SNIA
Solid State Storage Initiative

Solid State Storage Performance Test Specification

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SSSI Members and Authors:
Neal Ekker
Khaled Amer
Paul Wassenberg, Marvell Semiconductor

The Solid State Storage Initiative

About SNIA

The Storage Networking Industry Association (SNIA) is a not-for-profit global organization made up of some 400-member companies and 7,000 individuals spanning virtually the entire storage industry. SNIA's mission is to lead the storage industry worldwide in developing and promoting standards, technologies, and educational services to empower organizations in the management of information. To this end, SNIA is uniquely committed to delivering standards, education, and services that will propel open storage networking solutions into the broader market. For additional information, visit the SNIA web site at http://www.snia.org.

About SSSI

The SNIA Solid State Storage Initiative (SSSI) was formed to foster the growth and success of the market for solid state storage in both enterprise and client environments. It consists of various subcommittees that are focused on developing technical standards and tools in order to educate users about the advantages of SSS devices. For additional information, visit the SNIA SSSI web site at http://www.snia.org/sssi.

About the SSS TWG

The SNIA Solid State Storage Technical Working Group (SSS TWG) was formed by the SNIA Technical Council and is ultimately responsible for the technical development, ratification, and publication of solid state storage standards. It consists of member companies across the storage industry. For more information, see http://www.snia.org/forums/sssi/programs/twg/.

Introduction

The Storage Networking Industry Association's (SNIA) Solid State Storage Technical Work Group (SSS TWG) has developed a very important document: **The Solid State Storage Performance Test Specification (SSS PTS)**. The SSS PTS sets forth a standard methodology and nomenclature for measuring the performance of solid state storage devices. Participation in the SSS TWG came from a number of solid state storage (SSS) industry companies and stakeholders from all parts of the SSS industry, including the designers and manufacturers of SSS devices, computer systems, controller chips, test labs, and end users. It was a monumental achievement and ensures that the SSS PTS represents many points of view.

The Challenge: Hard to Compare Performance of SSS Devices

Hard disk drives (HDD) have been the technology of choice for enterprise and client data storage for over 30 years. HDDs are well understood and provide predictable performance. However, they use moving mechanical parts which create rotational latency and slow data access rates. Likewise, solid state storage devices have been around for decades; however, the market has been relatively small. As NAND Flash becomes more reliable and affordable, solid state drives (SSD) will increasingly complement HDDs by improving system performance.

NAND Flash has unique performance issues, and mitigating these challenges has kept battalions of storage engineers well employed for years. The current crop of Flash engineered solutions has led to a broad but confusing array of Flash SSS products with sometimes conflicting claims from SSS vendors about basic product performance.

Solid State Storage (SSS)

A nonvolatile storage medium that employs integrated circuits (RAM or Flash memory) rather than rotating magnetic or optical media. It generally offers very high access performance compared to that of rotating magnetic disks, because it eliminates mechanical seek and rotation time. It includes all form factors, interfaces, and technologies, including Flash and RAM solid state drives.

Until today, there has been no widely accepted industry standard test methodology or specified test environment for measuring solid state storage device performance. As a result, each SSS manufacturer utilizes different measurement methodologies to derive performance specifications for their SSS products, and marketing collateral from different SSS vendors or test reviewers may not specify the performance state, read/write mix, or data transfer size. How do you know if the performance numbers are measured during the "fresh out of the box (FOB)," "transient," or "steady state" performance state? How do you know if the device was tested with a stimulus data access pattern that has a 100% or other read/write mix? How do you know if a small or large data transfer size was used? Without a consistent set of tests and test methodologies, comparing the performance of one SSS device to another was problematic.

Solid State Drive (SSD)

A subset of solid state storage which uses the same interfaces and form factor as hard disk drives (HDDs).

The Solution: Solid State Storage Performance Test Specification

To address current SSS market confusion, the SNIA SSS TWG in association with the Solid State Storage Initiative (SSSI) began developing the Solid State Storage Performance Test Specification. The SSS PTS defines a suite of tests and test methodologies that effectively measure the comparative performance characteristics of SSS products. When executed in a specific hardware/software environment, the SSS PTS will provide measurements of performance that may be fairly compared to those of other SSS products measured in the same way in the same environment.

