



Flash Memory Summit

The key to Interpreting SSD Performance Numbers

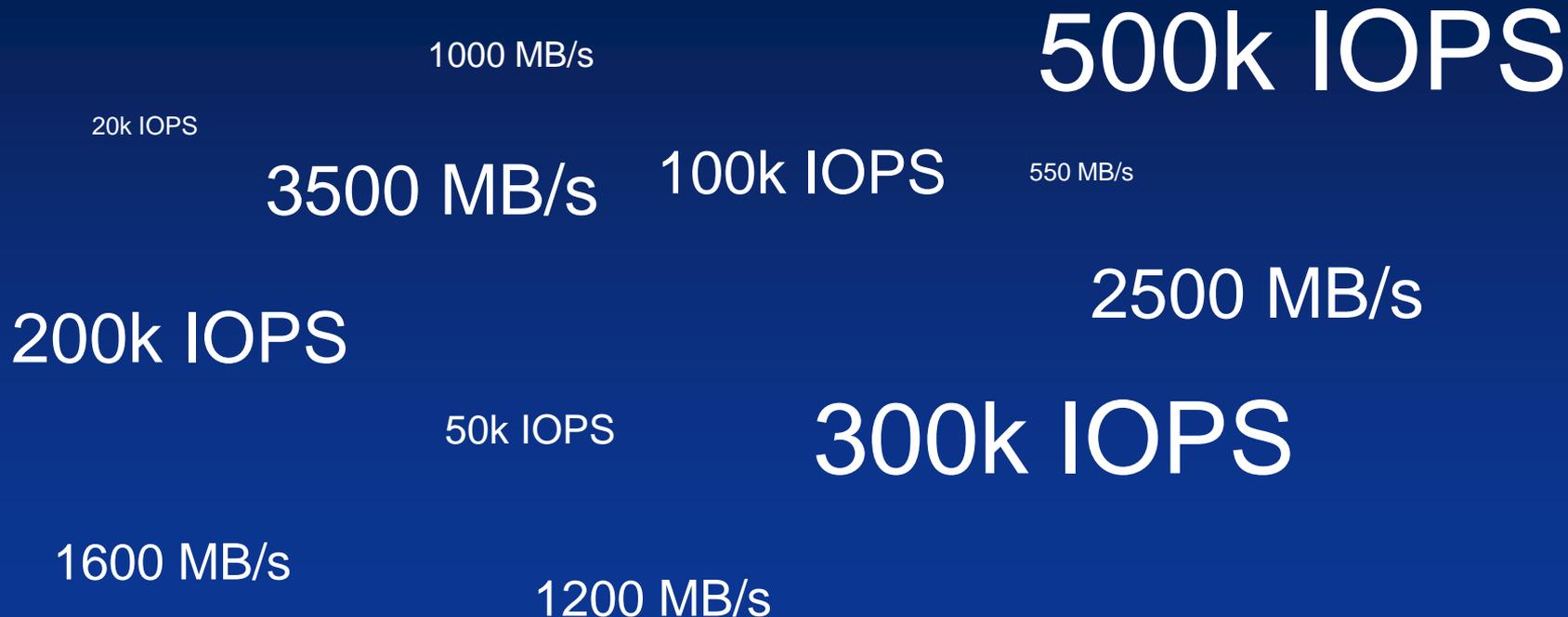
Jan Peter Berns
Managing Director

EMBD-101B-1: Embedded Applications, Part 2 – Applications



Flash Memory Summit

Performance Claims





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Agenda

- Datasheet Performance vs Real Life Performance
- How to Enhance Real Life Performance
- Thermal Throttling
- Conclusion

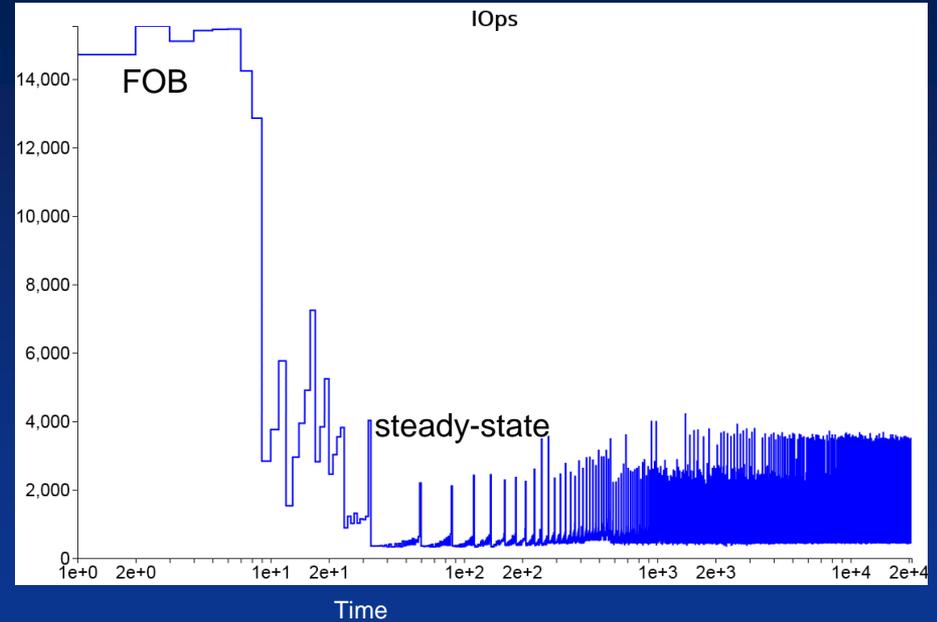
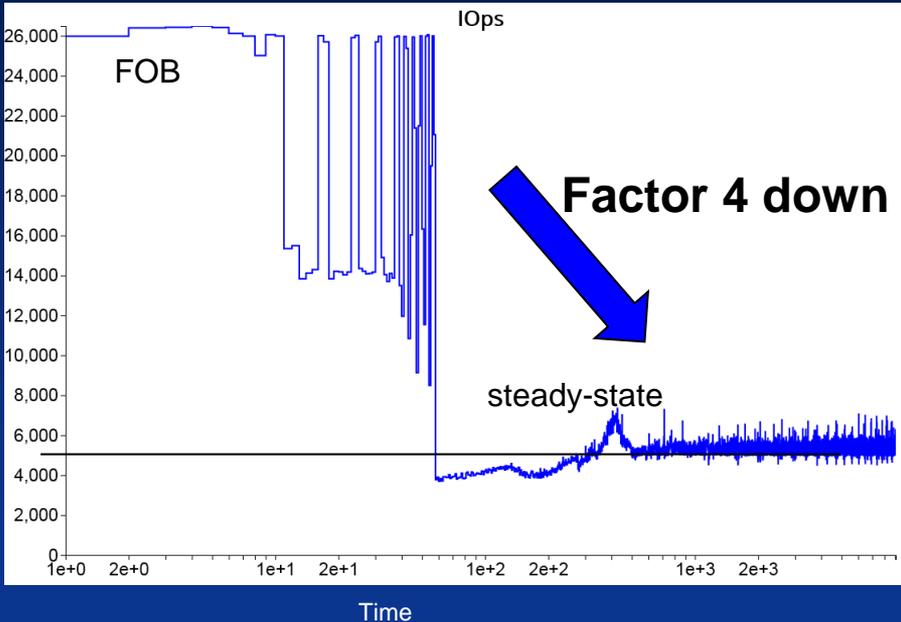


