

## The PTS User Guide

*The Hows & Whys of the SNIA  
Solid State Storage Performance Test Specification*



by SNIA SSSI Members:

**Eden Kim** Calypso Systems, Inc.

**Chuck Paridon** Hewlett Packard

## About the Solid State Storage Initiative

The SNIA Solid State Storage Initiative (SSSI) fosters the growth and success of the market for solid state storage in both Enterprise and Client environments. Members of the SSSI work together to promote the development of technical standards and tools, educate the IT communities about solid state storage, perform market outreach that highlights the virtues of solid state storage and collaborate with other industry associations on solid state storage technical work.

SSSI member companies come from a wide variety of segments in the SSD industry [www.snia.org/forums/sssi/about/members](http://www.snia.org/forums/sssi/about/members).



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The Storage Networking Industry Association (SNIA) Solid State Storage Performance Test Specification (PTS) has been published in both Client and Enterprise versions. The PTS prescribes a methodology for comparative performance testing of Solid State Storage products at the device level.

This PTS User Guide is intended to provide an easy to understand, step-by-step guide to using the PTS test methodologies and tests. The term “SSD” is used throughout this Tech Note to refer to M.2, mSATA, SATA, SAS and PCIe mass storage devices - whether in module, 1.8”, 2.5” or other form factor or PCIe edge card.

This Tech Note discusses four basic PTS 1.1 tests - Write Saturation (WSAT), IOPS, Throughput (TP) and Response Time (or Latency) - as updated per SNIA draft PTS-E version 1.1. The draft PTS-E 1.1 also introduces new workload-based tests that are outside the scope of this document. The PTS-E 1.1 draft is pending SNIA wide approval with release targeted for late summer 2013.



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## **I. Issues to be aware of when testing SSD Performance**

NAND flash SSDs are unique - performance changes over time. The device write history and the user workload significantly affects SSD performance.

For example, large block sequential (SEQ) Read/Write (RW) performance can be significantly lower if preceded by a small block random (RND) write workload. Thus, the PTS requires a device PURGE (to create a known and repeatable test start point) followed by a prescribed Pre-conditioning and Steady State methodology for SSD testing.

SSD performance is also affected by the test platform. Test hardware platforms should produce sufficient Demand Intensity to test (or saturate) the SSD so as not to bottleneck measured performance. Test software should not contribute to the test results in an unknown fashion and must be reliable, accurate and repeatable.

Using different test platforms can generate different results for the same SSD. For this reason, the SNIA SSSI has defined a Reference Test Platform (RTP) for SSD performance test. The SSSI RTP is a standard hardware configuration that prescribes specific test software capabilities.

Finally, the PTS requires disclosure of test parameters and set-up conditions - the storage space used for Pre-conditioning and test (LBA Ranges), the Demand Intensity setting (or number of Outstanding IOs) and the test workload and parameters (data pattern, access pattern, etc.).

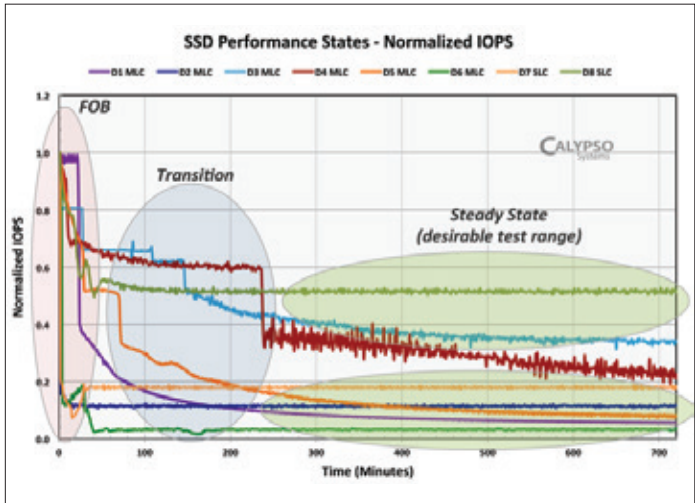
## **2. PTS I.I Test Suite - Four Dimensions of Performance**

The PTS is intended to provide a comprehensive view of the test SSD's overall performance behavior and focuses on four dimensions of SSD performance: Evolution over Time, Transaction Rate, Data Transfer Rate and Response Times. Taken together, PTS I.I tests can be used for comparative measurement and, by varying parameters and test set-up conditions, as a tool to examine overall SSD behaviors.