Solid State Storage Performance Test Specification (SSS PTS)

Defines a set of device level tests and methodologies to enable comparative testing of Solid State Storage (SSS) devices.

The SSS PTS is intended for use by individuals and companies engaged in the design, development, qualification, manufacture, test, acceptance, and failure analysis of SSS devices, systems, and subsystems. This first SSS PTS iteration is focused on conducting SSS performance testing at the device level (block storage versus file system) in order to understand the characteristics and behaviors of different SSS devices under the same test conditions. It offers the first step toward an industry standard that eventually can be used to compare performance, apples to apples, SSS device to SSS device.

The Benefit: Realistic, Accurate SSS Device Performance Comparison

The SSS Performance Test Specification is an important contribution to the suddenly very active enterprise and client solid state storage marketplaces. The SSS PTS establishes a common terminology, standardized tests, and consistent test methodologies for evaluating SSS device performance. Bringing clarity to an otherwise confusing marketplace, the SSS PTS will lead to greater confidence in solid state storage solutions and ultimately higher adoption rates of this very beneficial technology.

It is the intention of the SSSI and SSS TWG to continue to develop and promote the SSS PTS to the point where all SSS industry and end user stakeholders in both the enterprise and client market segments will be able to employ it to make realistic, accurate, and fair judgments about the performance of individual SSS devices.

Unique Characteristics of Flash

Though some solid state storage has in the past and will continue to be made from Dynamic Random Access Memory (DRAM), the majority of new SSS products coming onto the market today are built with NAND Flash as their basic storage medium. NAND Flash offers the very important benefit of being non-volatile, unlike DRAM, which requires battery and disk backups to achieve data persistence. While Flash based storage offers much faster read speeds and lower power consumption per transaction than HDDs, Flash also brings some particular behaviors and engineering challenges that are very different from traditional HDD storage. It is these differences that have given rise to the need for the SSS PTS.

Flash Read / Write Asymmetry

One difference between Flash SSS and its HDD counterparts is in how data is read from and written to the storage medium. HDDs can overwrite existing data with new data, but Flash can only write to a pre-erased group of cells or blocks. NAND Flash SSS devices when new or preconditioned to an FOB state have many pre-erased blocks available and thus often exhibit relatively high read/write performance. However, this initial high performance state tends to be transient as the Flash SSS devices run out of pre-erased blocks and the Logical Block Address (LBA) to Physical Block Address (PBA) look-up tables become randomized. This invokes background controller processes that can significantly slow write performance. While reads can occur randomly anywhere within the 16,384 blocks of a typical Flash chip, writing data to a Flash chip first involves an erase operation followed by a program operation, collectively called the Program/Erase cycle (P/E). This results in the asymmetric characteristic of NAND Flash based storage having very fast reads and significantly slower write speeds.

Data read from Flash SSS can be one to two orders of magnitude faster than similar reads from HDD storage, but without significant help from the Flash controller, writes to Flash SSS, while still faster than HDDs, can be much slower than SSS read speeds. How each Flash SSS vendor mitigates this read/write asymmetry becomes a major differentiator between Flash SSS products. The design choices made affect the cost, endurance, reliability, and performance of the products. One of the main goals of the SSS PTS has been to furnish to the marketplace a reliable and straightforward means of deriving truly comparable read and write performance metrics.

Garbage Collection

Existing software designed for HDD storage does not accommodate Flash's P/E cycle or erase-before-write requirements; the controller inside the SSS must take care of this bit of housekeeping. The controller handles previously written-to blocks with a process known in the industry as "garbage collection" (GC). Garbage Collection can improve write performance by eliminating the need to perform whole block erasures prior to every write (once the pool of pre-erased blocks that are available to new and unused SSS are used up or written to). Working in the background, GC accumulates data blocks previously marked for deletion, performs a whole block erasure on each "garbage" block, and returns the reclaimed space for reuse by subsequent write operations.