Real Life Performance Test

- CrystalDiskMark run #1
- 72h of IOMeter (write-only)
- CrystalDiskMark #2



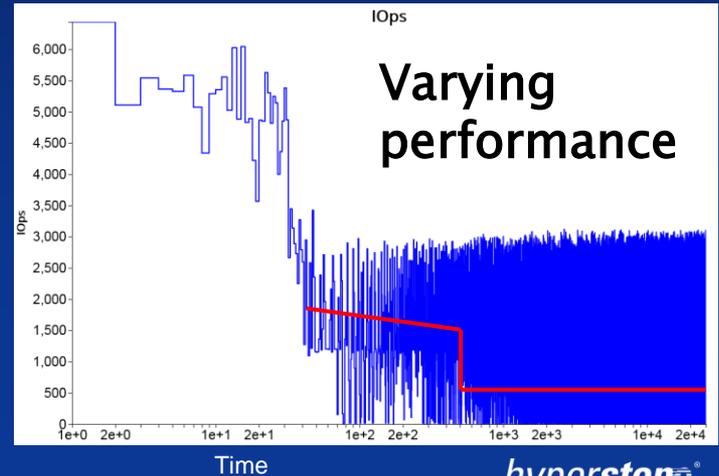
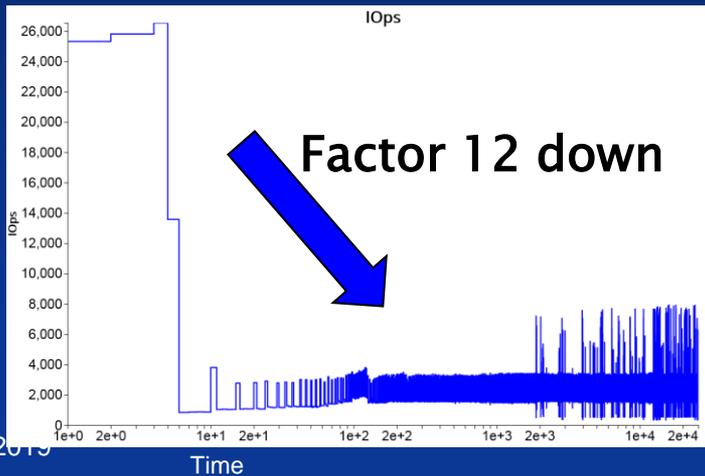
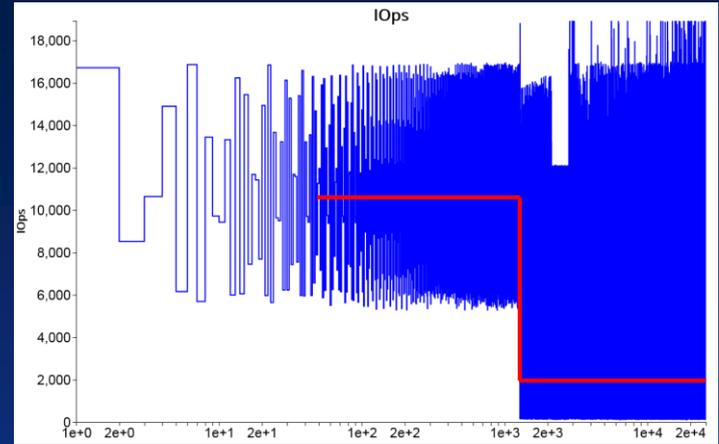
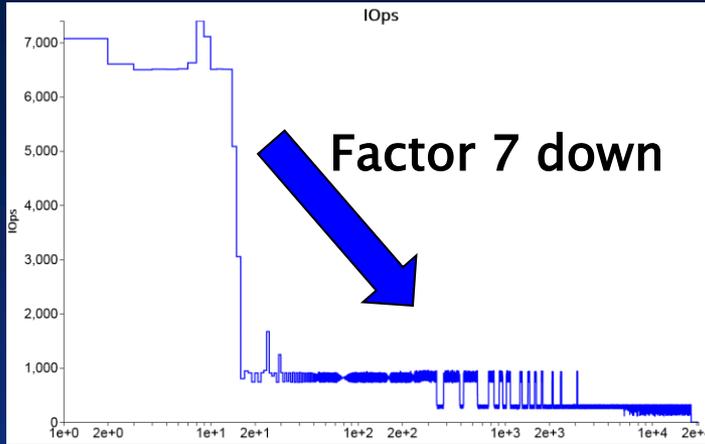
IOmeter for different drives



