Flash Memory Summit

Thermal Challenge and Performance Balance on SSD

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From ATP Electronics Inc.

ATP

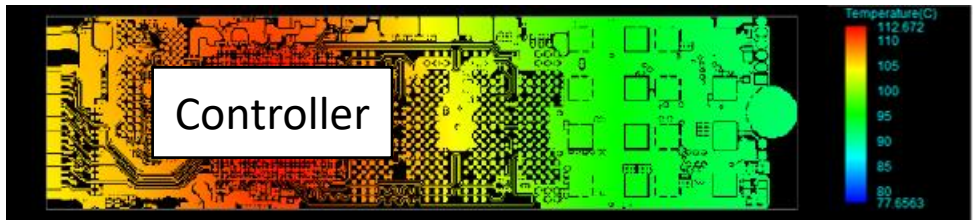
35 YEARS OF NAND FLASH MEMORY INNOVATION

Agenda

- Thermal Simulation
  - Simulation (Airflow, Thermal Dissipation Plan) / Customization
- Hardware Solution
- SMART Thermal Throttle Architecture
- Eco System Joint-Development to Maintain Higher sustained performance

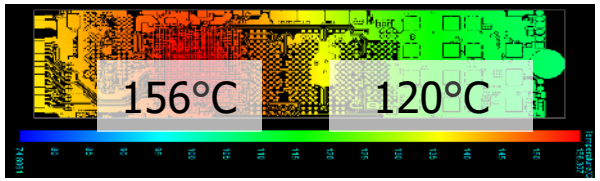
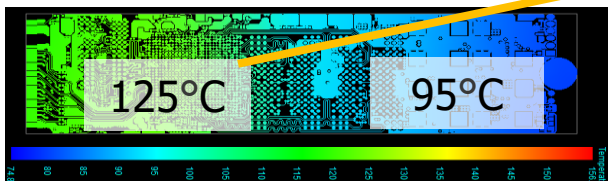
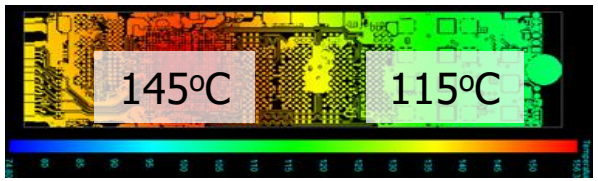
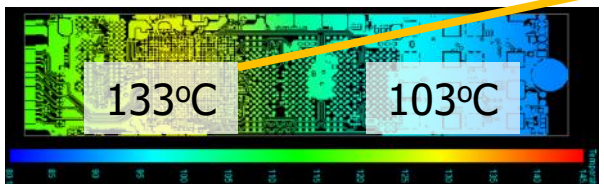
SIMULATION: Cadence Component-Level Simulation

1. **During <u>product design</u> stage, we conduct Cadence Simulation for IR drop analysis (signal integrity) and thermal simulation.**
2. Hardware engineers **fill in Component / package information**, such as case dissipation (watt), power loss (watt), PCB dissipation (watt), junction temperature, case / board temperature, etc.
3. **To generate Temperature distribution result:** It's the distribution of heat in each PCB layer, indicating the potential risk of heat accumulation area. Hardware engineers may consider to adjust the layout circuits, wire thickness, the qty/position of through holes and so on.



NOTE: PCB Top layer heat distribution example
This is pure hardware simulation based on full-speed operation (worst-case scenario)

SIMULATION: Cadence Component-Level Simulation (8 mm heatsink)

Bare SSD	8 mm Heatsink
A. Ambient condition: 55°C, 600 ft/m	
	
B. Ambient condition: 70°C, 1200 ft/m	
	

Controller Temp. reduced 31°C

Controller Temp. reduced 12°C

1. **Cadence Simulation is pure hardware simulation based on full speed operation (worst-case scenario)**
2. **Though the Temperature is high, a sufficient cooling solution helps distribute the heat.**

NOTE: Component-level simulation consists of various factors, including ambient temperature, airflow and thermal resistance/power consumption of main components.