How well each Flash SSS product performs garbage collection significantly affects overall performance. The SSS TWG carefully considered GC and other Flash SSS background processes to ensure test methodologies would measure SSS performance only during steady state performance.

Wear Leveling

Another peculiarity of NAND Flash as a storage medium is the fact that it has a limited number of P/E cycles. The number of P/E cycles varies depending on density (storage capacity per physical area), vendor, and NAND Flash type. Generally speaking, Single-Level Cell (SLC) NAND Flash is normally rated for ~100,000 P/E cycles, whereas Multi-Level Cell (MLC) Flash is usually rated for 3,000 ~5,000 P/E cycles. As P/E cycles are used up, the NAND Flash device becomes increasingly susceptible to bit errors.

Good SSS management involves ensuring that the writing of data is spread out evenly across the storage space over time. To facilitate wear leveling, SSS device controllers implement a virtual-to-physical mapping of LBAs to PBAs on the Flash media and sophisticated error correction codes. This is typically accomplished both at the time the data is initially programmed (referred to as dynamic wear leveling) and later, as part of the management of the data, to provide wear leveling across the entire storage space (referred to as static wear leveling). Depending on the capabilities of the individual SSS controller, wear leveling activities can significantly affect SSS device performance and therefore were an issue addressed by the SSS PTS.

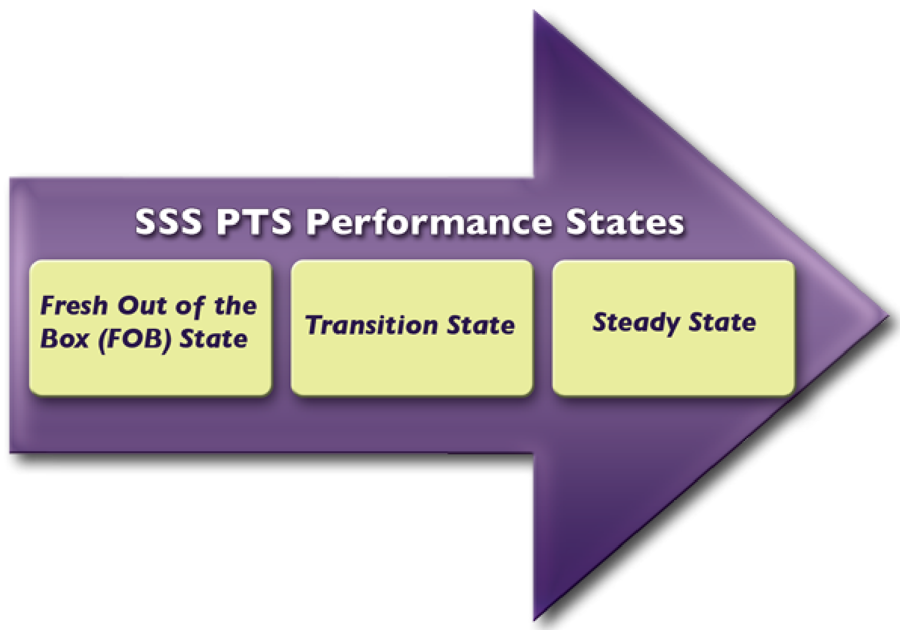
Over Provisioning

To improve the probability that a write operation arriving from the host has immediate access to a pre-erased block, many Flash SSS products contain extra Flash storage capacity. This extra Flash capacity is reserved for use by the controller and is not visible to the host as available storage. This practice of incorporating extra Flash storage capacity reserved for controller use is called "over provisioning." Over provisioning is common because it can help SSS designers mitigate various performance challenges resulting from garbage collection and wear leveling solutions, among other Flash management activities.

For more details, see the SNIA SSSI white paper titled: NAND Flash Solid State Storage for the Enterprise: An In-depth Look at Reliability.