**Evolution Over Time** - The Write Saturation (WSAT) test provides a mechanism to observe an SSD's performance behavior over time. While WSAT has various Steady State determination criteria, WSAT is intended to focus on how the SSD progresses through various performance states.

WSAT shows the SSD Fresh-Out-of-Box (FOB), Transition and Steady States (see chart below). FOB is a temporary level of peak performance that occurs when there is no write history (or immediately after a device PURGE). SSDs quickly transition from FOB until they settle into a Steady State (which is a specifically defined PTS region where performance is relatively time invariant). A Time or Total GB Written (TGBW) based WSAT test can show a given SSD's many levels of performance (such as a series of steps or slopes). Many SSDs of a similar architecture, controller or firmware may share similar WSAT curves while a specific SSD can show a unique performance curve or "WSAT Signature."



**Transaction Rate** - The IOPS test examines IO transaction rates for different random access Block Size (BS) and Read/Write (RW) mix combinations. A table of Steady State IOPS measurements allows the reader to quickly select BS/RW combinations contained in their workload of interest.

For example, a write intensive database application may be typified by an access pattern (see Access Patterns below) of small block RND RW activ-



ity. Accordingly, in the table below, the top two rows of small block IOPS (highlighted in salmon) - or perhaps the single “RND 4KiB 100% W” value (highlighted in yellow) - may be of particular interest to the reader.

Client IOPS - ALL RW Mix & BS - Tabular Data							
Block Size (KiB)	Read / Write Mix %						
	0/100	5/95	35/65	50/50	65/35	95/5	100/0
0.5	49,053.4	32,137.8	21,205.1	21,452.2	22,868.5	45,001.1	112,880.9
4	62,079.1	27,433.1	18,450.9	18,515.8	19,760.5	37,734.1	70,630.4
8	32,683.6	16,954.9	11,394.2	11,547.9	11,968.9	22,078.8	45,403.6
16	16,306.5	10,776.8	7,430.6	7,536.9	7,756.2	12,587.9	26,747.9
32	8,137.5	6,903.3	4,821.4	4,894.0	5,156.5	7,500.5	15,215.7
64	4,070.8	4,097.6	2,980.1	3,044.3	3,218.5	4,650.9	8,169.2
128	2,034.1	2,113.2	1,830.5	1,912.9	2,034.1	2,827.4	4,224.2
1024	253.4	263.6	293.6	317.5	352.9	474.9	540.6

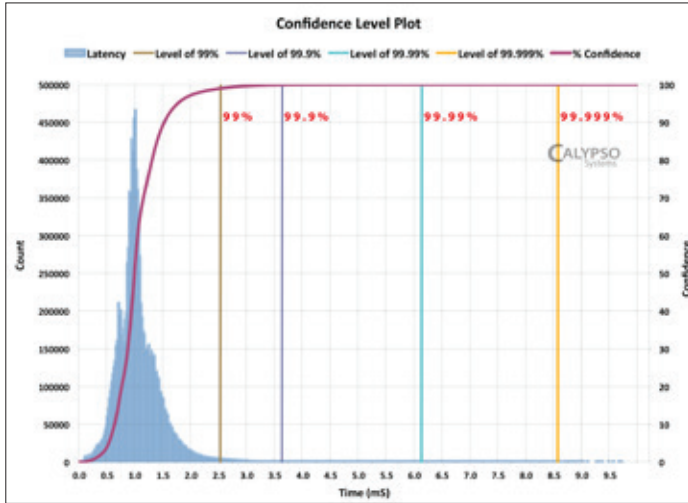
Note: SSD Industry convention is to use base2 (KiB, MiB & GiB) for storage amounts (block sizes) and base10 (KB, MB & GB) for capacities and transfer rates.