SIMULATION: Thermal Simulation (System-Level Simulation)

Thermal Elements Input

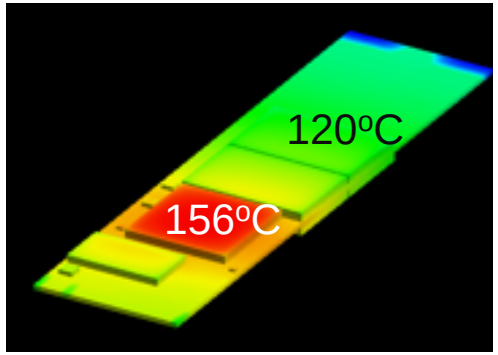
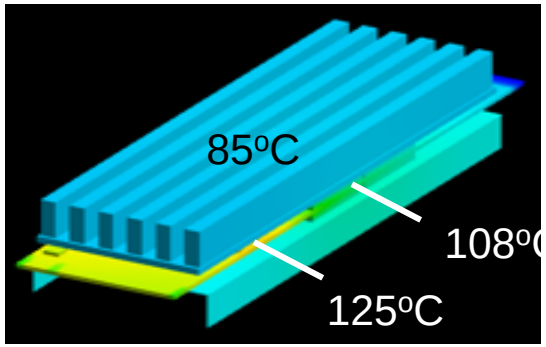
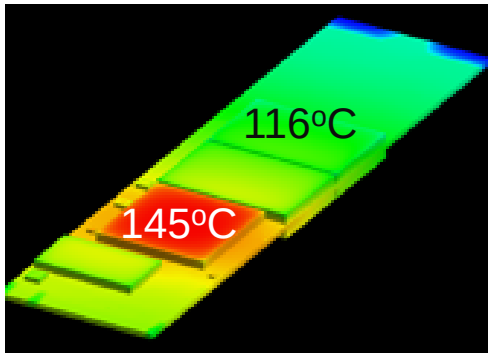
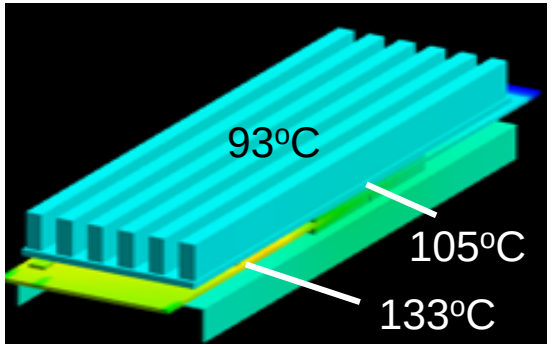
Ambient setup

Thermal component setup

PCB component setup

Thermal Elements Output

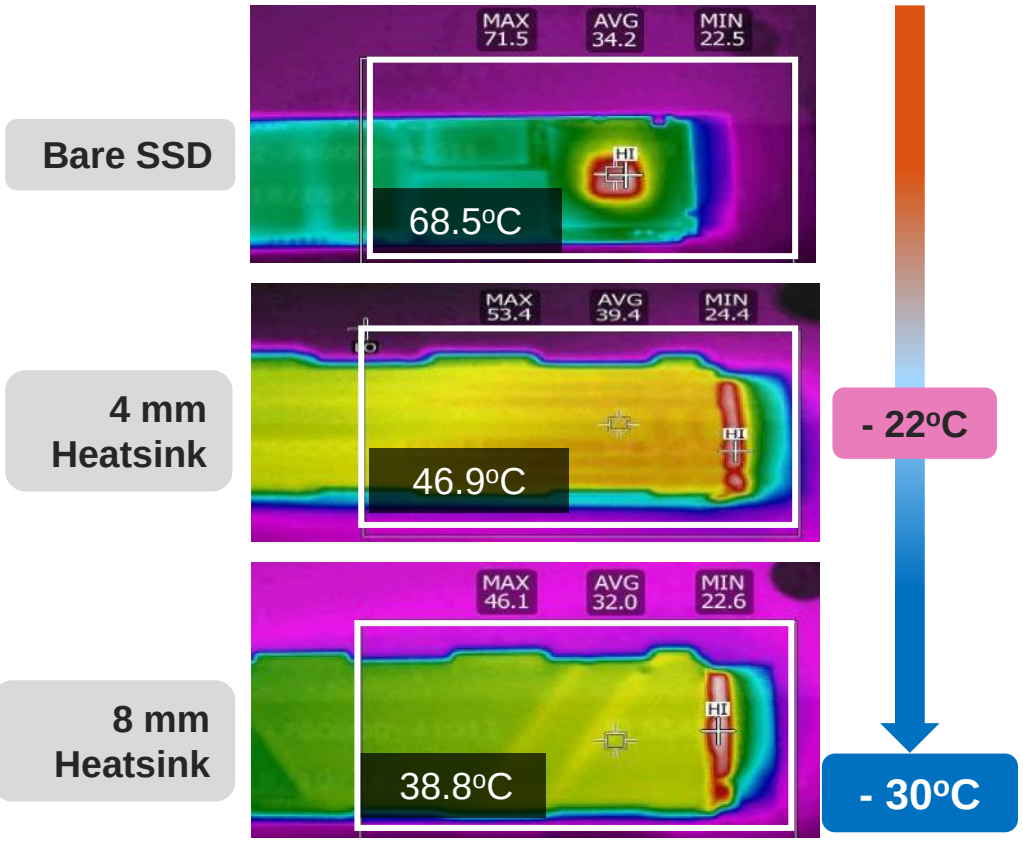
- Temperature plot
- Component level
- System level