Flash Performance States

Flash SSS devices exhibit a great variation in performance behaviors. Many Flash SSS devices show an initial state of enhanced performance that quickly transitions to a state of lower, more stable performance. One of the key objectives of the SSS PTS is to define and identify when a device reaches and maintains a steady state and how to measure SSS device performance during a steady state measurement window..



Fresh Out of Box State (FOB)

This is the condition of a new/unused SSS device when first received from the manufacturer. SSS devices which are FOB, or initialized (or Purged) to a near FOB state, exhibit a short period of higher performance which then levels off to a relatively sustained level of performance called Steady State. Typically, the storage cells on an FOB device will have experienced few or no P/E cycles (the exception would be any P/E cycling done at the factory as part of the manufacturing process). This device is ready to have data stored with ample pre-erased blocks..

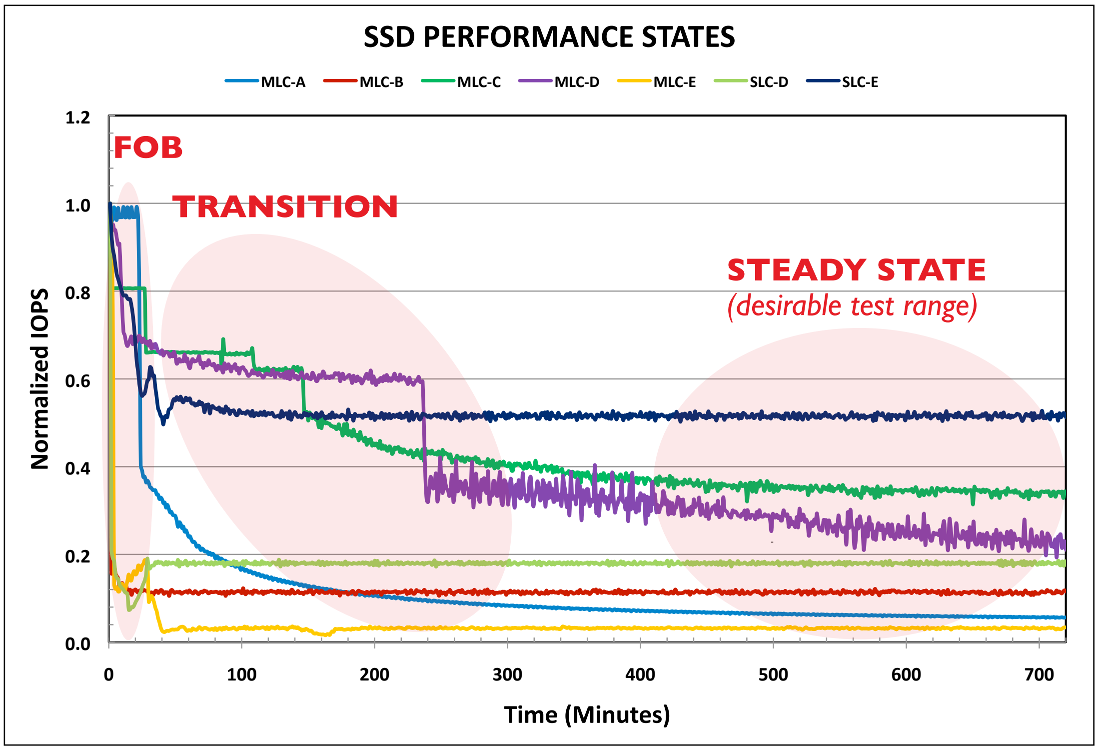
Transition State

Transition State is the performance state during which the observed performance is transitioning from one state to another or otherwise not in a steady state (as defined in the SSS PTS).

Steady State

Steady State performance is achieved when there is a relatively small change in performance over a specified measurement window. Steady State performance can vary among SSS devices and is affected by combinations of underlying Flash management, Flash controller architecture, and vendor-specific algorithms. Some devices show stable Steady State behavior very quickly, while others may take time to settle into a steady performance state. Often, the cost of the device, amount of NAND Flash over-provisioning, intended workload/use case, and the device write history dictate what type of Steady State behavior a Flash SSS device will exhibit.

