

Throughput and Endurance Improvement with Online Read Level Tracking

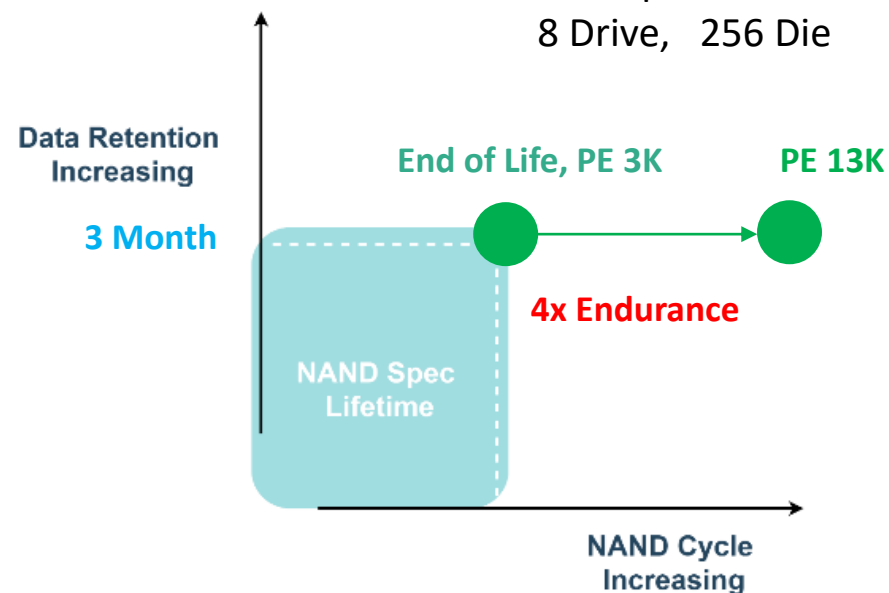
Cloud Zeng, Phison Electronics
Imran Hirani, Phison Electronics

Real Drive Testing 4x cTLC Endurance Extension

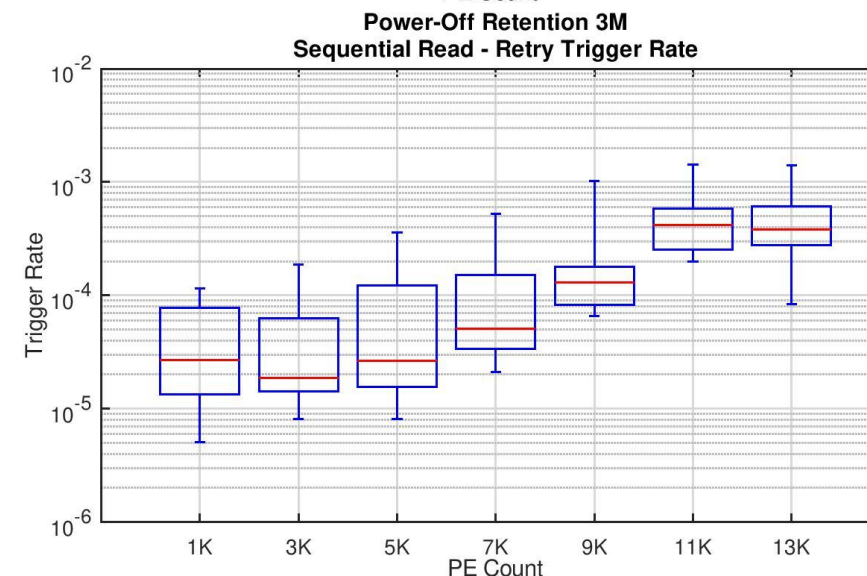
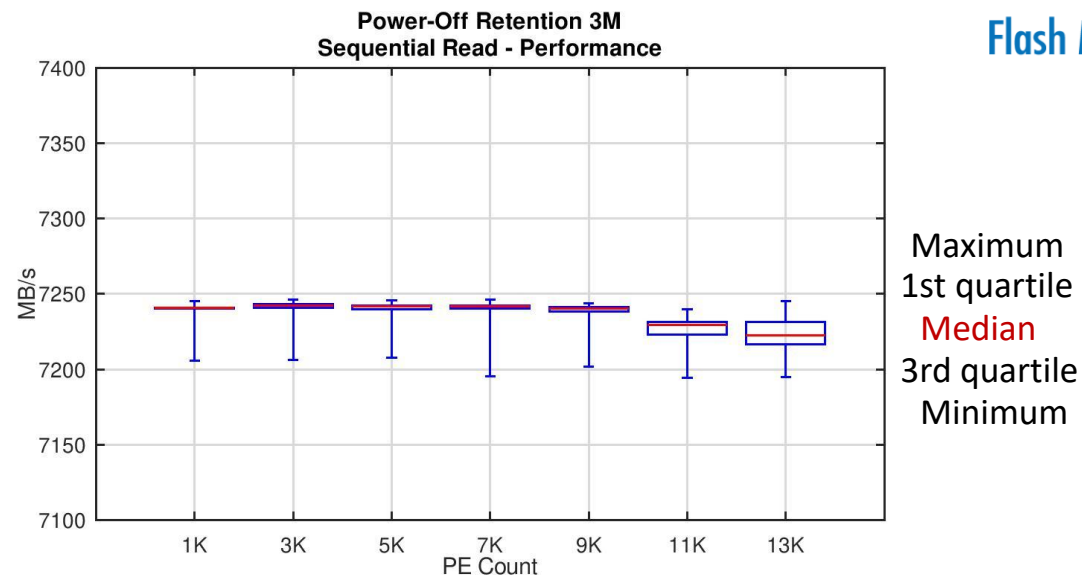