Advertised IOPS: only for a minute



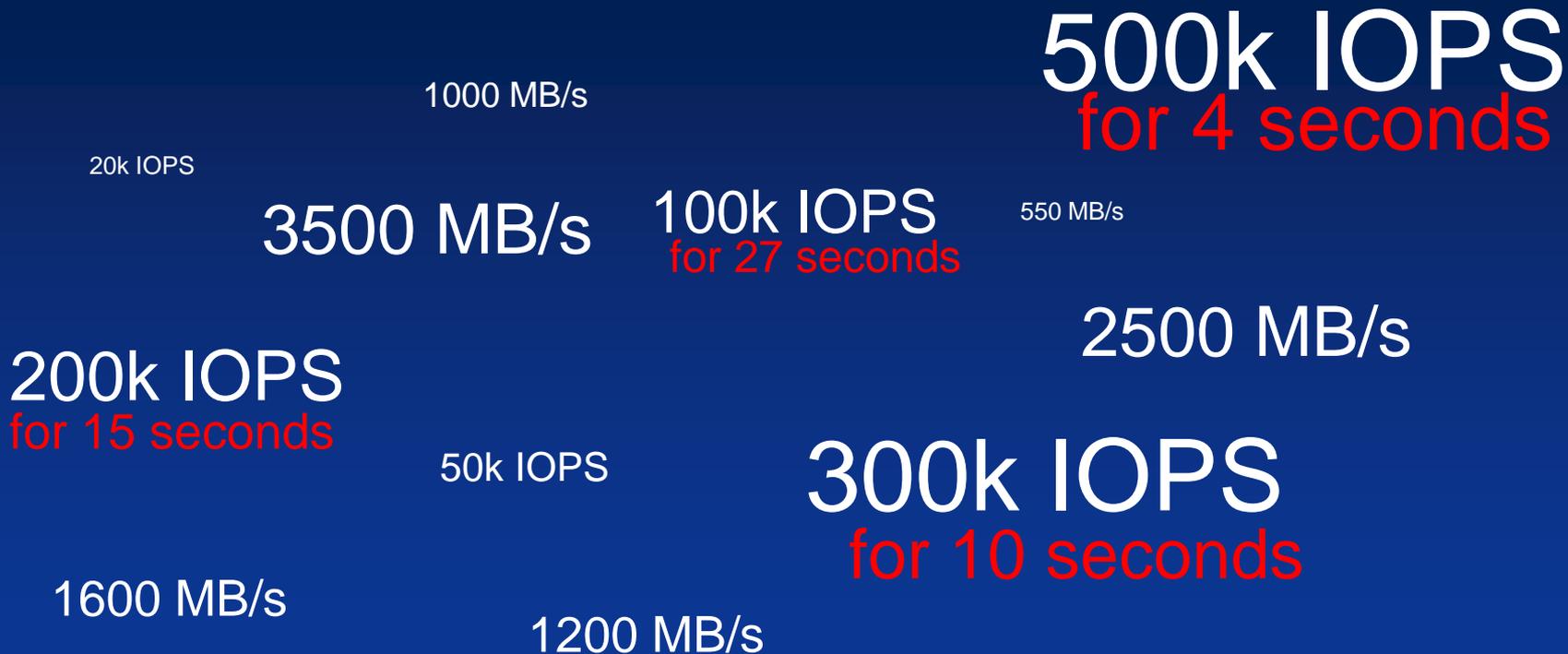
IOmeter





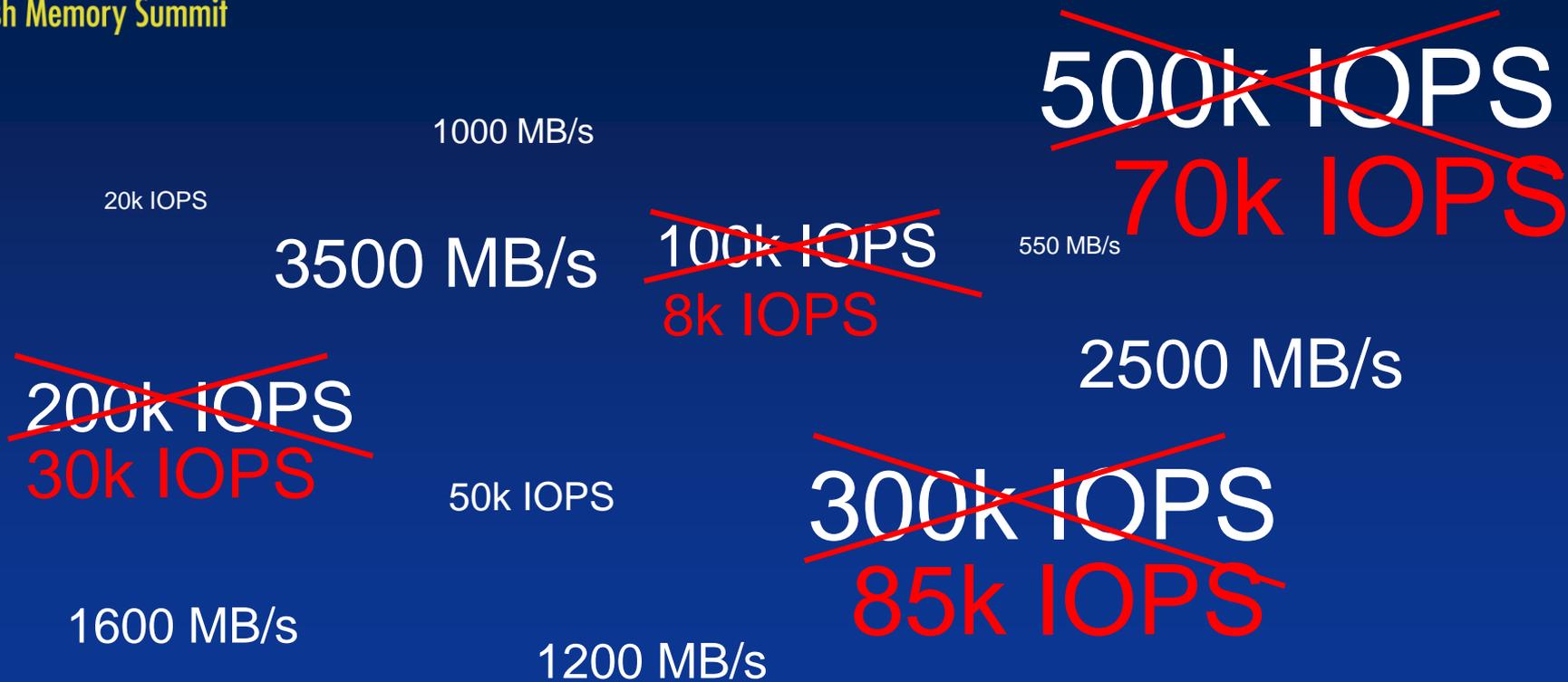
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Performance Claims





