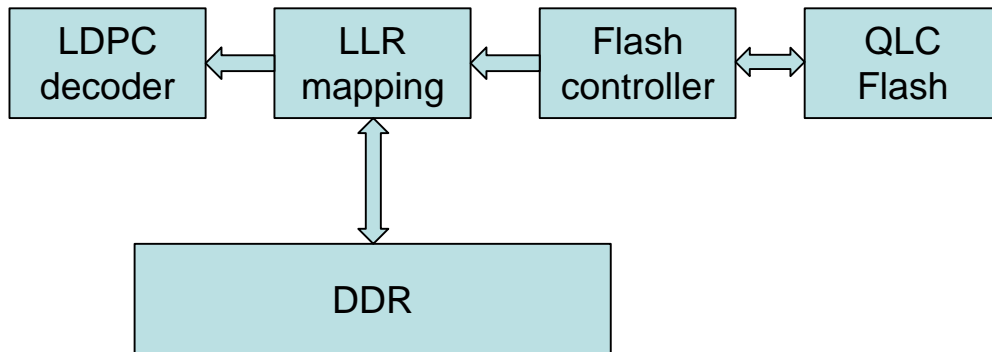
- Soft bit read cost more time
  - 1 hard bit + 1 soft bit = 3 reads
  - 1 hard bit + 2 soft bits = 5 reads
  - 1 hard bit +  $N$  soft bits =  $1 + 2 * N$  reads
- For TLC, 1 soft bit read is widely adopted





# Soft bit read

- More soft bits for better life cycle with little cost
- Soft bits were saved in DDR
- Hard bit decoding performance is not decreased
- LLR map strategy can be configured



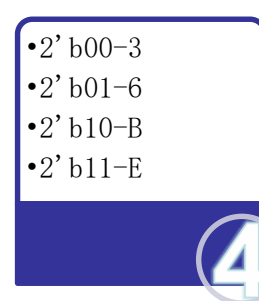
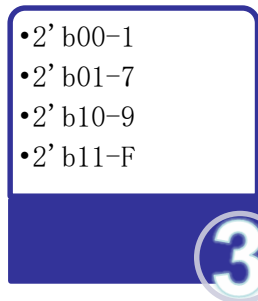
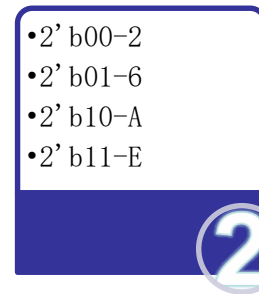
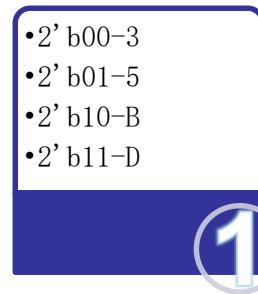




# Soft bit read

- Machine learning
  - Baseline: best read retry as hard bit
  - Vt variation in fix step
  - Use multiple LLR map value sets
  - Soft bits number from 1 to 4

## LLR Map Options





# RAID6

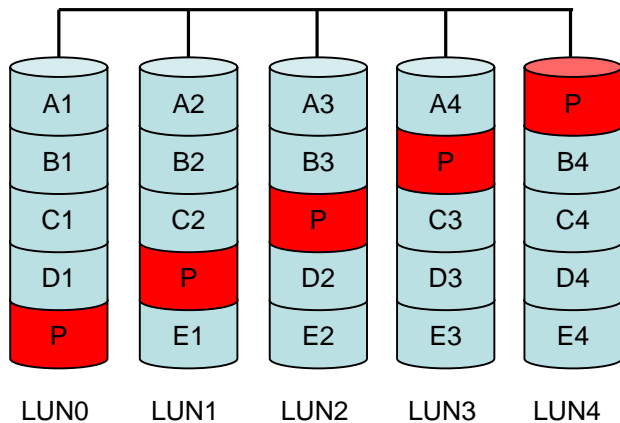
## Single Parity Block

- 7 data blocks+1 parity block
- 15 data blocks+1 parity block
- 31 data blocks+1 parity block

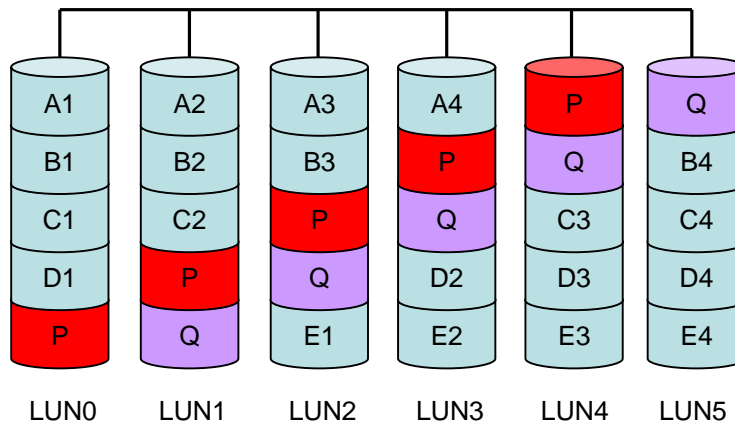
## Double Parity Block

- 6 data blocks+2 parity blocks
- 14 data blocks+2 parity blocks
- 30 data blocks+2 parity blocks