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Phison X1 + cTLC



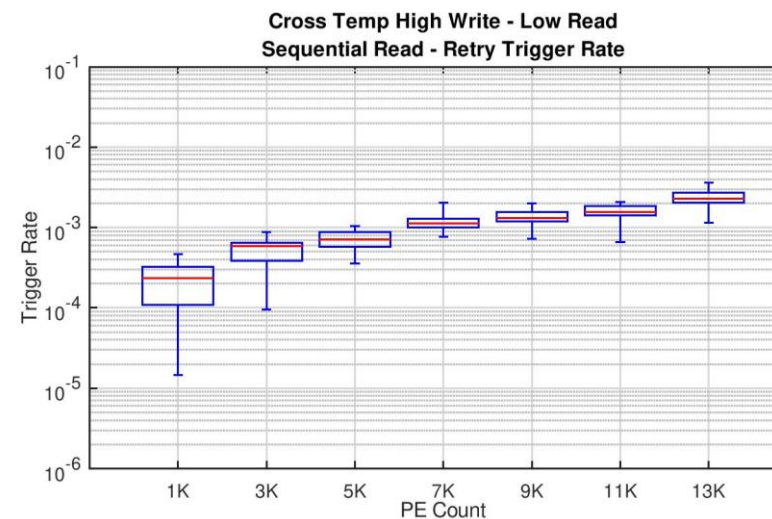
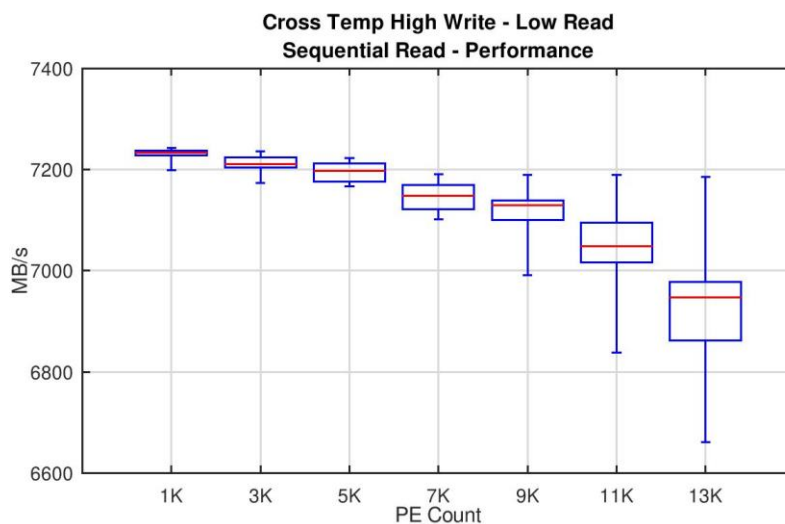
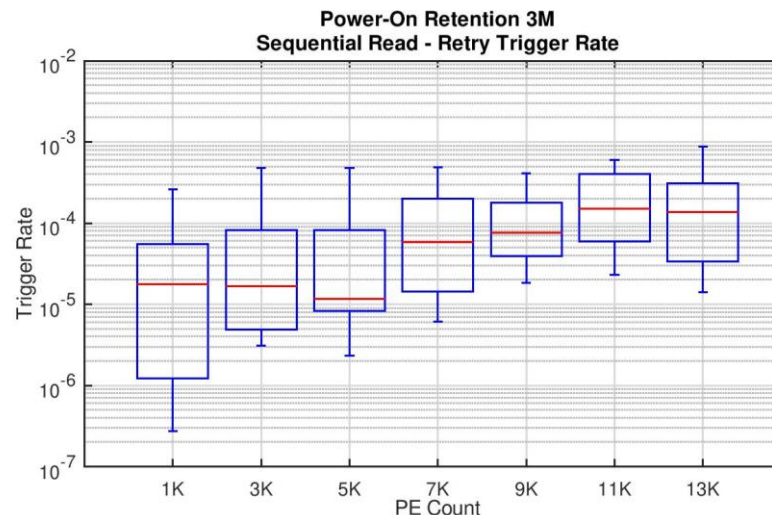
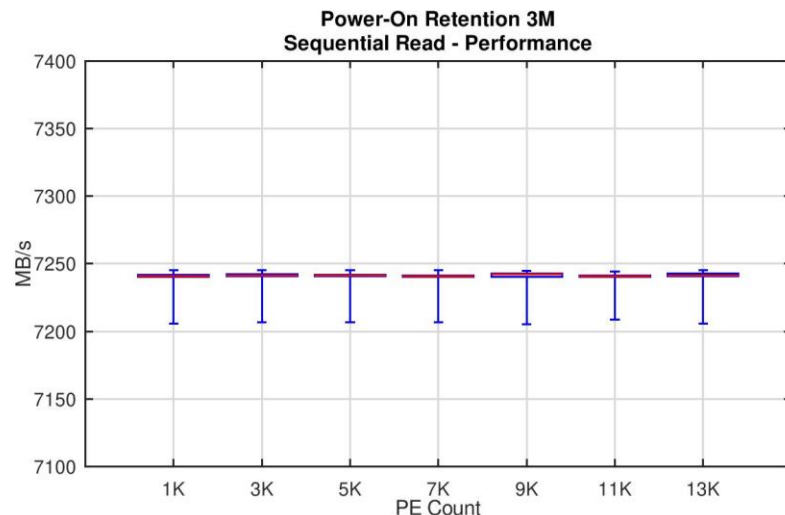
1. Reliability → No Data Loss : **No Soft Decode Triggered**
2. Performance → Read Performance : **7200 ~ 7250 MB/s**
3. Online Read Level Tracking
 - Background and Run-Time adjusted Operation
 - Retry Trigger Rate : **1e-5~1e-3**
 - Soft Decode Trigger Rate : **0**