Performance Claims Sustained

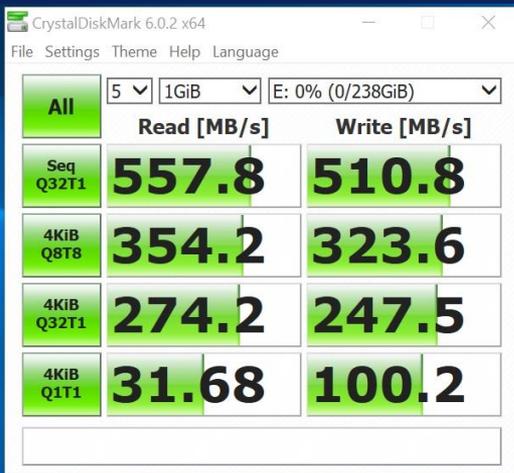




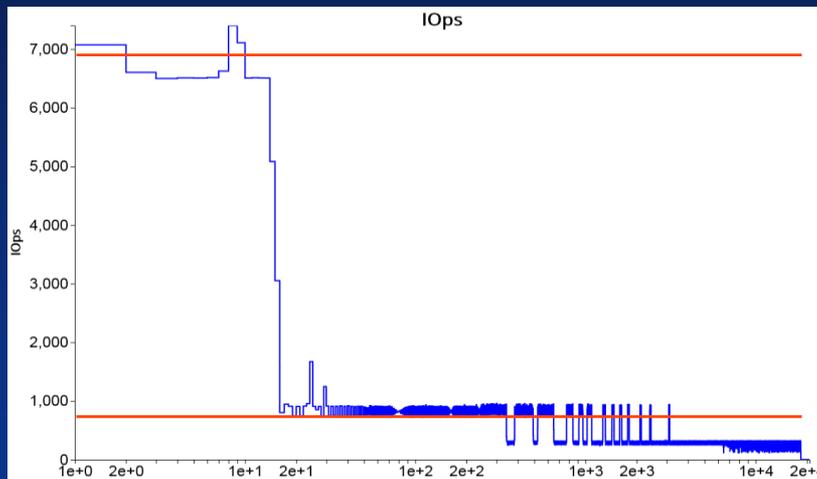
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Sustained Performance

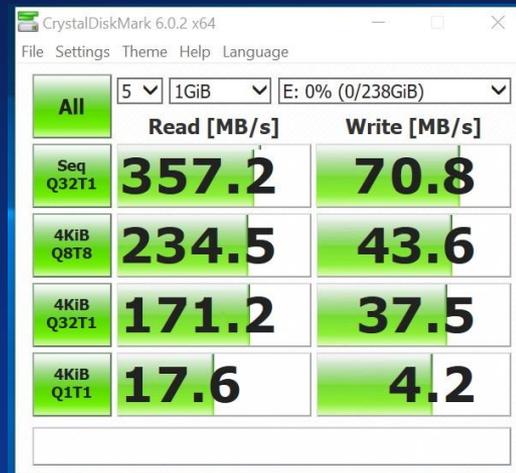
CrystalDiskMark run #1



IOmeter



CrystalDiskMark run #2



$$\text{Sustained Performance} = \frac{\text{CrystalDiskMark run \#2}}{\text{CrystalDiskMark run \#1}}$$



Further Test Results

	Hy. 1	Hy. 2	Device 1	Device 2	Device 3	Device 4	Device 5
Sustained Sequential Write*	86.2 %	58.6 %	0.7 %	1.0 %	2.8 %	13 %	9.5 %
Sustained Random Write*	85.0 %	57.8 %	1.0 %	4.4 %	13.9 %	38.0 %	18.7 %
Sustained Write IOPS*	59.4 %	34.2 %	1.0 %	38.8 %	13.9 %	38.0 %	18.7 %
Max. response time (milliseconds) ²	150	170	4000	700	2800	14000	4800

*Percentage indicates the remaining performance in „steady-state“ in relation to the „fresh-out-of-the-box state“

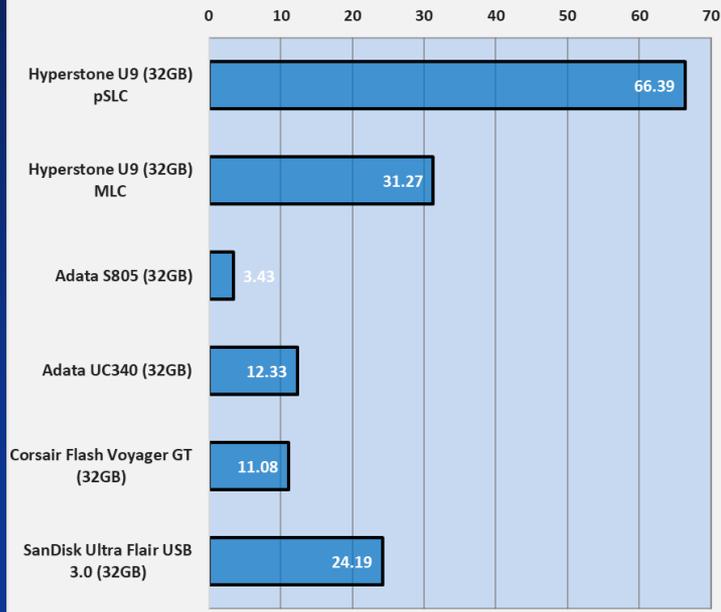
² out of all IOPS over the 72h of IOMeter