Bare SSD	8 mm Heatsink
Ambient condition: 55ºC 600 ft/m*	
	
Ambient condition: 70ºC 1200 ft/m*	
	

NOTE: Simulation under worst-case scenario

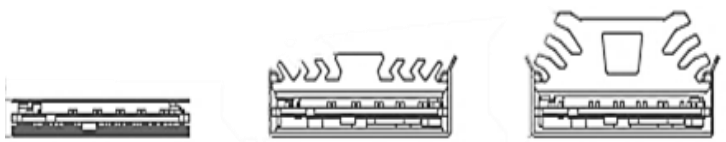
* ft/m: feet per minute

SSD Thermal Enhancement Options



NOTE: Images were taken at Room temp./450 LFM, 100% Sequential write after 30-mins test.

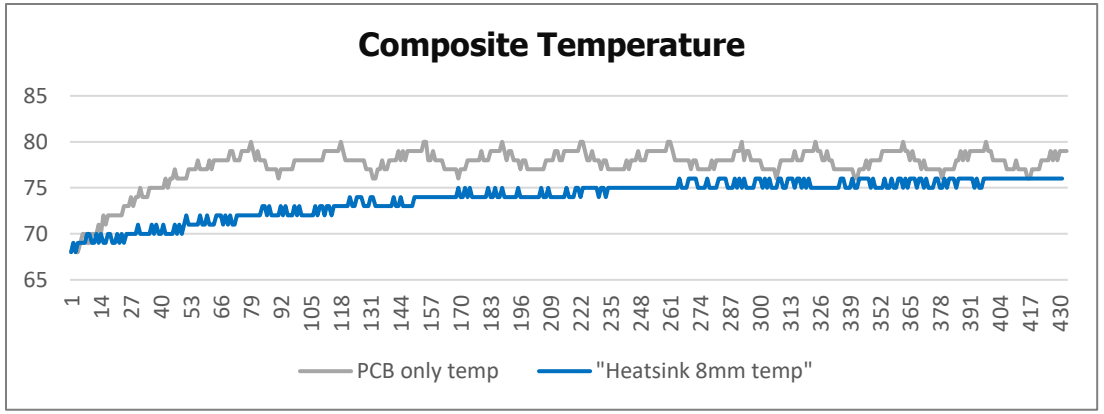
	Heat Dissipation Solution		
Type	**Copper Foil**	**4 mm Heatsink**	**8 mm Heatsink**
Length Width	L: 80 mm W: 22 mm	L: 80 mm W: 24.4 mm	L: 80 mm W: 24.4 mm
Height	3.9 mm	4 mm: 8.3 mm	8 mm: 12.3 mm
Material	Copper	Upper: Aluminum alloy Bottom: Stainless steel	Upper: Aluminum alloy Bottom: Stainless steel
Suitability	Limited space	Enough space for effective heat dissipation	
Fixedness	Stick	Clips design	Clips design