Real Drive Testing 4x cTLC Endurance Extension



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Extra Failure Mode

1. Power-On Retention
2. Cross Temperature (0/70°C)

Power-Off Retention 3 Month
+ Power-On Retention 3 Month

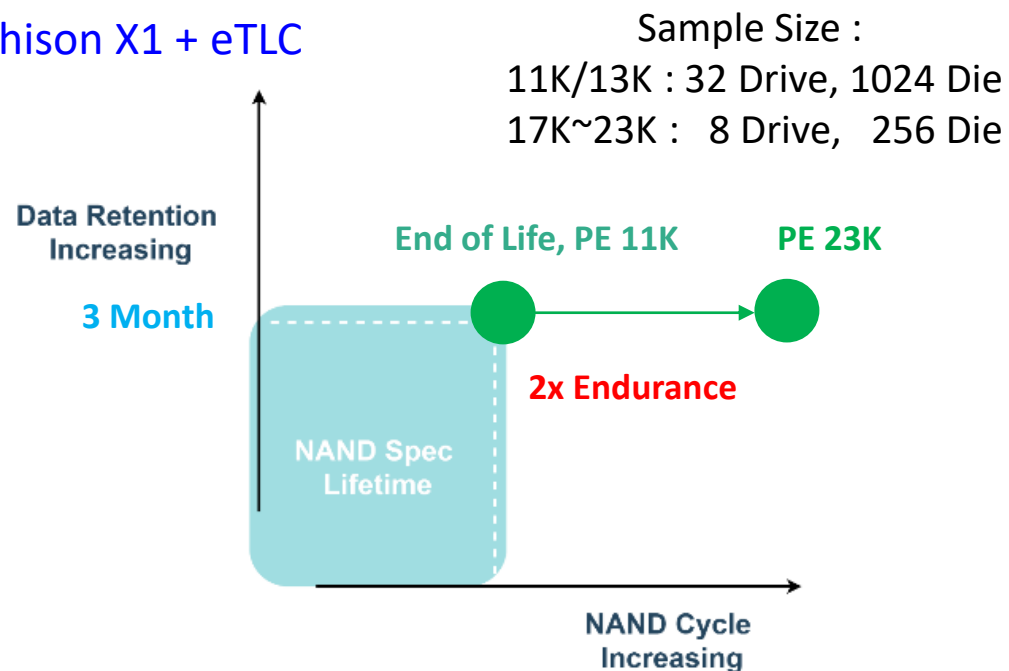
- No Data Loss (No Soft Decode Triggered)
- Read Performance : 7200 ~ 7250 MB/s
- Retry Trigger Rate : 1e-6~1e-3
- Soft Decode Trigger Rate : 0

Real Drive Testing 2x eTLC Endurance Extension

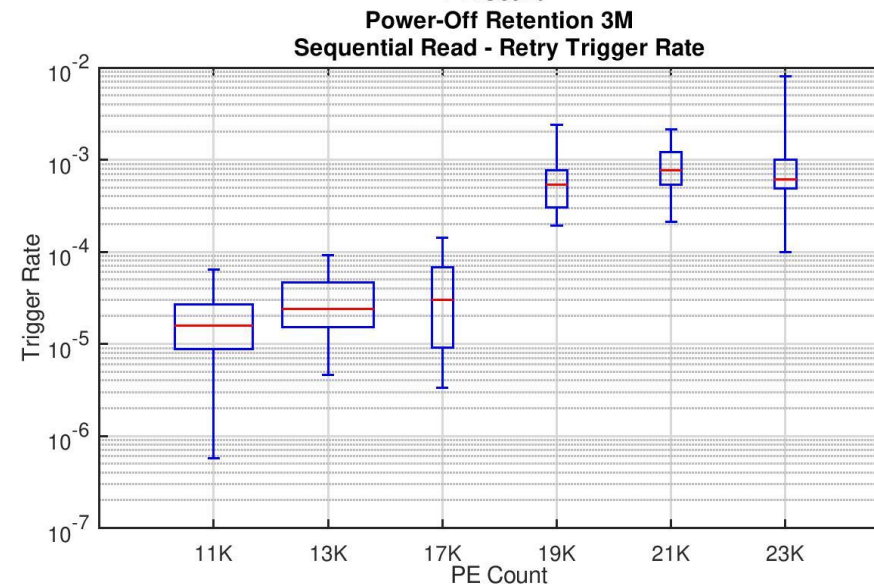
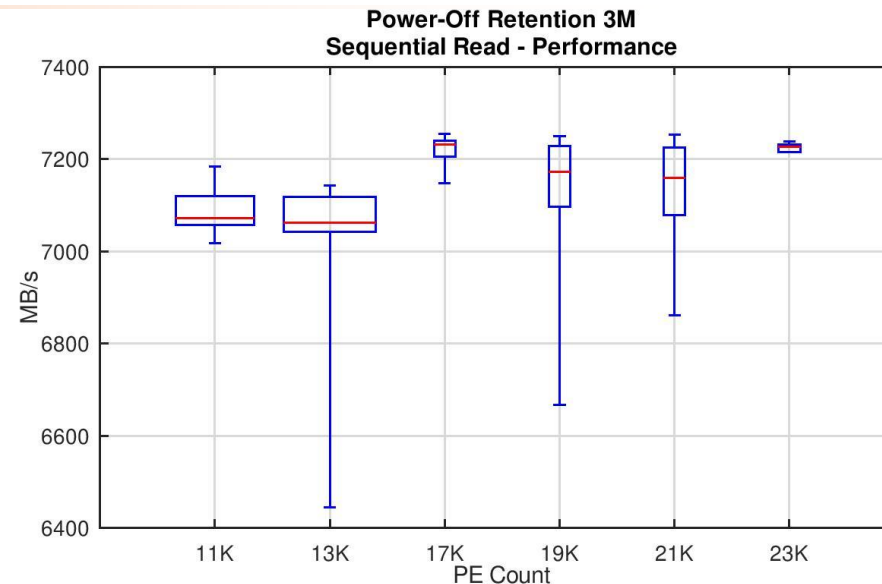