TweakTown

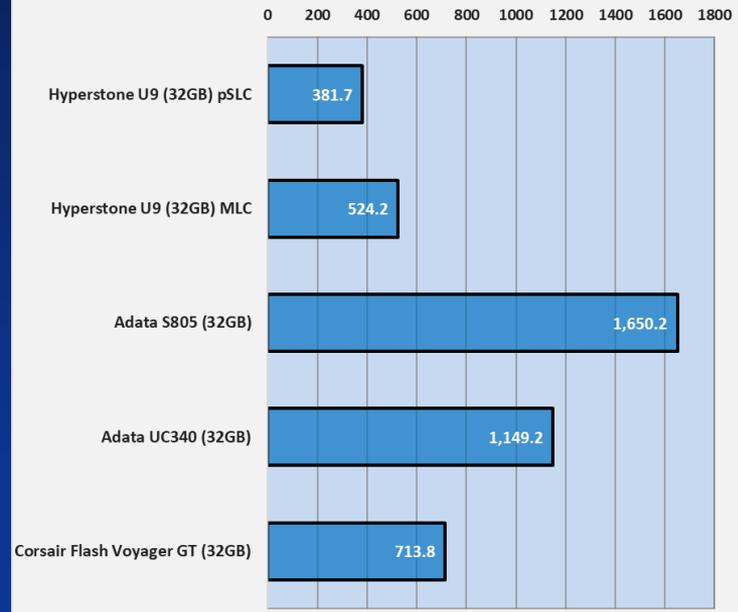
Storage Bandwidth

MB/s - Higher Is Better



Photoshop Heavy

Seconds - Lower Is Better



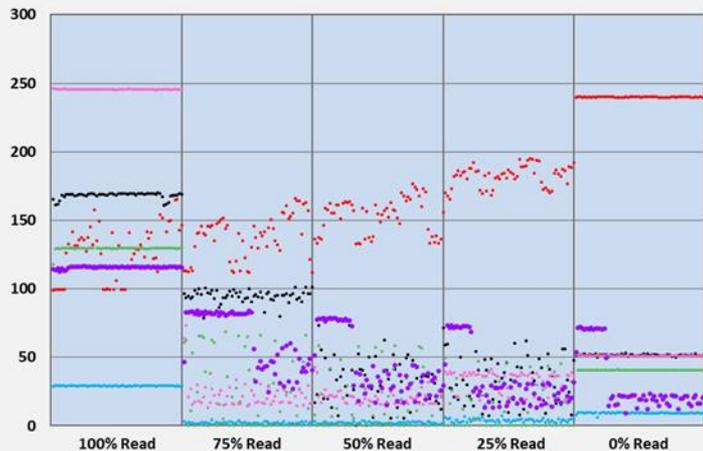


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TweakTown

128KB Sustained

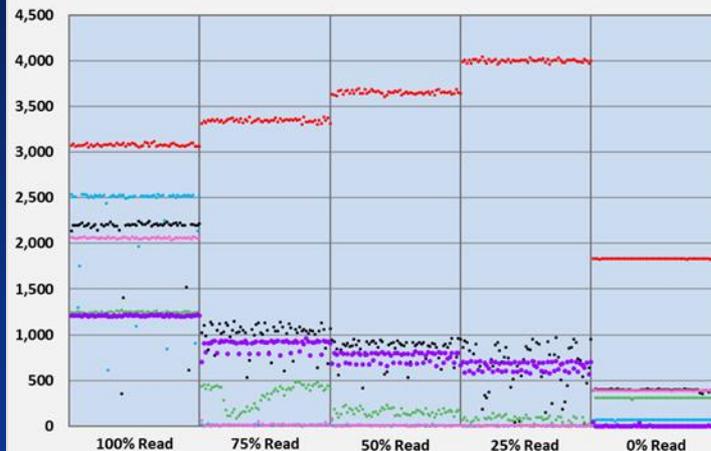
MB/s - Higher Is Better



- Hyperstone U9 (32GB) pSLC
- Hyperstone U9 (32GB) MLC
- Adata S805 (32GB)
- Adata UC340 (32GB)
- Corsair Flash Voyager GT (32GB)
- SanDisk Ultra Flair USB 3.0 (32GB)