The following chart contains actual measurements of several SSS devices and shows how the devices exhibit the performance states in various ways.



Based on empirical data taken from a wide range of client and enterprise SSS devices, the SSS TWG has defined Steady State as when, after a Purge and Preconditioning:

- ☑ There has been no more than a 20% variation from the average performance for 5 consecutive measurements and
- ☑ There is a maximum of 10% difference between the minimum and maximum measurements on a curve fitted to those 5 measurements.

It is left to the test operator to decide how to detect that an SSS device undergoing testing is in Steady State. This can be done by inspection, programmatically, or by other methods. The SSS PTS requires that the test operator demonstrate that Steady State has been reached prior to the test data being recorded or, failing that, to document that Steady State was not reached when the data was recorded so a reviewer will know that the SSS device was in a dynamic performance state during the test.

When it comes to Flash SSS performance, there is more to consider than the existing HDD-inspired metrics of inputs/outputs per second (IOPS), throughput, and response time (latency). SSS device performance is highly dependent on the device write history and the test workload, as well as the test hardware and software environment. To test the performance of Flash SSS accurately, you must address test parameters and test conditions that are not as important or not even considered with HDD performance testing, such as preconditioning and steady performance states, among others.

SSS PTS Key Considerations

The following questions were evaluated in detail by the SSS TWG in the development of the Solid State Storage Performance Test Specification and Reference Test Platform.

What Metrics Should Be Used?

The metrics used to quantify the performance of SSS devices under test must reveal the performance characteristics of the SSS device, provide consistent results, and be repeatable and reproducible. The selected metrics must also differentiate quantitatively the differences in performance of various SSS devices to allow users to make "apples to apples" comparisons. After analyzing the performance data from many SSS devices, the SSS TWG decided that the best metrics to use include IOPS (measured in inputs and outputs per second); Throughput (measured in MB per second); and Latency (measured in average milliseconds).

However, the trickier part was to decide what test parameters should be used and to define a proper methodology that would achieve the SSS TWG goals.

Should all SSS Devices be Tested the Same Way?

Client and enterprise application classes have very distinct and different workload characteristics. Accordingly, while the core tests and methodologies are similar for both, client and enterprise performance tests have different prescribed test parameters and settings to more closely measure the workloads typical for each respective class of application. For example, a client workload is one that is typified as a single user who may be running a few applications in a serial fashion. This is completely different from the enterprise server which is typically used by many users with overlapping I/O demand, each accessing some portion of data (reading or writing), making the access pattern more random and placing much more stress on the storage device with potentially many more block sizes, threads, and queued I/O operations than in client environments.

What Test Parameters and Values Should Be Specified?

Deciding what test parameters and values are needed was another challenge. Should the SSS PTS specify all the parameter values or should some of the parameters be left for the tester to choose and document? The SSS TWG determined that SSS device performance was highly dependent on some critical parameters that must be specified in the SSS PTS explicitly, such as the read/write mix (because the performance of reading vs writing may be very different in SSS devices), block sizes, and the number of iterations. Additional test parameters such as outstanding I/O operations per thread and thread count, while still significant, could be left to the test operator to select according to the device under test (These parameters must be specified by the test operator and documented in the performance report). This area will be more fully developed as the SSS PTS evolves and the suite of tests is refined.

How Should SSS Devices be Preconditioned?

As mentioned earlier, SSS device performance is highly dependent on write history. For the SSS PTS to provide performance tests that are meaningful for users, the tests must provide consistent, repeatable, and reproducible results, allowing fair comparison between SSS devices. To achieve that, the SSS PTS needed to specify a repeatable test starting point (by defining a Purge step) and a procedure to precondition SSS devices before running each of the performance tests. Developing the preconditioning specifications took a significant amount of time and effort. It involved experimenting with several proposed methodologies for preconditioning, analyzing data for each methodology when applied to many SSS devices and deciding what would be the most suitable. This was one of the more challenging and certainly most important tasks of developing the SSS PTS.