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Phison X1 + eTLC



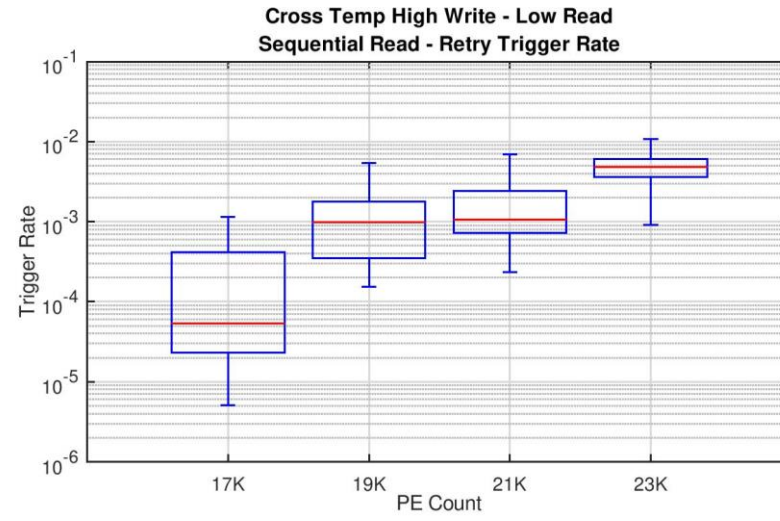
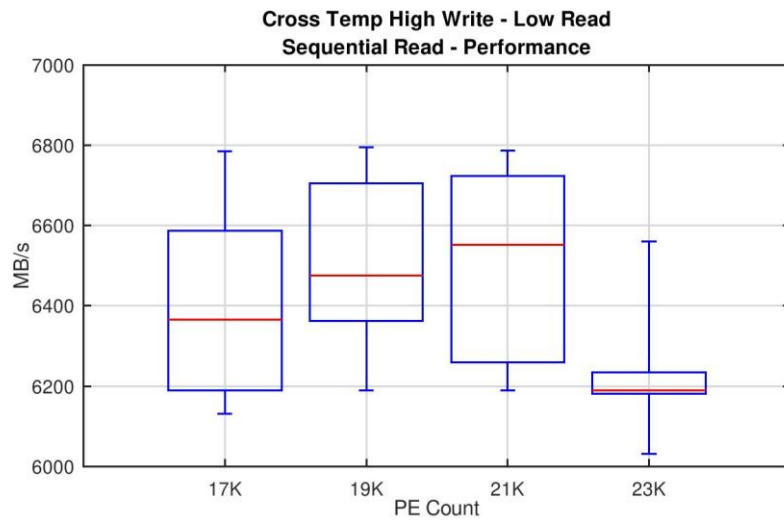
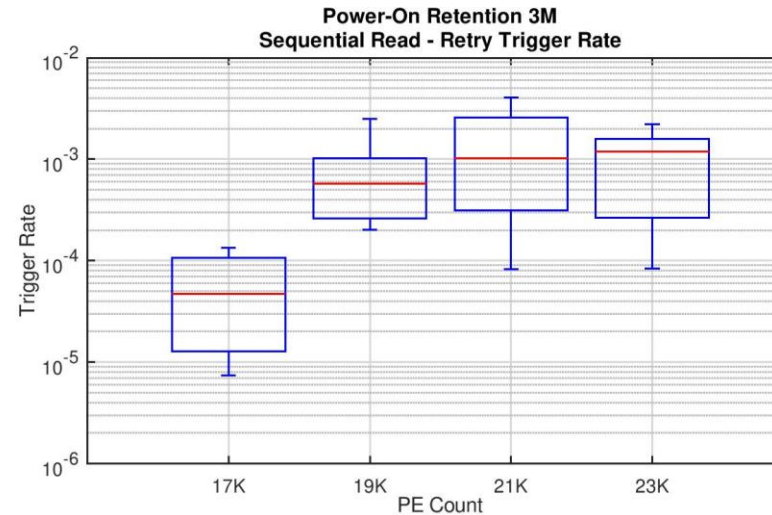
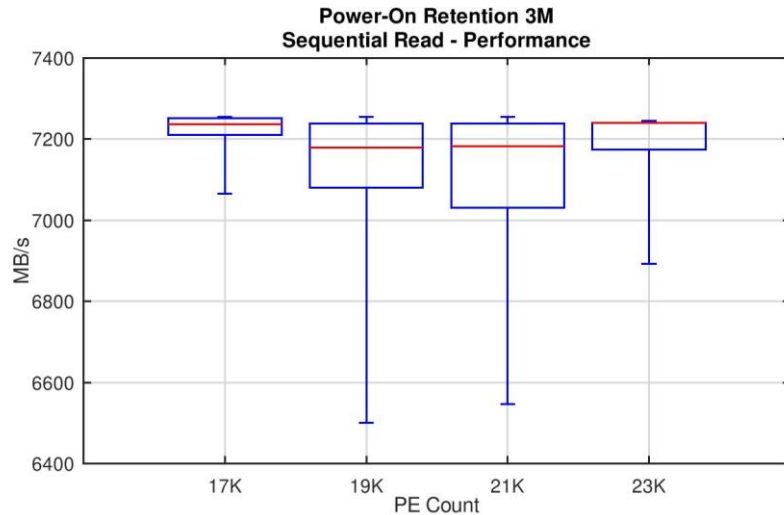
1. Reliability → No Data Loss : **No RAID Triggered**
2. Performance → Read Performance : **6400 ~ 7250 MB/s**
3. Online Read Level Tracking
 - Retry Trigger Rate : **1e-6~1e-2**
 - Soft Decode Trigger Rate : **1e-10~1e-7**