4KB Sustained

IOPS - Higher Is Better

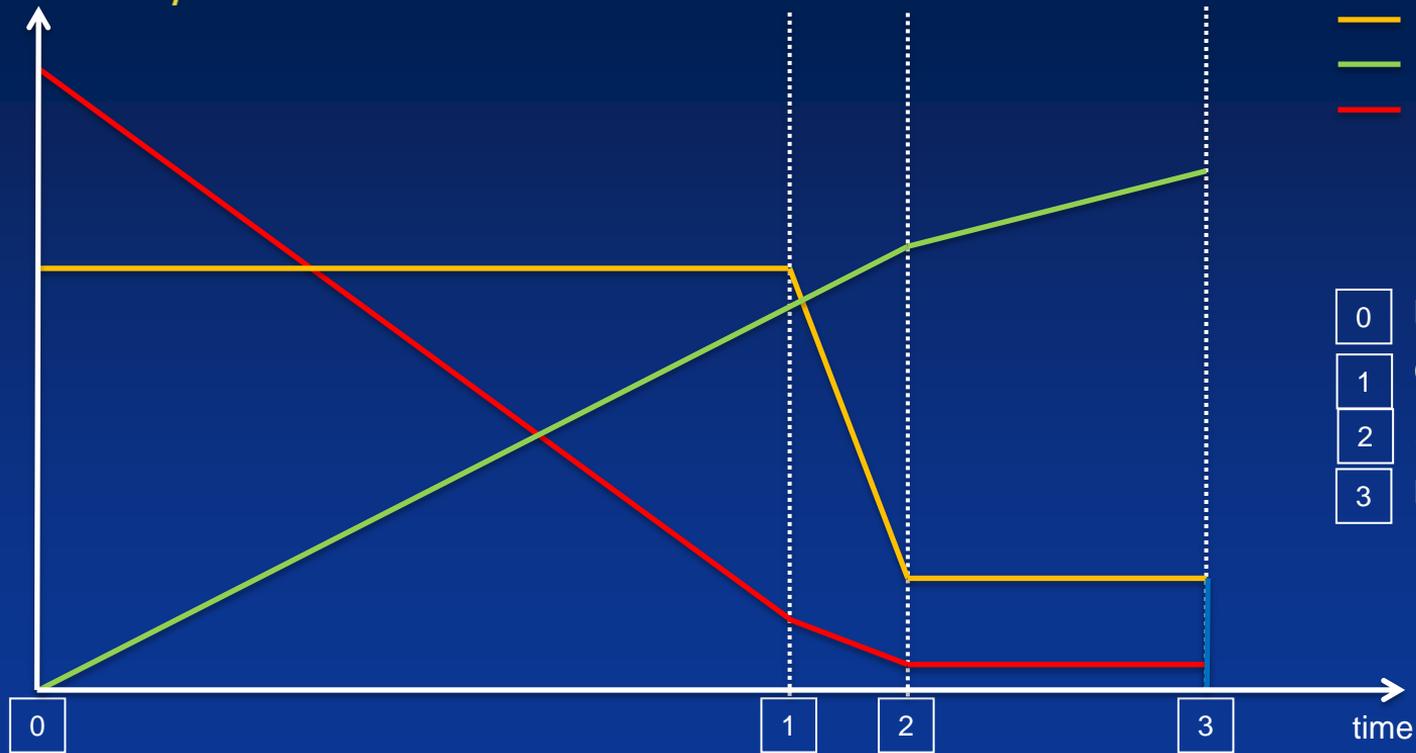


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Sequential Drive Write



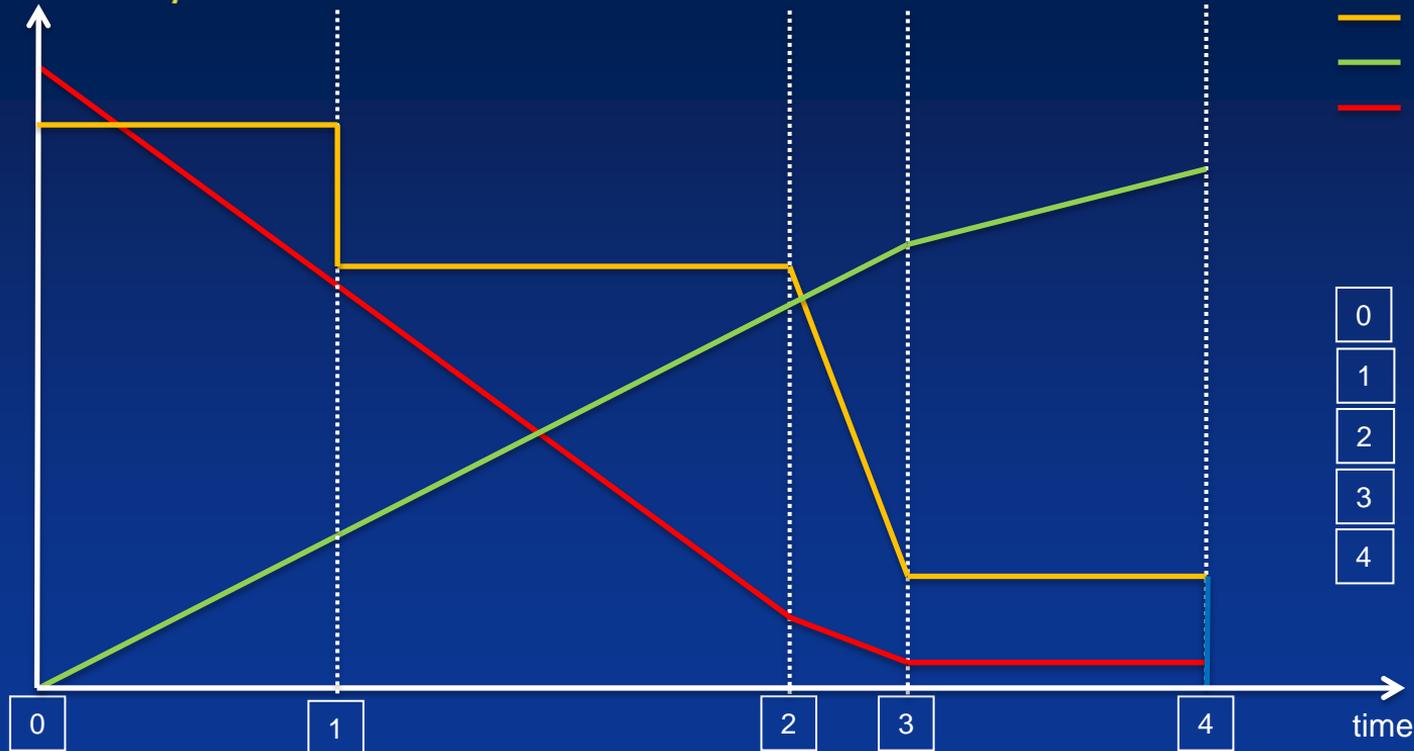
- Write bandwidth
- Device fill level
- Remaining writable blocks

- 0 Fresh (trimmed) device
- 1 Garbage Collection activated
- 2 Steady state reached
- 3 Device fully written



Sequential Drive Write (TLC flash)

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- Write bandwidth
- Device fill level
- Remaining writable blocks

- 0 Fresh (trimmed) device
- 1 pSLC cache full
- 2 Garbage Collection activated
- 3 Steady state reached
- 4 Device fully written