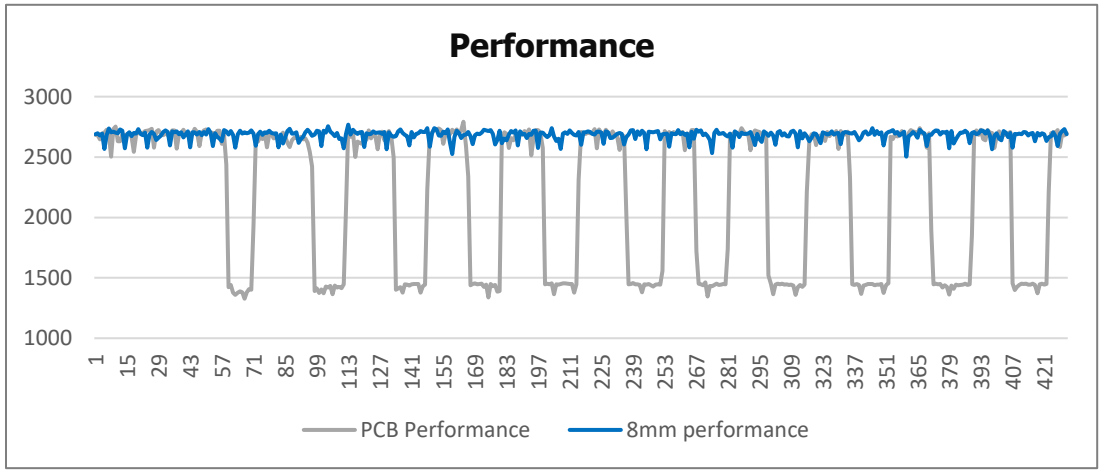


NVMe Performance vs Thermal - Bare PCB vs Heatsink

When the composite temp. keeps increasing, the SSD repeatedly slows down to cool it.

The 8 mm heatsink can dissipate heat complemented by airflow support.
The max. composite temp. of NVMe SSD is reduced, and the performance is steady with optimized FW algorithm.





(Ta: 55°C & Airflow: 600 LFM*)

Test result can be varied by case/ configuration

* LFM: Linear Feet per Minute

Simulation & Customization: One Scenario Doesn't Fit All

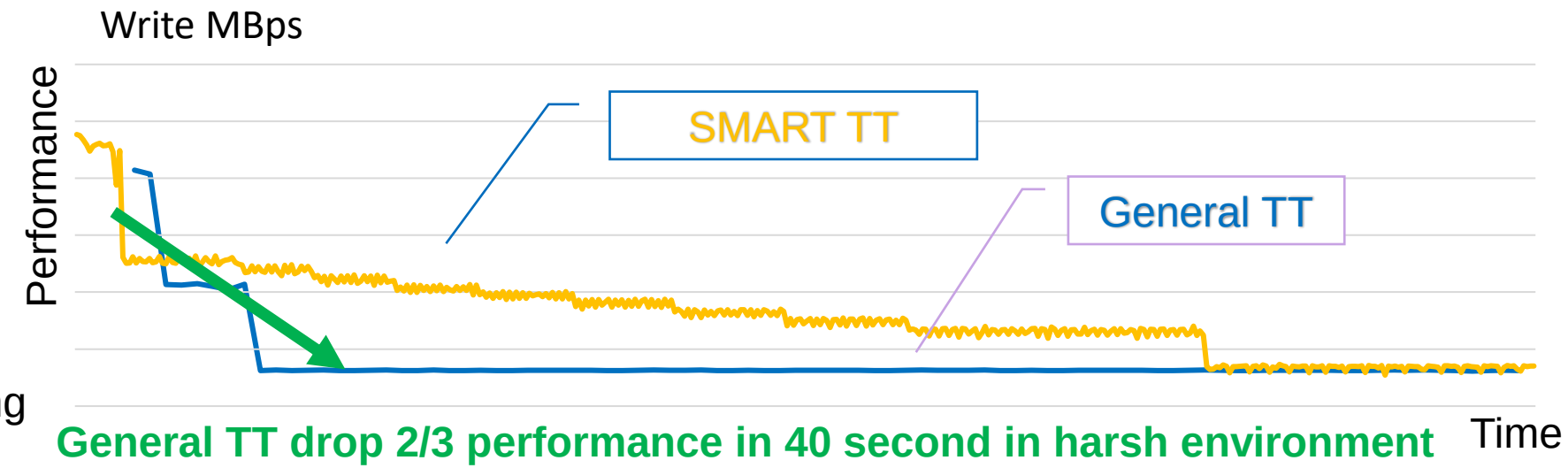
Scenario	Environment	Temperature	Heatsink Type	Test Result	Remark
Scenario 1	No Airflow	Ta: 65°C (Read)	Copper foil	Avg. Read: + 7% Avg. Temp.: -2°C	Sustained Read Performance
Scenario 2	600 LFM	Ta: 65°C (Write)	Copper foil	Avg. Write +100% Avg. Temp.: - 2°C	2X Seq. Write
Scenario 3	600 LFM	Ta: 55°C (Read)	Fin-type heatsink	Avg. Read: +28% Avg. Temp.: -5°C	Sustained Read Performance
Scenario 4	600 LFM	Ta: 55°C (Write)	Fin-type heatsink	Avg. Write: +12% Avg. Temp.: -5.5°C	Slowly temp. Ramping
Scenario 5	1200 LFM	Ta: 70°C (Write)	Fin-type heatsink	Temperature slop rate of Bare SSD is 7 times higher than 8 mm heatsink	Fin-type Heatsink: Slower ramping temp. Slower performance drop