Is Preconditioning Enough?

After running many experiments and analyzing significant amounts of data, it became clear that preconditioning was essential but not sufficient to ensure consistent, repeatable, and reproducible results. The SSS PTS methodology must ensure that the SSS device is also in some sort of steady performance state before running the tests. Defining what would be a reasonable definition of "steady state" became yet another challenge.

Data Patterns

The SSS PTS prescribes the use of random data patterns. While some SSS devices can optimize performance when using a non-random data pattern, the SSS TWG determined that a fair starting point would be to require testing using a random data pattern with the option to report an additional test using a non-random data pattern if the test operator so chooses.

What Data Access Patterns Should be Used for Testing?

The SSS PTS prescribes standard data access patterns for its tests. These generally call out a matrix of read/write mixes and block sizes that are applied to the SSS in one-minute test rounds. These test rounds are used to determine the steady state measurement window.

What Workloads and Benchmarks Should be Used for Testing?

Developing test workloads that are legitimately representative of various classes of applications is difficult due to the wide variety of applications within each application class and the varied data patterns that users generate even within a single application. The same applies to selecting benchmarks that could represent a user environment.

The SSS TWG agreed to define synthetic device level workloads across a wide range of test parameters from which the test reader can extract measurements for workloads of interest. The use of synthetic device level tests allows for the creation of repeatable tests that can be used to derive an ordinal ranking of SSS devices. The SSS PTS enables users to decide which test parameters are most relevant to their specific use environments. Future revisions of the PTS will investigate composite synthetic tests that may more closely emulate real world workloads and applications.

What Should be Reported?

To make the running of consistent tests and using of common metrics meaningful, it is important that results be reported in a standardized way. This enables SSS PTS users to understand the results and make legitimate comparisons between SSS products. The SSS PTS defines the test reporting formats and includes the following report elements:

- ☑ Testing environment
- ☑ Test parameters
- ☑ Steady state verification
- ☑ Standardized report format.

SSS PTS Strategy

The unique dependencies noted earlier and the substantial differences in SSS device characteristics compared to the more familiar HDDs mean that Flash SSS performance must be characterized differently in order to accurately reflect the performance of different SSS products in a consistent, repeatable, and reproducible fashion. Flash SSS tests must also help demonstrate differences between SSS devices and HDDs to enable users to make informed decisions.

Scope

The SSS PTS was developed solely as a standard for testing and comparing the performance of solid state storage devices. In its initial version, the SSS PTS includes three basic components:

1. Pre-conditioning methods
2. Performance tests (workloads to be applied)
   Tests: IOPS, throughput, and latency
3. Common test reporting requirements.

Items determined to be out of scope and not included in this version of the SSS PTS include:

- Application performance tests
- Benchmarks
- Application workloads
- SSS device reliability, availability, or data integrity
- Reference Test Platform definition (hardware / software tools)
- SSS device certification.

Test Metrics

The metrics used in the SSS PTS include:

- ☑ **IOPS:** The number of inputs and outputs per second is a good indication of the read/write per formance for workloads with random reads and/or writes, which tends to be the case in many applications and especially with enterprise application classes (e.g. online transaction processing)
- ☑ **Throughput:** A good indication of the read/write performance for workloads with sequential reads and/or writes
- ☑ **Latency:** A good indication of the delay encountered by data being read or written to the SSS device, which affects most of the other metrics, especially IOPS.

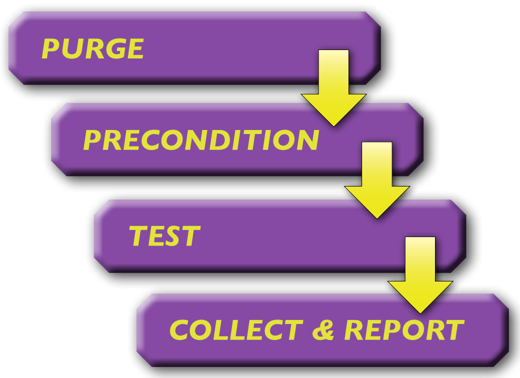
Test Sequence

To achieve the most accurate and comparable performance test results, the SSS PTS defines the following simple test sequence:

1. **Purge the Device:** Purge is intended to provide a repeatable test start point by putting the device in an FOB state, as closely as possible. The test operator should document which method of Purge is used, or if none was used.