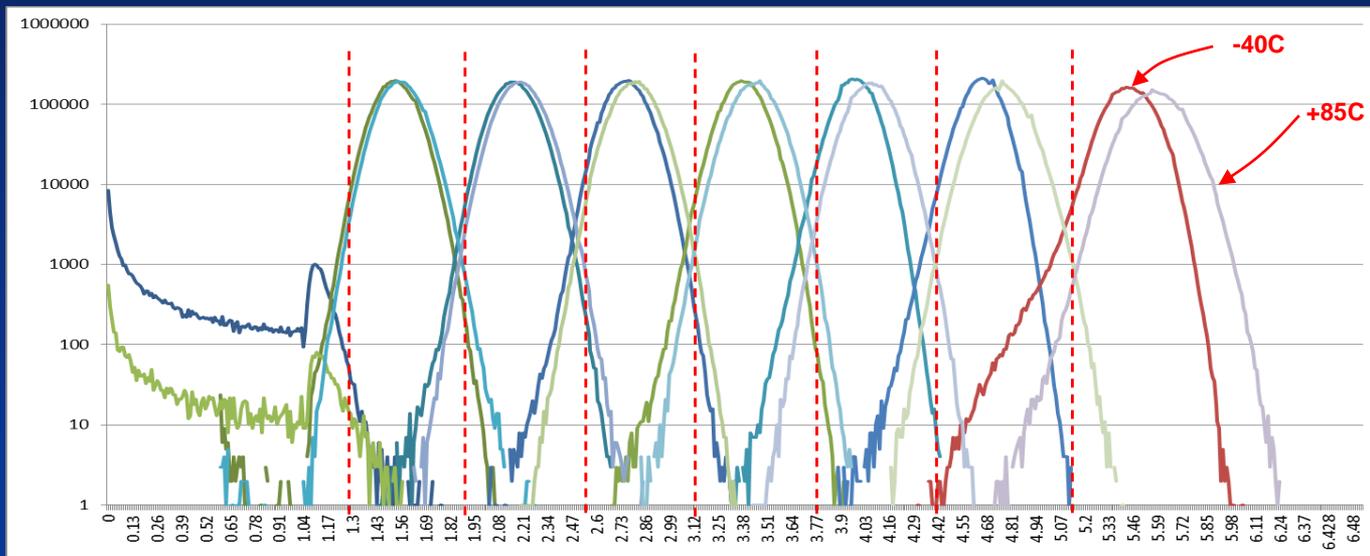
Background Operations

- Garbage Collection
- Wear Leveling
- Dynamic Data–Refresh
- RAID
- Boot after dirty shutdown
- Calibration (mainly for 3D)



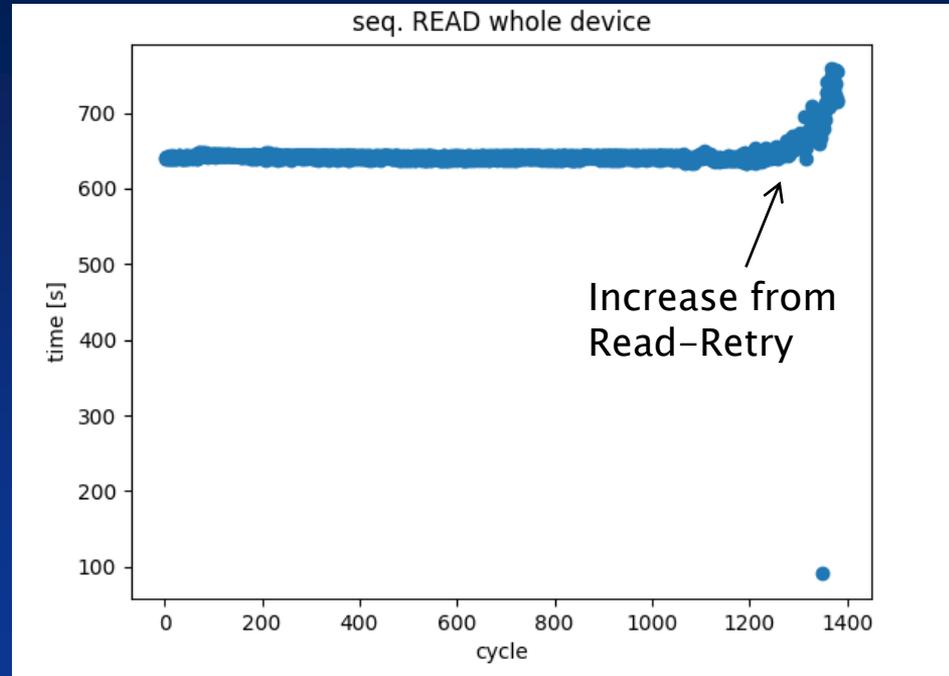
3D TLC Distributions

- Fresh block
 - Distribution @-40C has pattern programmed @+85C
 - Distribution @+85C has pattern programmed @-40C