* LFM: Linear Feet per Minute

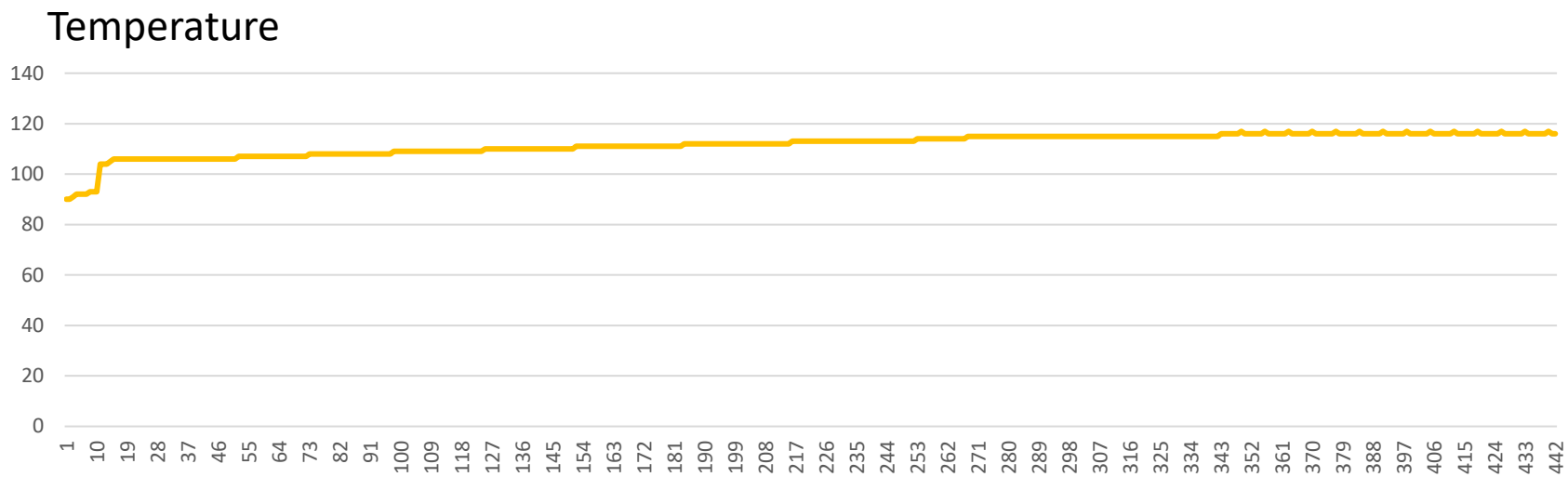
SMART Thermal Throttle Architecture

In a harsh environment, thermal throttling can quickly impact performance

SMART Thermal Throttling controls the drop in performance.