Real Drive Testing 2x eTLC Endurance Extension



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Extra Failure Mode

1. Power-On Retention
2. Cross Temperature (0/70°C)

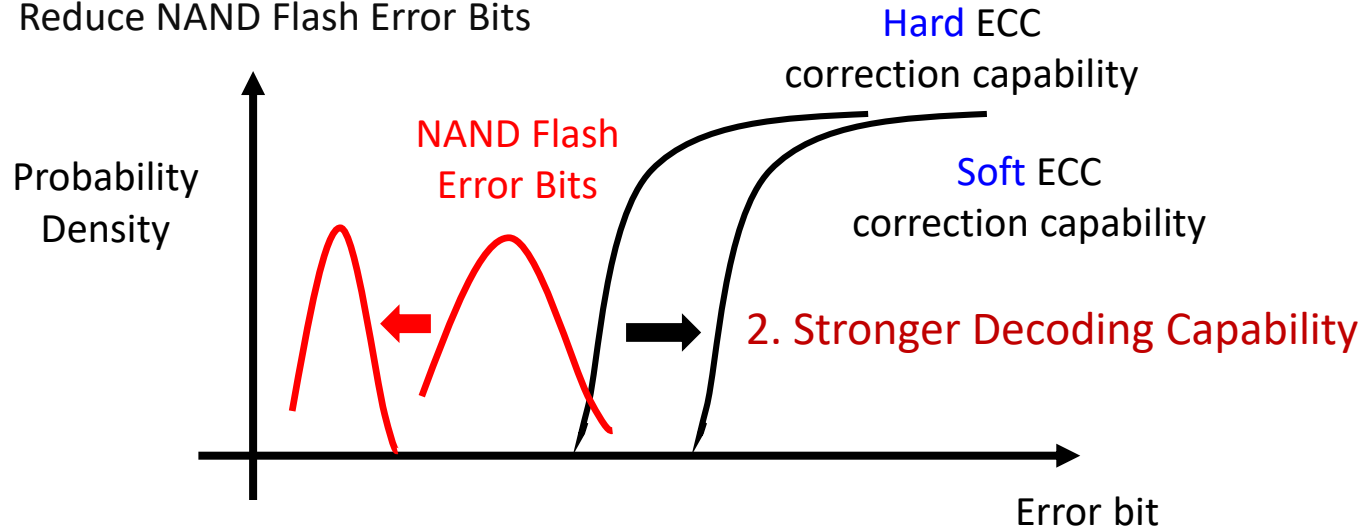
Power-Off Retention 3 Month
+ Power-On Retention 3 Month

- No Data Loss (No RAID Triggered)
- Read Performance : 6650 ~ 6800 MB/s
- Retry Trigger Rate : $1e-5 \sim 1e-3$
- Soft Decode Trigger Rate : $1e-10 \sim 1e-8$