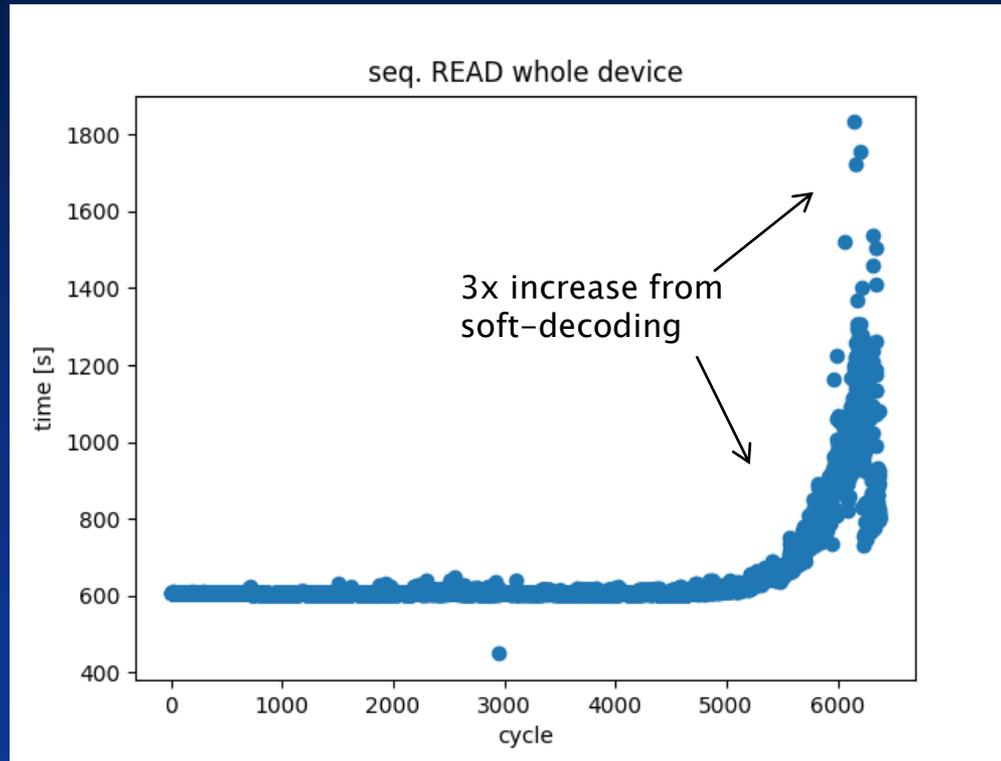


Performance Over Lifetime



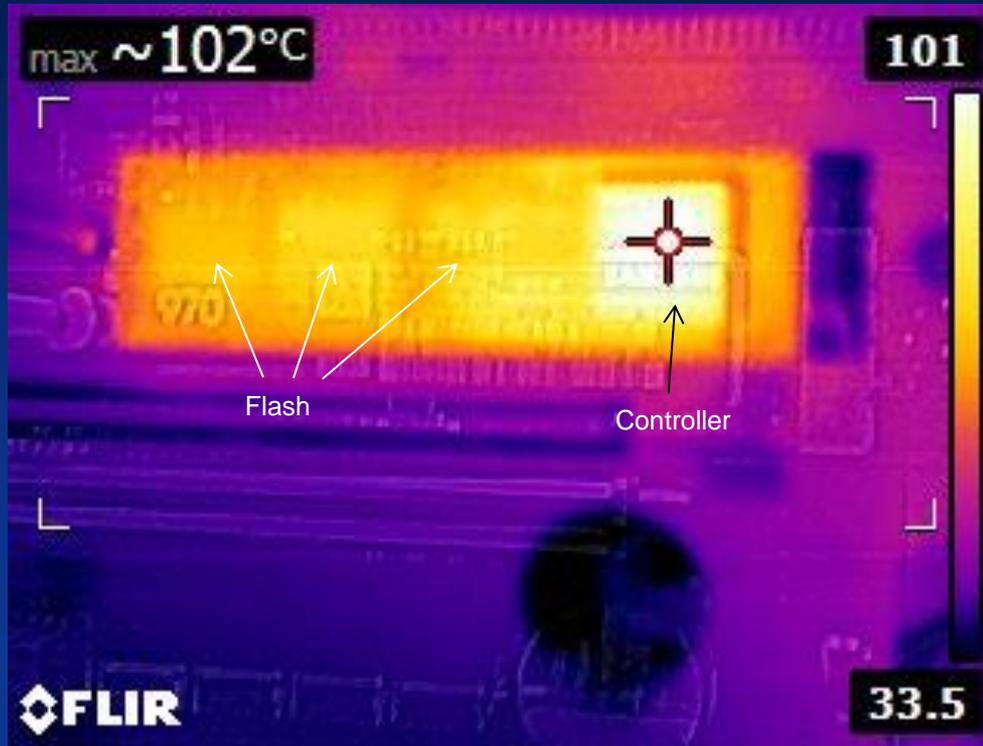


Performance Over Lifetime





Thermal Throttling

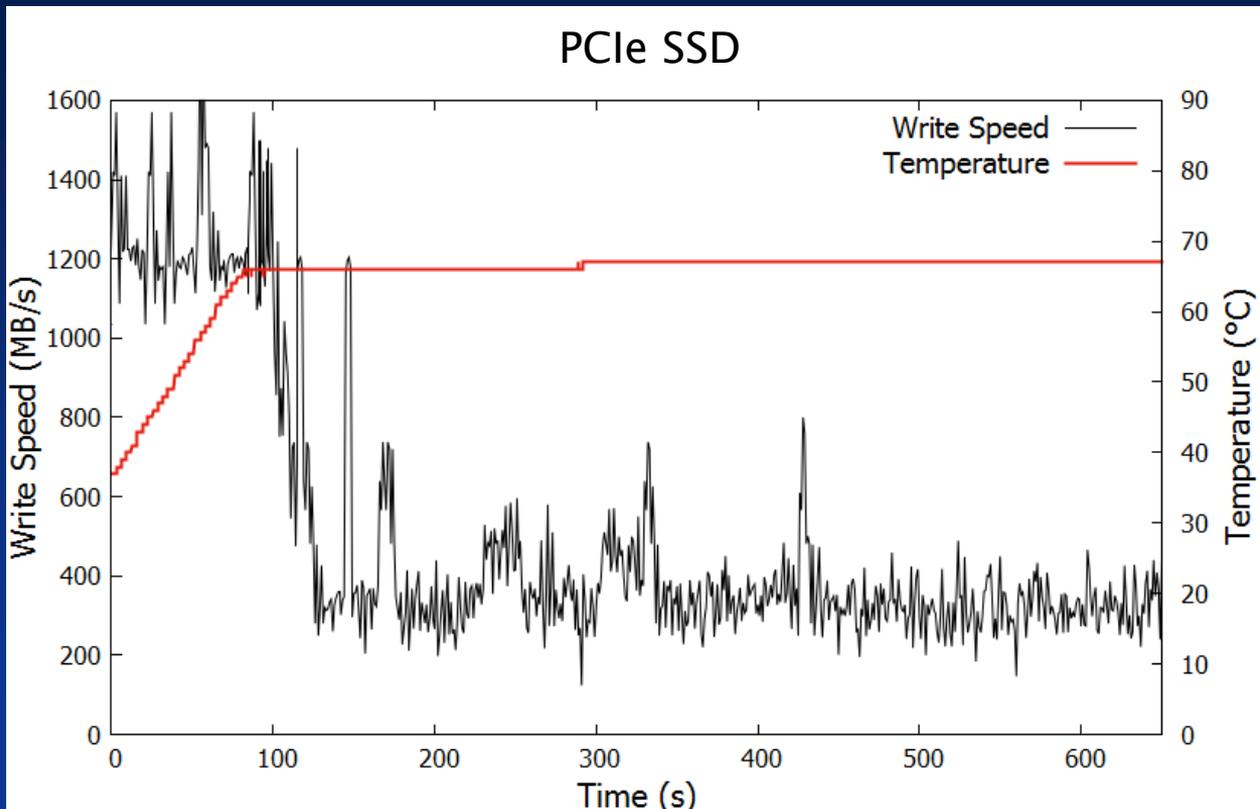


Techpowerup: “We recorded a thermal image of the running SSD as it was completing the write test. The hottest part reached 102° C, which is significantly higher than what the drive’s own SMART temperature monitoring reports.”

<https://www.techpowerup.com/review/samsung-970-pro-ssd-512-gb/7.html>



Thermal Throttling





Conclusion

- Don't trust datasheets
- Know your use-case
- Mind the design target (e.g. industrial)