SNIA Solid State Storage Performance Test Specification

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Abstract

SNIA Solid State Storage Performance Test Specification

- This session will appeal to End Users, OEMs, Drive Manufacturers, System Integrators, as well as those that are seeking a fundamental understanding of the SNIA's Solid State Storage Performance Test Specification.
Available now for public review

Download the spec:  
www.snia.org/tech_activities/publicreview

Upload Feedback:  
www.snia.org/tech_activities/feedback

Updates to Spec:  
www.snia.org/forums/sssi
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- Key Issues Considered
- Test Environment

PTS Specification
- PTS v1.0 – Purpose, Scope, Exclusions
- Test Setup, Purge, Steady State
- Tests Contained in the PTS v1.0
- Example: Enterprise IOPS and Enterprise Latency Tests

PTS Roadmap
- Follow-on Work In Progress or Consideration

SNIA Organization and the SSSI
- Feedback & Involvement
Motivation

- No Industry Standard
  - No standard methodology, common terminology, nor test environment for measuring SSS performance

- Myriad of Applications on Various Platforms
  - SSS makers/reviewers use different applications, OS and hardware; produces and uses selected metrics

- Market Confusion
  - Difficult to compare test results from different sources; difficult to ensure accuracy in representing SSS products to end users; box-top numbers are pretty useless
SSD Performance Varies Over Time

SSD PERFORMANCE STATES - IOPS v TIME: GB

- FOB
- Transition
- Steady State

IOPS v TIME

IOPS v TGBW
Many Different Kinds of Behaviors
SSD’s are Complicated Devices

NAND-based SSD’s are quite different from HDDs

- No moving parts
- Generally no direct overwrite
- Not true “random access devices” → page read/writes, block erase
- Limited cell cycle life → wear leveling required
- Various NAND flavors: SLC, MLC, XLC, SLC+MLC….
- Internal data flow management key to performance differentiator
## Items Impacting SSD Performance

<table>
<thead>
<tr>
<th>Write History</th>
<th>PC Active Range</th>
<th>Test Active Range</th>
<th>Data Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What was previously written</td>
<td>• Where data was previously written</td>
<td>• Where and how much data is written</td>
<td>• What is the content</td>
</tr>
<tr>
<td>• Trim effects</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Access Pattern</th>
<th>Demand Intensity</th>
<th>Throttling</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Manner in which data is being accessed</td>
<td>• How hard apps are driving the device</td>
<td>• How fast data is allowed to be written</td>
<td>?</td>
</tr>
</tbody>
</table>
A Solution is in Emerging

SSS PTS

SNIA SSSI & TWG Solid State Storage Performance Test Specification (SSS PTS) Enterprise Draft v 1.0 – Public Review

Standardized Tests & Methodologies

Effectively measure device performance of SSS products

Fair Comparisons

Using a standardize test methodology and reporting requirements, performance can be more easily compared, particularly done using a reference environment
The SSS PTS is grounded in a few key concepts:

- **Common Starting Point** - start test by first placing the drive into a known, repeatable state
- **Pre-Conditioning** – from the common starting point, pre-conditioned the drive to a “used” state
- **Steady State** – measurements are taken only when key performance metrics are relatively time invariant
- **Required Reporting** – establishes required testing conditions and results reporting
Agnostic to Test Platforms

- no specific test environment
- however, a Reference Test Platform (RTP) is outlined to facility direct comparisons

Generic Test Tool Requirements

- sets minimum requirements a test application and the test environment must be able to do

Standardized Test Report Format –

- Draft test report format is proposed with required conditions, variables & data formats
SSD Reference Test Platform

- The SNIA SSS TWG approved a “Reference Test Platform”, which specified a set of hardware and options for software to allow direct comparisons.
- Calypso has developed a RTP product based on this recommendation.
- A significant portion of the data used as input to inform the formation of the Spec is taken on the Calypso RTP.
- The Calypso RTP has been used extensively to validate the current Draft V1.0 Specification.
- Calypso’s RTP is fully PTS-compliant, and has been used by Calypso for 2010 Blind Survey of SAS/SATA SSDs & other 3rd Party Comparison Reports.
SSSI Reference Test Platform

- Intel S5520HC
- Single Intel W5580, 3.2GHz, Quad-core CPU
- 12GB, 1333MHz, ECC DDR3 RAM
- LSI 9212-4e4i 6Gb/s SAS HBA
- Intel ICH10R 3Gb/s SATA
- 8X Gen-II PCI-e

- CentOS 5.5
- Calypso RTP Backend V1.5
- Calypso Test Suite (CTS) V6.5
R/W=65/35, Various Block Sizes
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overview
- motivation
- key issues considered
- test environment

PTS specification
- enterprise PTS v1.0 – purpose, scope, exclusions
- test setup, purge, steady state
- tests contained in the enterprise PTS v1.0
- examples: enterprise IOPS and enterprise latency tests

PTS roadmap
- follow-on work in progress or consideration

SNIA organization and the SSSI
- feedback & involvement
“…This Specification defines a set of device level tests and methodologies to enable comparative testing of Solid State Storage (SSS) devices in Enterprise systems.”