Phison Error Recovery Feature Overview

1. Intelligent NAND Flash Management :

Reduce NAND Flash Error Bits



Phison Feature

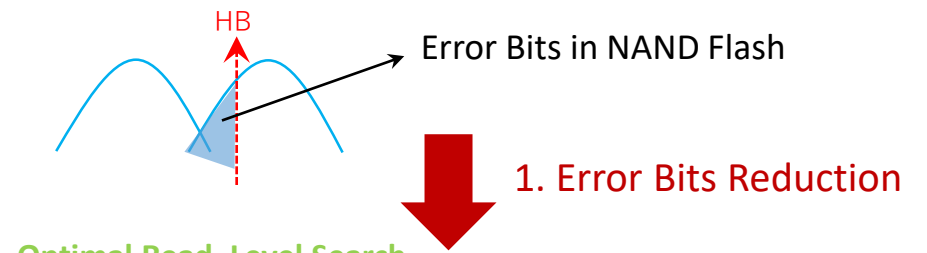
Error Reduction/Performance/Latency

1. Optimal Read Level Search (Coarse/Fine Tune)
2. Online Read Level Tracking
3. Dynamic Error Recovery Sequence

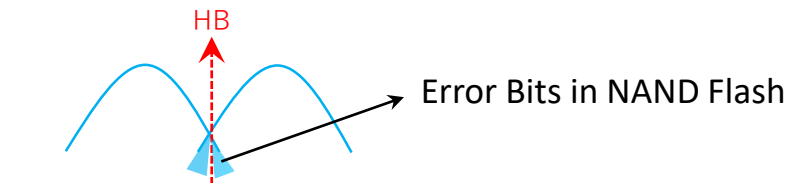
Reliability/Endurance

1. Soft Decode : Auto-Calibrated LLR
2. Soft Decode : Interference Cancellation (DSP2+)
3. Soft RAID

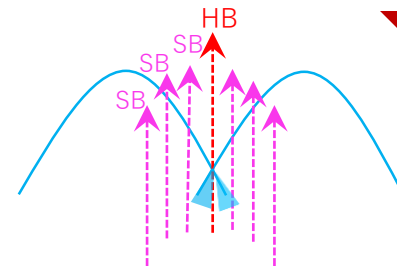
Default Read Level/Retry Table



Optimal Read Level Search



Soft Bit Decode



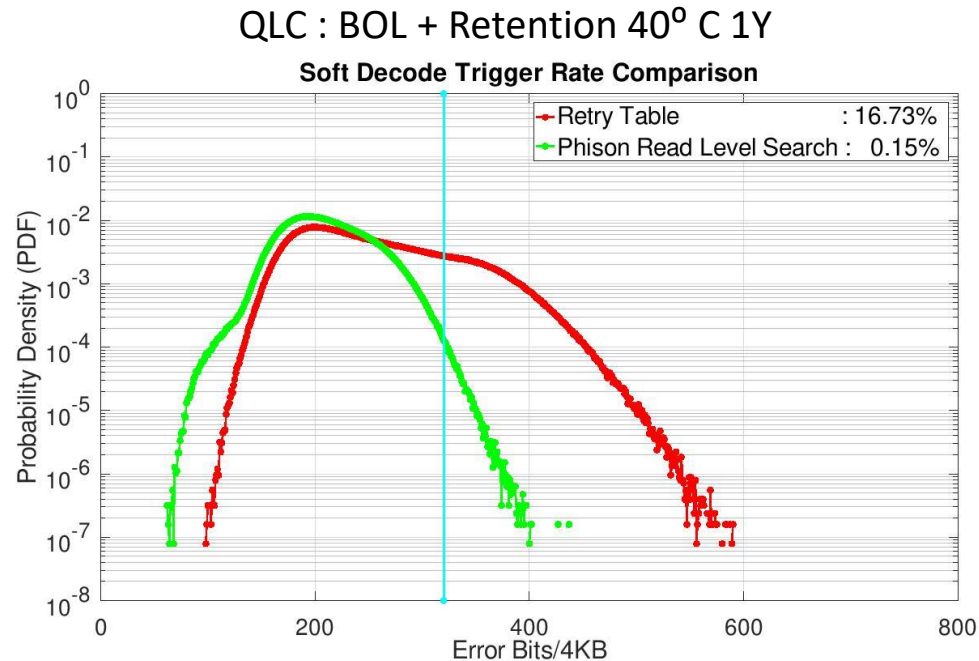
Optimal Read Level Search



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Optimal Read Level vs Traditional Retry Table

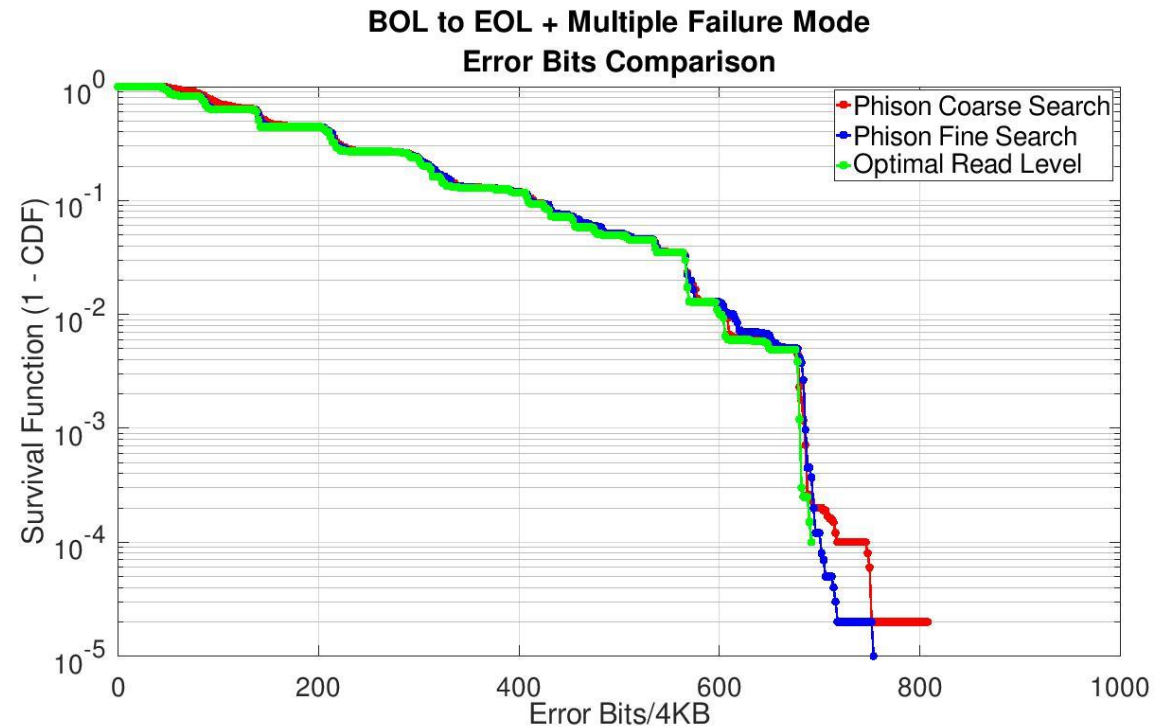
- Huge Error Bits between Retry Table and Optimal Read



Robust Read Level Search Algorithm

- Phison Read Level Search Process is **Fast, Simple, Accurate**
- Works for all kinds of NAND Flash and Operation Condition
- Read Level Search is the fundamental of Online Read Level Tracking

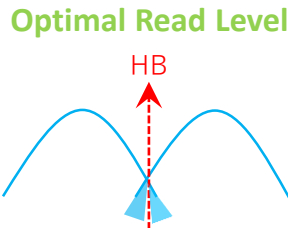
TLC : Multiple Failure Mode
(Retention/Cross-Temp/Read Disturb)