General TT drop 2/3 performance in 40 second in harsh environment

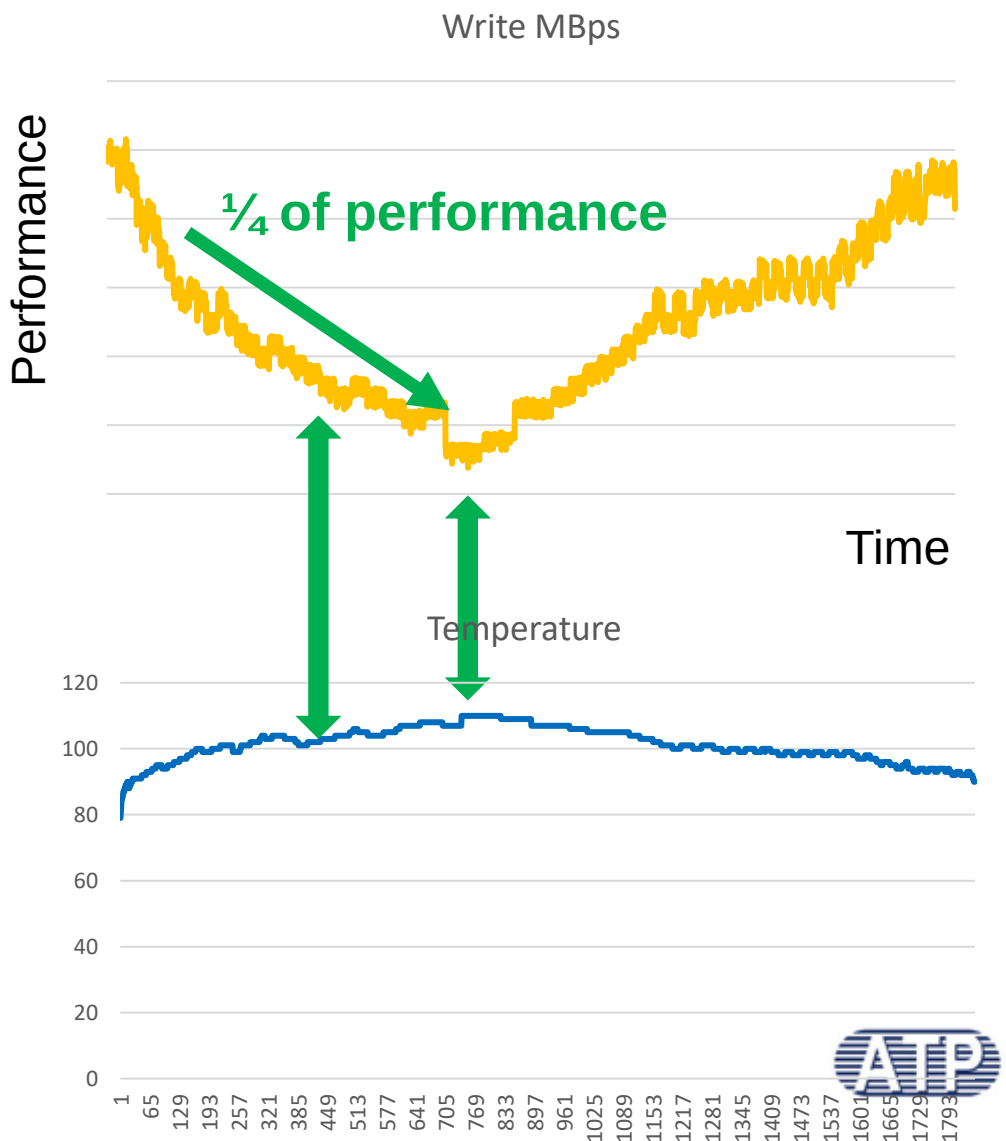


Ta=85°C + Airflow 1200 ft/min + 100% Seq. Write 1MB, QD32

Example of Joint-Development

Eco system (Host) responds to cool down environment temperature to ramp SSD performance.

The more agile of host thermal design to check and balance temperature, the better sustainable performance can be expected.



Simulation & Customization: One Scenario Doesn't Fit All

- Thermal evaluation is more critical for the next generation SSD
- Total Solution Provider can Save Engineering Resource and Development Time
- Joint-Development can be optimized for better System Performance