- Performance Test Specification v1.0 – Section 1.1
Tests Contained In Draft V1.0 Spec.

The V1.0 Specification encompasses:

- A suite of basic SSS performance tests
  - Write Saturation
  - IOPS
  - Throughput
  - Latency
- Preconditioning and Steady State requirements
- Standard test procedures
- Standard test reporting requirements
What Is NOT Covered In the Spec

- Application workload tests
- Matching to user workloads
- Energy efficiency
- Required test platform (HW/OS/Tools)
- Certification
- Device endurance, availability, data integrity

- Performance Test Specification v1.0 – Section 1.4
The SNIA PTS Enterprise Draft V1.0

Write Saturation
- Random Access
- R/W: 100% Writes
- BS: 4K

Enterprise IOPS
- Random Access
  - R/W:
    - 100/0, 95/5, 65/35, 50/50, 35/65, 5/95, 0/100
  - BS:
    - 1024K, 128K, 64K, 32K, 16K, 8K, 4K, 0.5K

Enterprise TP
- Sequential Access
  - R/W:
    - 100/0, 0/100
  - BS:
    - 1024K, 64K, 8K, 4K, 0.5K

Enterprise Latency
- Random Access
  - R/W:
    - 100/0, 65/35, 0/100
  - BS:
    - 8K, 4K, 0.5K
Basic Test Flow

1. **Purge**
   - Security Erase, Sanitize, Format Unit, other proprietary methods where indicated

2. **Set Conditions**
   - Set user selectable test parameters, such as Active Range, Data Pattern, Demand Intensity

3. **Pre-Condition**
   - Workload independent (WIPC)
   - Workload dependent (WDPC)

4. **Run Until SS**
   - Reiterate loops until Steady State is reached, or run to a prescribed maximum number of loops

5. **Collect Data**
   - Collect data from Steady State Measurement Window

6. **Generate Reports**
   - Use standard report formats and include required and optional elements
SSS PTS Test Sequence

- Purge
- Precondition
- Test
- Collect & Report
Key Concepts Used in the Spec.

A. Purge

B. Pre-Condition
   - Workload independent
   - Workload dependent

C. Active Range
   - Pre-conditioning
   - Test

D. Steady State
   - Measurement window
   - Data excursion condition
   - Slope excursion condition
A: Purge

As per the PTS V1.0 Specification, purge is defined as:

“The process of returning an SSS device to a state in which subsequent writes execute, as closely as possible, as if the device had never been used and does not contain any valid data”

Example implementation includes: ATA Security Erase, Sanitize, SCSI Format Unit
B: Pre-Conditioning

- Pre-Conditioning is a key requirement in getting repeatable, representative results
- Goal is to put drive into “Steady State”, using:
  - **Workload independent** – *PTS v1.0 Section 3.3*
    - Use a prescribed workload unrelated to the test loop
    - Write 2X user capacity using SEQ/128KiB blocks
  - **Workload dependent** – *PTS v1.0 Section 3.3*
    - Run test workload itself as pre-conditioning (self pre-conditioning)
C: Active Range

As per the PTS V1.0 Specification, Active Range is defined as:

“… ActiveRange is the range of LBA’s that may be accessed by the preconditioning and/or test code…”

They are normally defined as % of the maximum LBA available to the user.

Note Pre-conditioning and Test can have different Active Ranges.
D: Steady State Definition

- Premise is that reported data should be take only 
  **AFTER** the test loop results shows the drive has 
  reached and maintained “Steady State”

- The Measurement Window is the interval, 
  measured in Rounds, when the test results have 
  entered and maintained Steady State for 5 Rounds
D: Steady State Definition

Steady State is reached only if BOTH of the following conditions are satisfied (assuming “y” is the variable being tracked):

1. Variation of y within the Measurement Windows is within 20% of the Average
   
   “Max(y)-Min(y) within the Measurement Window is no more than 20% of the Ave(y) within the Measurement Window; and ”

2. Trending of y within the Measurement Windows is within 10% of the Average
   
   “[Max(y) as defined by the linear curve fit of the data within the Measurement Window] – [Min(y) as defined by the best linear curve fit of the data within the Measurement Window] is within 10% of Ave(y) within the Measurement Window. “
D: SS Measurement Window

Tracking Variable = RND/4KiB IOPS

Measurement Window

IOFS
Average
110% Average
90% Average
Slope

IOPS

Round

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D: SS Measurement Window

Steady State Measurement Windows (Rounds 12-16)

- IOPS
- Average
- 110% of Average
- 90% of Average
- Slope

Data Excursion
Slope Excursion
10% of Average
20% of Average
D: Steady State

♦ Compare
  ◆ [Data Excursion] with [20% of Average]
  ◆ [Slope Excursion] with [10% of Average]