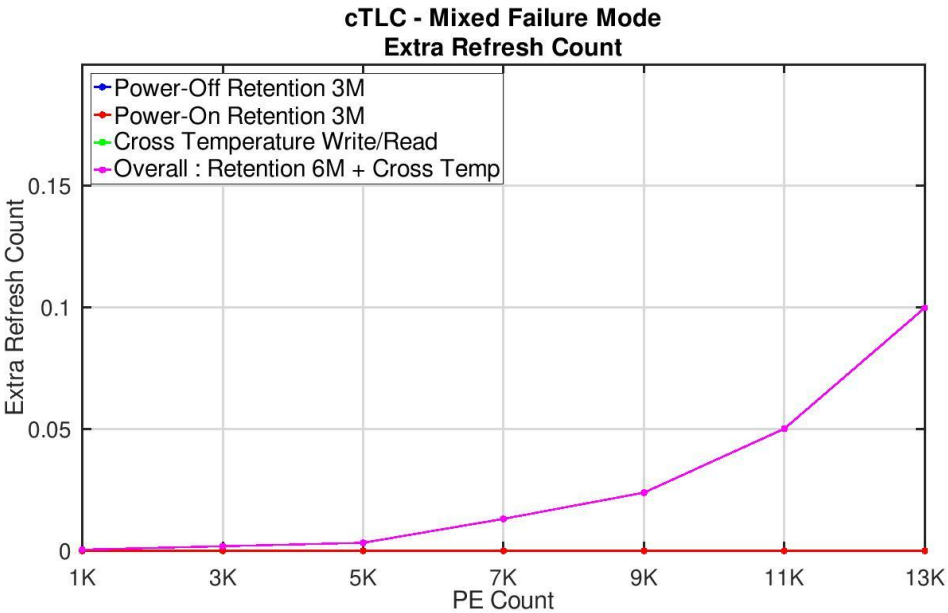
Online Read Level Tracking

Ideal Design Target

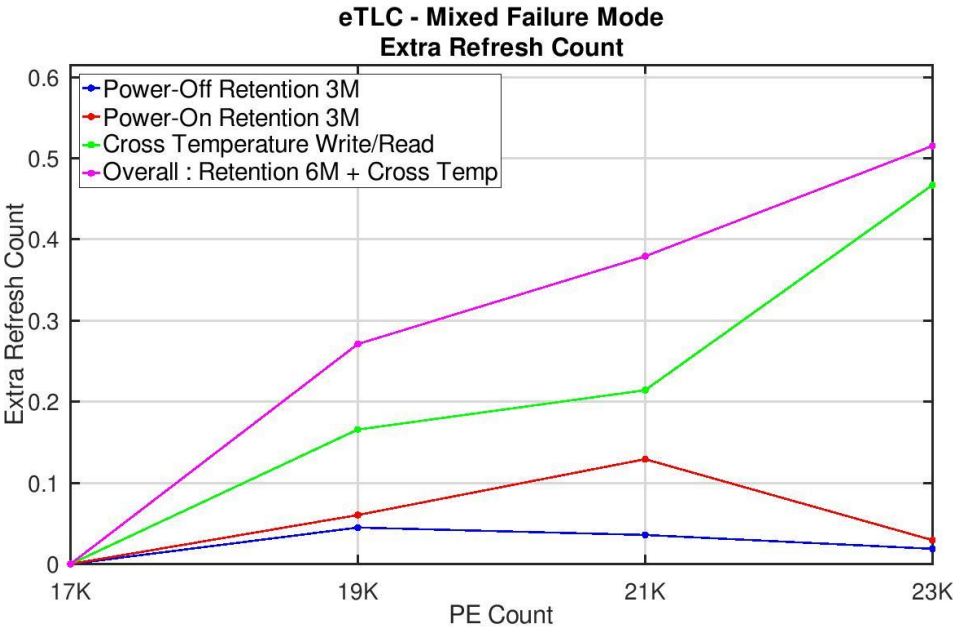
- Every read command with Optimal Read Level
- Keep Performance/Reliability with minimum Refresh Operation



Phison Tracking Algorithm can keep Performance/Reliability with extreme low Refresh Count



cTLC PE 13K + Retention 6M + Cross Temperature
Average Extra Refresh Count : 0.1



eTLC PE 23K + Retention 6M + Cross Temperature
Average Extra Refresh Count : 0.5

Online Read Level Tracking

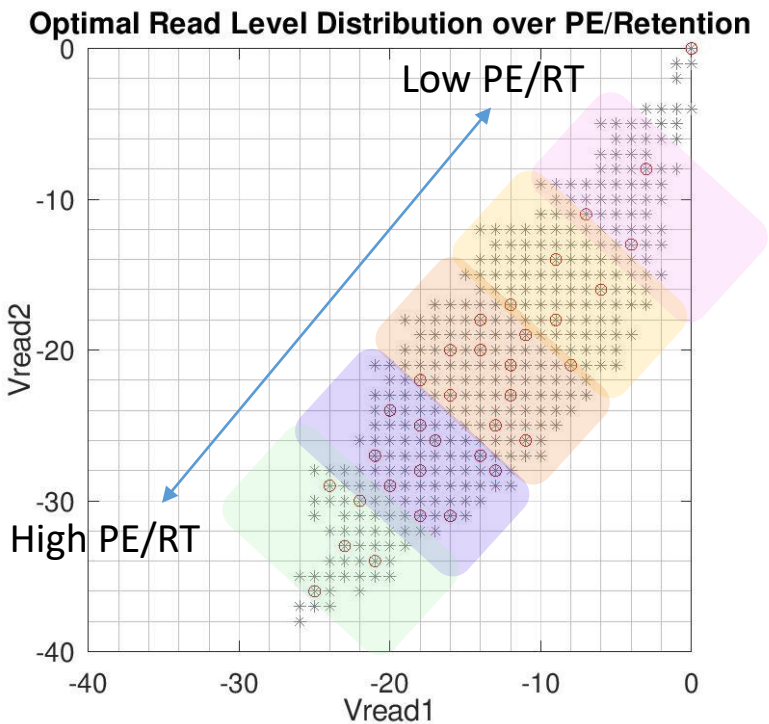


Basic Idea

- Tracking/Record Read Level Table Index for each Memory Unit (Wordline/WL Group/Block/Plane/Die...)
- Apply Tracking Read Level to Every Read command

Memory Unit

	Die0		Die1	
	P0	P1	P0	P1
VB0				
VB1				
VB2				
...				
VB999				



Gray Points : Optimal Read Level
Red Circle : Run-Time Generated Table

Offline Retry Table

Cons : Table Size vs Coverage
(Variance, Failure Mode..)

