THERMAL THROTTLING TECHNOLOGY

White Paper

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Revision 1.0

This Application Note Describes the Thermal Throttling Technology for Fortasa Solid State Drives Products

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Overview

Solid-state drives (SSDs) are a type of data storage device that use a non-volatile semiconductor-based memory, such as a flash memory, to store data. As SSD capacity increases, performance demands increase respectively. With an increase in performance requirement multiple storage components need to be addressed simultaneously, increasing the power usage by the SSD. At the same time the physical size requirements of the SSD generally stay the same or become even smaller.

When SSDs are subjected to sustained workloads from peak performance sequential writes over a long period of time the drives tend to internally heat up. If and when the SSD temperature exceeds that of the rated operating conditions, data errors are very likely to occur. In addition, to compound the problem, SSDs used in industrial applications must be able to tolerate higher ambient temperatures, which naturally hinder heat dissipation. This temperature increase can potentially put data stored on the SSD at the risk of being corrupted and hardware components in danger of being permanently damaged, both of which, naturally, lead to significant reduction in the life expectancy of the drive.

To address this problem, Fortasa current generation SSD products are designed with a built-in thermal sensor to monitor the temperature of the SSD. Additionally, the Flash Controller Firmware utilizes this real time temperature measurement data to automatically reduce the drive performance when the internal SSD temperature exceeds the device rated performance threshold. This feature reduces the drive performance which allows for SSD self-cooling and this, in-turn, increases SSD’s reliability and prolongs product’s lifespan.

The thermal management technique presented in this article can be applied to any thermal-sensor-equipped SSD, whether it supports Standard-grade temperature operating ranges (0°C to 70°C) or Industrial-grade temperature operating ranges (-40°C to 85°C).

Thermal Management

Fortasa’s thermal management technique consists of two distinct components: hardware implementation of a thermal sensor and firmware configuration of thermal throttling. Fortasa’s on-board thermal sensor is integrated into the design to monitor the physical temperature of an SSD. The Flash Controller constantly monitors the Thermal Sensor’s real-time reading to trigger the Thermal Throttling algorithm.

To prevent drive hardware components from operating at high temperature level and damaging the drive, the thermal throttling algorithm is implemented. This firmware component is critical to make sure that the temperature of the drive does not exceed its maximum rated temperature. The thermal throttling algorithm maintains an operating temperature threshold. Once this threshold is reached the algorithm forces the drive’s performance to be reduced to use less energy and, subsequently, self-cool. And once the SSD’s temperate drop below another threshold the thermal throttling algorithm releases the performance throttling and allows the drive operation to increase back to the regular operating condition.

In the following sections the impact the location of thermal sensor on a circuit board has on throttling will be elaborated, followed by a flow chart demonstrated to explain in greater detail the process of thermal throttling.