2. **Precondition the Device:** To enable consistent and meaningful results from an SSS PTS test, the test measurements must be taken when the device is in Steady State. The goal of performance test preconditioning is to get the SSS device from an initial state into Steady State as efficiently as possible. The test scripts in the SSS PTS give test operators options in terms of how many preconditioning loops must be run and what the test operator should do if convergence is not observed after a specified time.

SSS PTS Test Sequence



3. **Test the Device:** To create a measurement window from which the official test data is later extracted and reported, the test operator must run the test sequence until five consecutive test loops meet the Steady State measurement requirement.

Test Tools

Each SSS performance test will be run in a particular environment that includes certain test utilities or tools. The SSS TWG was very aware that test tools affect and influence test results. After much debate, the SSS TWG decided to simply identify and recommend reference test platforms and software tools but not require them in this iteration of the SSS PTS. Therefore, any tool capable of meeting the requirements of the SSS PTS may be used. Below are a few examples.

- ☑ **Calypso:** A commercial test tool that provides a complete hardware and software test environment for synthetic testing of SSS devices. It is an intelligent, scalable, modular test system designed to meet engineering, development, and manufacturing test requirements. It incorporates a full suite of SSS performance tests that provide automated testing and reporting to the SSS PTS. Calypso testers were the main test tools used by the SSS TWG to develop the SSS PTS.

- ☑ **IOmeter:** A widely used freeware measurement and characterization tool for the I/O subsystem. It was originally developed by Intel and given to the Open Source Development Lab. It is both a workload generator (it performs I/O operations to stress the system) and a performance measurement tool (it examines and records the performance of its I/O operations and their impact on the system). It can be configured to generate synthetic I/O workloads with a considerable amount of flexibility. Scripts can be developed to run the SSS PTS.

- ☑ **Vdbench:** An I/O workload generator for verifying data integrity and measuring performance of direct attached and network connected storage. It is open source software that can be downloaded and used.

Test Platform

The SSS PTS itself is platform agnostic. The SSS PTS tests and methodologies assume nothing about the underlying environment except some generic requirements. However, while individual test operators can run SSS PTS tests on their particular platform to compare the relative performance of SSS devices they are evaluating, in order for SSS PTS results to be compared on a true "apples-to-apples" basis across multiple testers, a consistent test platform must be used.

At present, the SSS PTS does not specify a particular hardware and operating system platform. Generic test tool requirements are stated in SSS PTS Section 6, and Annex B describes a sample platform. See also the Appendix of this white paper. This issue is the subject of on-going research and discussion within both the SSS TWG and the SSSI and may be addressed in a more comprehensive manner in a later version of the SSS PTS.

Reference Test Platform Requirements	
Repeatable	*Common starting point, common procedures*
Stable	*Test at steady state*
Applicable	*Results relevant to user's conditions*
Comparable	*Fair device-to-device comparison*
Practical	*Completes with reasonable time & effort*
Accessible	*Open specification; 3rd party validation; affordable*

How to Get Involved

To participate in the development of the SSS PTS, join the SSS TWG. For more information see http://www.snia.org/forums/sssi/programs/twg/. Status on updates to the specification and related white papers can be found at http://www.snia.org/forums/sssi.

APPENDIX

This Appendix describes the hardware / software Reference Test Platform (RTP) that was used by the SNIA Solid State Storage Technical Work Group (SSS TWG) to validate the SNIA Solid State Storage Performance Test Specification (SSS PTS). It is not required to utilize this RTP when running the SSS PTS tests, but this hardware and software have been confirmed to meet the requirements of that specification.

Background

The SNIA SSS PTS defines a suite of tests and test procedures necessary to enable comparative testing of SSS device performance. The hardware and software environment utilized can impact the results of such testing.

