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\textsuperscript{nd} 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 failed

Best retry 1

Failed?

Best retry 2

Failed?

Best retry 3

Failed?

Retry done

Y

N

Y

N

N

Y

Soft bit read
```
Smart/deep retry can predict the top three best retry reads in very high rate.
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
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
RAID6

Provides better data redundancy than RAID 5 but with slightly lower capacity and possibly lower performance.
RAID6
## RAID6

### Space efficiency

<table>
<thead>
<tr>
<th>RAID stripe size</th>
<th>RAID5</th>
<th>RAID6</th>
<th>RAID5-RAID6</th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>75.00%</td>
<td>50.00%</td>
<td>25.00%</td>
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<tr>
<td>8</td>
<td>87.50%</td>
<td>75.00%</td>
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<td>16</td>
<td>93.75%</td>
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<td>6.25%</td>
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<td>32</td>
<td>96.88%</td>
<td>93.75%</td>
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<td>64</td>
<td>98.44%</td>
<td>96.88%</td>
<td>1.56%</td>
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</tbody>
</table>

### Program efficiency

<table>
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<th>RAID6</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>100.00%</td>
<td>66.67%</td>
<td>33.33%</td>
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<tr>
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<tr>
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<td>100.00%</td>
<td>93.33%</td>
<td>6.67%</td>
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<tr>
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<td>3.23%</td>
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<tr>
<td>64</td>
<td>100.00%</td>
<td>98.41%</td>
<td>1.59%</td>
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</tbody>
</table>
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.
Thanks

Q&A

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