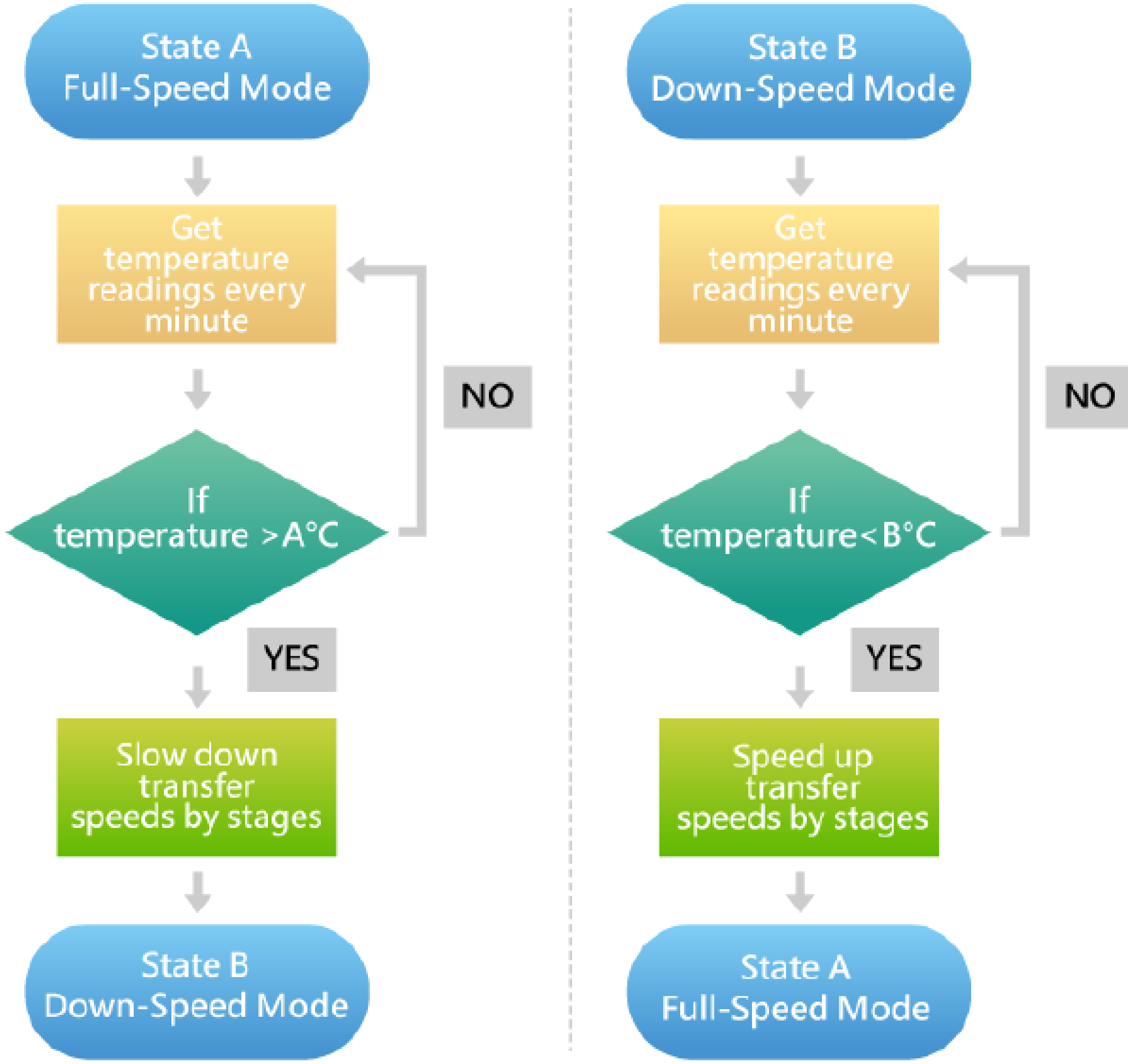
Thermal Sensor Discussion

For Fortasa's SSD products featuring built-in thermal sensors, device temperature values used by the thermal throttling feature are based on the readings from temperature sensor located on the device PCB and are accessible through S.M.A.R.T. command attributes. Depending on where the thermal sensor is located, the temperature which can be read by the sensor varies and has different impacts on throttling operation.

The construction of an SSD contains two critical components: Flash controller and the NAND Flash non-volatile memory. The optimal design implementation is to place the temperature sensor next to the Flash controller because the temperature generation of the SSD largely comes from the Flash controller. With the sensor positioned next to the controller, the moment when the drive is close to overheating can be reflected in the temperature reading of the drive. Oppositely, if the sensor is placed near the Flash storage chips, it may not serve as an accurate indicator of whether the drive is close to overheating.

With either deployment of the thermal sensor, Fortasa has configured the thermal throttling algorithm threshold levels depending on the sensor placement on the PCB. These threshold levels were statistically tested in engineering and production environments to guarantee reliable operation for all Fortasa products.

Thermal Throttling Flow Chart

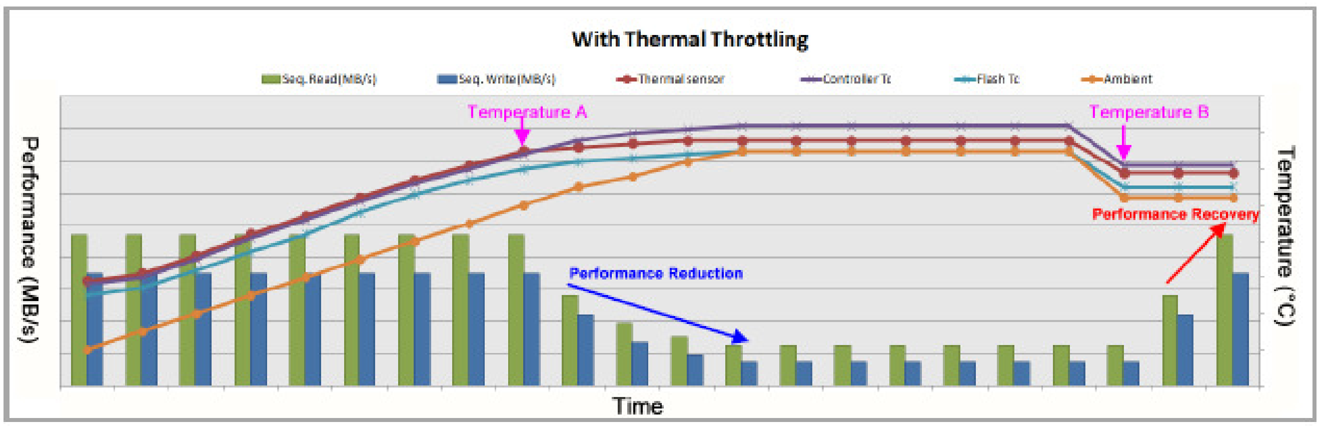


Test Result Comparison

The temperature of an SSD can be monitored via a thermal sensor integrated in the design of the drive. However, predicting data reliability with the sensor only is insufficient. Without the configuration of thermal throttling, both data and drive can be endangered as the drive temperature continues to increase as the drive gets heavier utilized. In the following sections, empirical test results are shown to illustrate the different impacts between SSDs with and without thermal throttling implementation.