When testing SSS device performance, the test platform must be optimized so as to not be a performance bottleneck. Potential contributions to performance test measurements that can come from the hardware, OS or software test tools should be removed or made insignificant. Operating system features that affect performance measurements, such as automatic updates of the operating system, should be disabled. Further, hardware/software components must be selected that don't throttle performance. For example, the interface bandwidth of the HBA should be greater than the bandwidth of the SSS device. The RTP described in this document is an example of that type of test platform.

The test platform must have appropriate connectivity for the SSS device, i.e. a 6Gb/s SAS HBA to connect to a 6Gb/s SAS SSS device. It is also necessary to ensure that the test platform motherboard contain a sufficient number and type of PCIe slots for PCIe components, as well as a power supply is of sufficient size to support the desired number of units to be tested.

To accurately compare the performance of different SSS devices, it is necessary that the test platform be in a fixed configuration. Any component changes, including hardware, the operating system revision, and even the version of test software may cause differences in performance that will result in inaccurate comparisons.

RTP Configurations

As defined by the SSS TWG and the SSSI, the RTP used to validate the SSS PTS was designed to be capable of being utilized in the testing most SSS devices. It can also be expanded, in order for it to be utilized in the testing of higher performance SSS products.

The table below shows the two possible configurations of this RTP. Note that the validation of the SSS PTS was performed using the Standard configuration.

Component	Type / Part	Standard	Extended Performance
Chassis	Intel SC5650DP or similar	1	1
Motherboard	Intel S5520HC	1	1
Processor	Intel 3.2GHz W5580	1	2
Main Memory	1333MHz DDR3, ECC	12GB	Up to 96GB
HDD	160GB, 7200 RPM	1	1
6Gb/s SAS/SATA HBA	LSI 9212-4i4e	1	1
Operating System	Linux	CentOS 5.4	CentOS 5.4
Test Software	Calypso CTS	CTS v6.5	CTS v7.0

RTP Components

Following is a more detailed description of the components used in the RTP.

The chassis used for this RTP was an Intel SC5650DP. The chassis has a limited effect on performance, so a similar chassis could be used, but it should have a 600W or larger power supply.

The RTP motherboard was an Intel S5520HC. Again, a similar motherboard could be used, but it is desirable to have two processor sockets to be able to support the Extended Performance configuration.

The processor used in the RTP was an Intel 3.2GHz W5580. The Standard configuration contained one processor, and the Extended Performance option would contain two processors.

The RTP main memory utilized 1333MHz DDR3 DIMMs with ECC. The Standard configuration included 12GB of RAM, and the Extended Performance configuration would be populated with up to 96GB of RAM. The DIMMs were selected from the following list of Intel approved memory:
http://serverconfigurator.intel.com/configure-memory.aspx?id=MTY2NCMxLDI1MTcjMSwyNjE4IzIsMjUzMyMx&ShowNavigation=false
It's advisable to install the memory in multiples of three DIMMs, to optimize performance.

The HDD used in the RTP was 160 GB, 7200 RPM, with a SATA interface.

The RTP used a LSI 9212-4i4e Host Bus Adaptor containing the IT firmware set. Other sufficiently high performance HBAs are available, but were not tested.

The RTP hardware platform had a dedicated power supply for all test bays that was separate from the main power supply.

The RTP utilized test software made by Calypso Systems, Inc (www.calypsotesters.com)
CTS v6.5 is the Standard version
CTS v7.0 is the Extended Performance version
Note that this software requires CentOS 5.4 Linux is ready to have data stored (all storage elements are pre-erased).

A Special Thank You

Calypso Systems, Inc., a SNIA SSSI company member, actively participated in the development of the SSS PTS and contributed significant time and resource to validate all aspects of the specification through the testing of various SSDs and other SSS devices.

Storage Networking Industry Association
425 Market Street, Suite 1020 • San Francisco, CA 94105 • Phone: 415-402-0006 • Fax: 415-402-0009 • www.snia.org