### *RAID5*



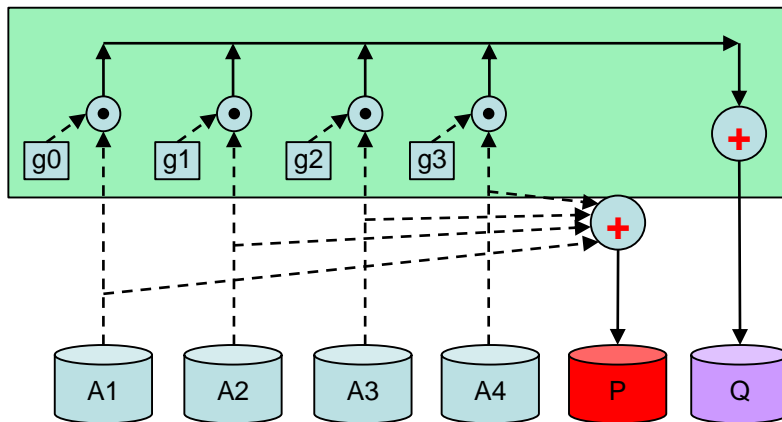
### *RAID6*





# RAID6

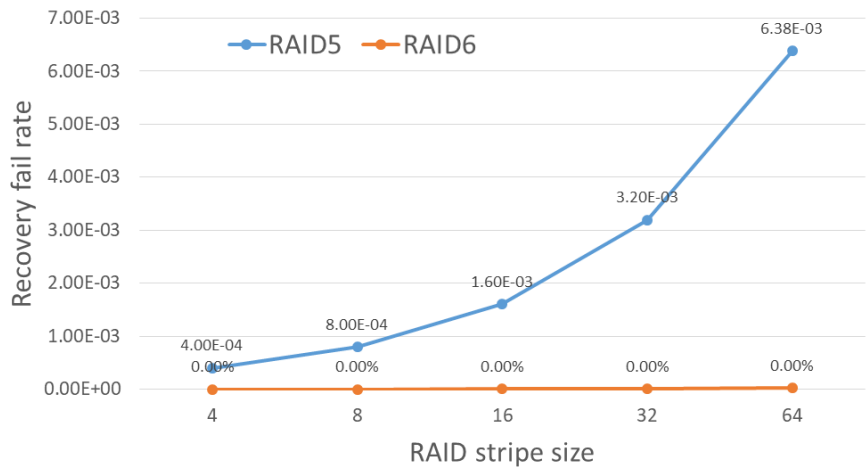
Provides better data redundancy than RAID 5 but with slightly lower capacity and possibly lower performance.



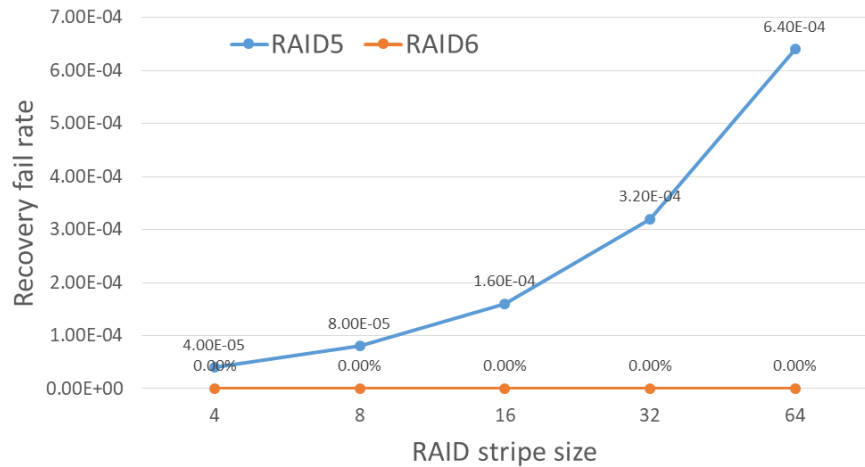


# RAID6

Read Fail Rate @ FER=1E-04



Read Fail Rate @ FER=1E-05





# RAID6

## Space efficiency

| RAID stripe size | RAID5  | RAID6  | RAID5-RAID6 |
|------------------|--------|--------|-------------|
| 4                | 75.00% | 50.00% | 25.00%      |
| 8                | 87.50% | 75.00% | 12.50%      |
| 16               | 93.75% | 87.50% | 6.25%       |
| 32               | 96.88% | 93.75% | 3.13%       |
| 64               | 98.44% | 96.88% | 1.56%       |

## Program efficiency

| RAID stripe size | RAID5   | RAID6  | RAID5-RAID6 |
|------------------|---------|--------|-------------|
| 4                | 100.00% | 66.67% | 33.33%      |
| 8                | 100.00% | 85.71% | 14.29%      |
| 16               | 100.00% | 93.33% | 6.67%       |
| 32               | 100.00% | 96.77% | 3.23%       |
| 64               | 100.00% | 98.41% | 1.59%       |



# Conclusion

- With optimized read retry and soft bit read strategy, QLC got 1.3x life cycle. Combined with RAID6, 1.7x life cycle can be got.
- As a low cost NAND flash, QLC with acceptable reliability and better data integrity assurance method can be use in a lots of applications, such as client SSD and surveillance.



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Thanks

Q&A

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