Improving the Performance of M.2 NVMe SSDs at Industrial Temperatures

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NVMe Introduction

- Trend of embedded storage: SATA to PCIe
- Over the years, CPU and DRAM technology have been continually improving and increasing the speeds to meet escalating data-hungry requirement.
- SATA is generally the least expensive and most extensively used SSD interface today.
- To narrow the widening gap between fast CPU/DRAM and slow storage, Non-Volatile Memory Express, also known as NVMe™, was developed.
NVMe Introduction

The following table compares bandwidths by generation. ATP’s M.2 NVMe SSD is designed for a PCIe 3.0 interface and fits in a x4 lane, delivering up to 7.9 Gb/s transfer rate and up to 3.9 GB/s throughput.

<table>
<thead>
<tr>
<th>Generation</th>
<th>PCIe Transfer Rate</th>
<th>PCIe Throughput per Lane</th>
<th>SATA Generation</th>
<th>SATA Transfer Rate</th>
<th>SATA Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen1</td>
<td>2.5 Gb/s</td>
<td>x1: 250 MB/s</td>
<td>x4: 1 GB/s</td>
<td>Gen1</td>
<td>1.5 Gb/s</td>
</tr>
<tr>
<td>Gen2</td>
<td>4.9 Gb/s</td>
<td>x1: 500 MB/s</td>
<td>x4: 2 GB/s</td>
<td>Gen2</td>
<td>3 Gb/s</td>
</tr>
<tr>
<td>Gen3</td>
<td>7.9 Gb/s</td>
<td>x1: 984.6 MB/s</td>
<td>x4: 3.9 GB/s</td>
<td>Gen3</td>
<td>6 Gb/s</td>
</tr>
<tr>
<td>Gen4</td>
<td>15.8 Gb/s</td>
<td>x1: 1,969 MB/s</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NVMe Performance

- The actual NVMe performance is boosting to catch up the speed requirement.
- However, the heat accumulation from full performance running becomes a big challenge during the system design.
Embedded Application in I-Temp

- In the embedded application, it usually has fanless design due to the space limitation. The heat inside the system becomes one of the key factors that impact the performance.
- Usually, the NVMe controller has different thermal settings to adjust the clock under the different temperatures in order to slow the performance to ease the heat dissipation issue.
- For the I-Temp environment, it’s also very important to optimize this setting. Therefore, the performance could maintain in certain level with balance instead of keeping drop down.
NVMe M.2 2280 Form Factor

- Printed Circuit Board (PCB)
- NVMe Controller
- Thermal Sensor
- DRAM Cache
- NAND Flash chips
Thermal Throttling Setting

Controller

36 Thermal Throttling Stage 0

Controller

36 Thermal Throttling Stage 1

Controller

36 Thermal Throttling Stage 2
Dynamic Thermal Throttling

ATP vs. Other Brand 1TB NVMe SSD
Dynamic Thermal Throttling & Performance Comparison
Seq Write 128kb at Ambient 55°C (1 hr)

ATP Dynamic Thermal Throttling activated

Controller Temperature

60-80°C  Between 80-100°C  100°C

ATP lometer

Other lometer

Flash Memory Summit 2018
Santa Clara, CA

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Dynamic Thermal Throttling

ATP 1TB NVMe SSD (T \text{ambient}: 25^\circ C \sim 85^\circ C)

Performance

<table>
<thead>
<tr>
<th>MBytes/s</th>
<th>IOMeter Seq. Write 128KB</th>
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</table>

Graph showing performance over time at different temperatures.
Dynamic Thermal Throttling

ATP 1TB NVMe SSD (T_{ambient}: 25\degree C~85\degree C)