Run-Time Table Management

Pros : Suitable for all the operation condition

Run-Time Generate/Delete/Management of Retry Table
Start with empty retry table

Efficient Tracking Algorithm → Small Tracking Interval
→ Better Reliability/Performance

Online Read Level Tracking



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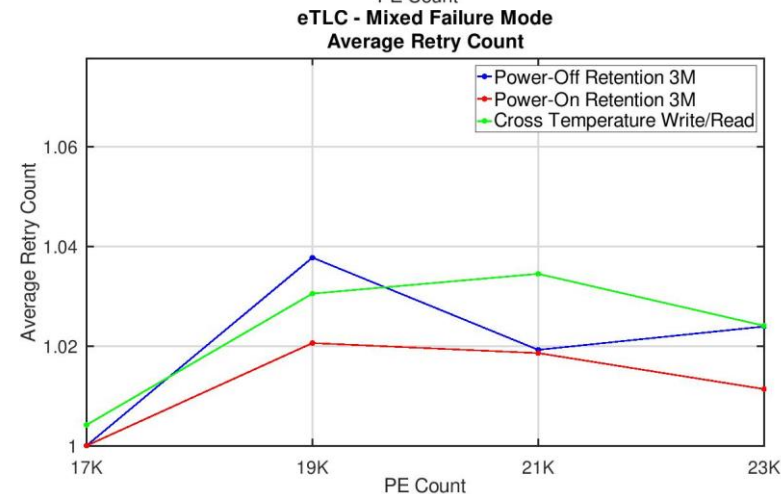
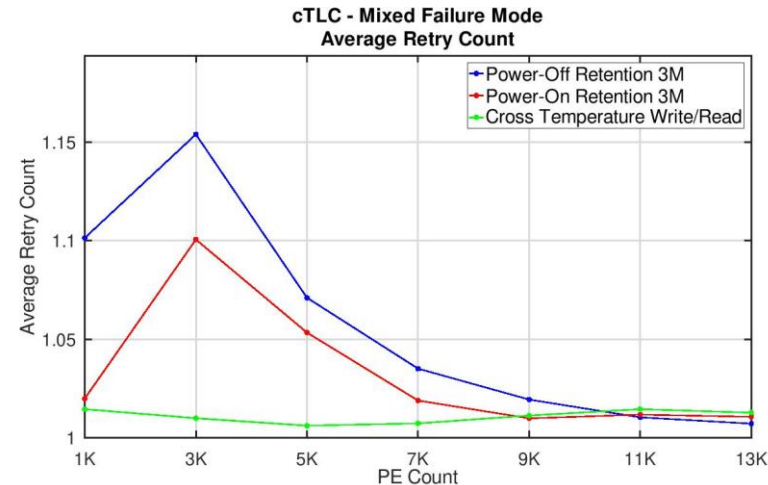
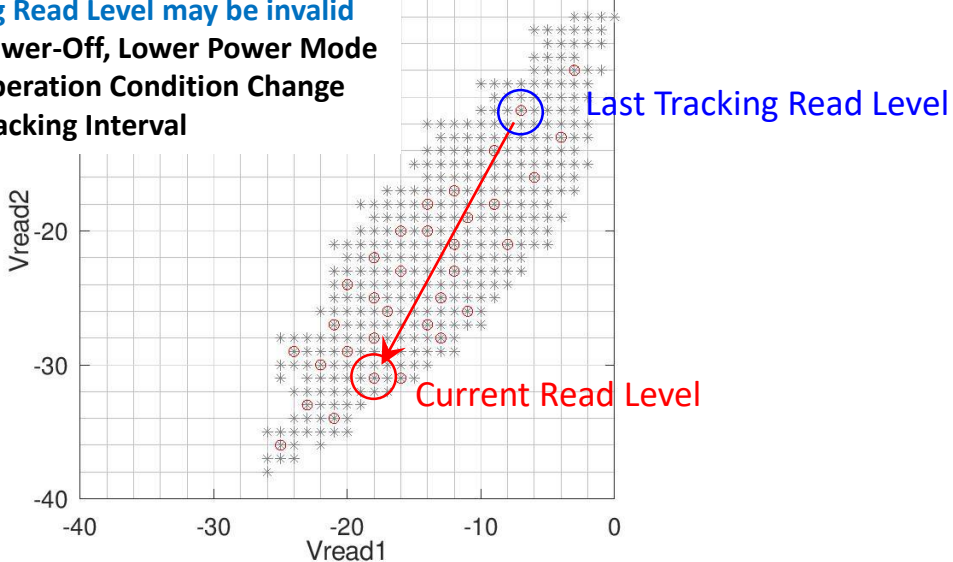
Quick Tracking Correction

- Tracking Read Level may be invalid
- **Run-Time** Update Read Level Table for each Memory Unit
- **Find Correct Read Level Quickly** when Tracking Read Level invalid

Optimal Read Level Distribution over PE/Retention

Tracking Read Level may be invalid

1. Power-Off, Lower Power Mode
2. Operation Condition Change
3. Tracking Interval



Average Retry Count : the number of trials after Initial Read Fail

Maximum Average Retry Count over all Operation Condition : 1.15

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THANK YOU!



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