SSD with Thermal Throttling

According to the flow chart above, for an SSD with enabled thermal throttling algorithm, the drive is initially accessed at peak performance speed. As the drive starts to warm up due to continues access under high performance condition, its temperature indicated by the red line increases to the maximum threshold temperature of A°C.



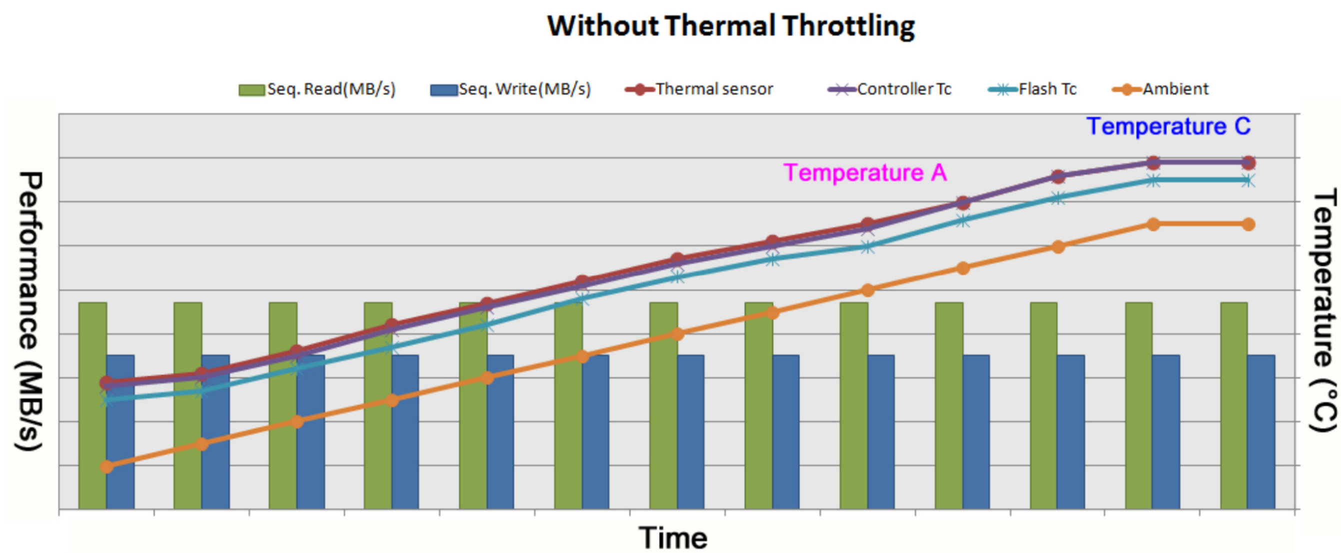
When the temperature exceeds the threshold value of A°C, the drive starts to throttle down the performance in multiple stages, thereby allowing the SSD to cool down. Temperature level is continuously being measured and monitored, and if it continuous to increase, the performance level is reduced by another step, until it reaches the low steady state performance level.

As shown in the diagram above, the SSD temperature measurement flattens out after Temperature A condition is reached and performance is reduced. The drive also does not cool down any further after measuring the minimum threshold temperature value of B°C after running at a slower speed for a period of time. With the temperature dropping below Temperature B, the drive again increases the performance level, upto the peak level achieved in the beginning of the test.

SSD without Thermal Throttling

For comparison, the SSD which is not configured with thermal throttling capability is also accessed at full speed in the initial phase of the test. As the drive continues to be accessed at the peak performance level, the drive temperature rises above Temperature A and beyond.

Unlike the SSD with thermal throttling, this SSD without the thermal throttling technology mechanism does not throttle back on sequential read/write when the drive temperature exceeds the maximum threshold value of A°C. Instead, the temperature keeps increasing until it reaches a high steady state at Temperature C and then the drive either overheats or shuts down (if the Flash controller has an overheating fault mechanism). Neither of these conditions is truly acceptable in continuous industrial operation.



Conclusion

As SSDs capacity is increasing to the terabyte range and beyond, the increase in performance is also mandated by the market. However, the downside of the performance gains is the likely outcome of drive overhead and reduction of component life expectancy and/or data loss. Thermal sensors are therefore required to be placed on a circuit board to monitor the temperature of the drive in real time.

The thermal throttling algorithm is triggered once the temperature of the drive exceeds the maximum threshold level to reduce performance step by step and self-cool the drive. Performance is only permitted to drop to the extent necessary for recovering a stable temperature to cool down the device. Once the temperature decreases to the minimum threshold value, transfer rate will rise back to an optimum performance level.

Thermal throttling is an optimal way to continue constant drive operation, prolong its' operational lifetime and improve data integrity.

Revision History

Revision	Date	Description	Comments
1.0	1/11/2019	Initial Release	