♦ Note
  ◆ This method is slightly more tolerant than +10% and – 10% data excursion method and +5% and – 5% slope excursion method
200G-Class MLC: 72 Rounds Pre-conditioning Report: 100% Writes

"Steady State"
## Workload Schematics

### Write Saturation
- Random Access
- R/W: 100% Writes
- BS: 4K

### Enterprise IOPS
- Random Access
  - R/W:
    - 100/0, 95/5, 65/35, 50/50, 35/65, 5/95, 0/100
  - BS:
    - 1024K, 128K, 64K, 32K, 16K, 8K, 4K, 0.5K

### Enterprise TP
- Sequential Access
  - R/W:
    - 100/0, 0/100
  - BS:
    - 1024K, 64K, 8K, 4K, 0.5K

### Enterprise Latency
- Random Access
  - R/W:
    - 100/0, 65/35, 0/100
  - BS:
    - 8K, 4K, 0.5K
Enterprise IOPS Block Sequencing

Block Size (KiB)

Test Duration (Min)

R/W=100/0  R/W=95/5  R/W=65/35  R/W=50/50  R/W=35/65  R/W=5/95  R/W=0/100

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Enterprise IOPS RW/BS Sequence

Block Size (KiB)

Time (Minutes)

R/W Mix

- R/W=0/100
- R/W=5/95
- R/W=35/65
- R/W=50/50
- R/W=65/35
- R/W=95/5
- R/W=100/0
- SEQ/128K Pre-Conditioning

Purge + SEQ WIPEC
TP RW/BS Sequence

Enterprise TP Block Size Sequencing

Test Duration (Min)

Block Size (kB)

1024K
512
256
128
64
32
16
8
4
2
1
0.5
0.25
128K PC
64K
8K
4K
0.5K
128K PC
128K PC
128K PC
128K PC
128K PC
128K PC
Enterprise Latency Block Sequencing

-10  -9  -8  -7  -6  -5  -4  -3  -2  -1  0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20

R/W=100/0  R/W=65/35  R/W=35/65  R/W=0/100

Block Size (KiB)

8  4  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5

-10  -9  -8  -7  -6  -5  -4  -3  -2  -1  0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20

Test Duration (Min)
Two Examples

.getKeyword("Enterprise IOPS")

Enterprise Latency
Enterprise IOPS

❖ DUT:
  ❖ 100GB-Class Enterprise SLC drive

❖ Test Parameters:
  ❖ Active Range = [0,100%]
  ❖ Thread Count=2
  ❖ Queue Depth (Outstanding IO/Thread)=16
  ❖ DP=RND
Enterprise Latency

- **DUT:**
  - 100GB-Class SLC drive

- **Test Parameters:**
  - Active Range = [0,100%]
  - Thread Count=1
  - Queue Depth (Outstanding IO/Thread)=1
  - DP=RND
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- PTS Roadmap
  - Follow-on Work In Progress or Consideration

- SNIA Organization and the SSSI
  - Feedback & Involvement
SNIA SSSI PTS Follow-On Work

- Enterprise SPEC
  - power measurement
  - cross stimulus recovery
  - response time histograms
  - ...

- Client SPEC
  - Constraints to better match client usage cases
    - active footprint, active span, segmentation, etc.
  - Trace-based workloads
  - ...

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IOPS/W
- Measure total W used over a period of time, and deriving the number of IOPS that can be achieved at a given block size and access pattern with unit power
- Measure the power efficiency of the device

Client Active Range Restriction
- Perform PC or Test in a restricted LBA range or ranges
- To better simulate the environment of client usage

Cross Stimulus Recovery
- Measure performance metrics when changing between RND/SEQ and small block/large block stimulus
- To see how drive handles switching between sustained access patterns

Demand Intensity
- Measure performance metrics with various outstanding IOS from the test application
- Understand the trade-off between achieving maximum IOPS vs acceptable maximum response time criteria
SNIA SSSI PTS Follow-On Work

Response Time Histogram
- Get detailed response time statistics during specific stimulus
- to provide better insight into a drive's response time performance beyond a single average response time number

Task-Based Synth. Workloads
- Synthetic approximation to IO Trace playback based on understanding of access characteristics of specific tasks, such as video streaming, office productivity, etc.
- Build a library of well-studied synthetic stimulus that can be used to form more complex user cases

SSD Figure of Merit
- Derive simplified metric(s) from data resulting from various PTS tests
- To allow simply comparison between drives to aid marketing

Industry Requests?
-?

-?

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SNIA – Organization Chart
Charter & Mission Statements

SNIA — Storage Networking Industry Association

”Lead Industry Standards for information storage management”

SSSI — Solid State Storage Initiative

“Foster the success of Enterprise & Client SSS markets”

SSS TWG — Solid State Storage Technical Working Group

“Develop SNIA Technical Specifications & Standards”
Feedback & Involvement

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- SNIA Education Committee

Eden Kim