**Data Transfer Rate** - The Throughput (TP) test examines the rate of data transfer, or the amount of data that can be accessed to or from the SSD, and is expressed as Megabytes per second, or MB/s (see table below). Throughput presents SSD data transfer rates for large block SEQ100% R and 100% W (as these are often optimal accesses for large data transfers).

Throughput - ALL RW Mix & BS - Tabular Data 1024KiB		
Block Size (KiB)	Read / Write Mix %	
	0/100	100/0
1024	157.5 MB/s	514.3 MB/s

Throughput is the amount of data transmitted across the SSD interface. Overall Throughput (or Bandwidth) is affected by the SSD interface, host register interface (AHCI, NVMe, SOP) and the motherboard PCIe lane bandwidth. For example, a SATA3 SSD may be able to transfer 500 MB/s or more, but if the SSD is connected via a slower SATA2 interface, the effective transfer rate can be limited to 300 MB/s or less.

**Response Times** - Response Time tests measure the time it takes for IO operations to complete. A Latency (LAT) test measures the response times of a single Outstanding IO (OIO) and isolates response time measurements from the effects of other concurrent outstanding IOs (or the effect of multiple concurrent IOs). The LAT test measures the average (AVE) and maximum (MAX) response times for 3 different block size / RW mixes.



A Response Time Histogram (blue bars above) shows the distribution and frequency of all of the response times by showing IO counts distributed over time in time bins. “Confidence level plots” (the red line in the plot above) show the percentage of IOs that occur relative to a given response time requirement.

### 3. Access Patterns and Test Workloads

**Access Patterns** - An access pattern is the order of “storage and retrieval operations” and is described in 3 main components:

- Random or Sequential access - the random or sequential nature of the data address requests
- Block Size - the data transfer lengths
- Read/Write ratio - the mix of Read and Write operations

Any particular “workload” or “test stimulus” is approximated by some combination of access patterns. That is, an access pattern is one component of a synthesized equivalent IO workload. For example, “RND 4KiB 65:35 R/W” describes an access pattern consisting of: a sequence of IO commands, each one 4KiB long (block size), to random locations on the storage device, in the proportions of 65% Reads to 35% Writes.





**Workloads** - What are workloads? In very general terms, a workload can be described by the access patterns of data measured during an observation period (e.g. 10 minutes of RND 4KiB 100%W). There are commonly accepted access patterns used by the industry to represent various use cases. These access patterns are combined with other parameters (such as demand intensity, data pattern, write cache setting and test range) to create a test workload that emulates specific use cases.

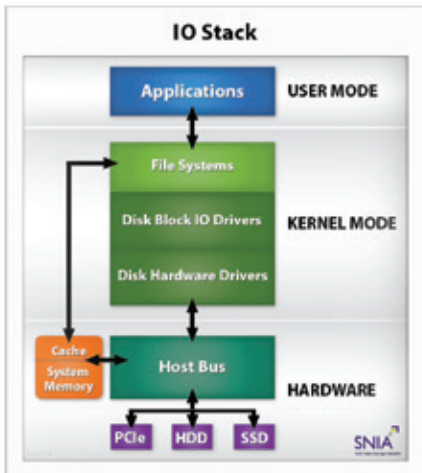
Once the characteristics of a particular use case are understood, the PTS can be used to examine the performance measurements for specific access patterns. For example, a write intensive application (e.g. OLTP metadata) is often characterized by an access pattern of small block random writes. Thus, an SSD with good performance for, say RND 4KiB RW, could be well suited for that type of application use case.

## 4. Device Level Test

The PTS is based on testing SSDs at the raw device, or block IO level. Device testing isolates the Device Under Test (DUT) and minimizes the effects of the OS and file system cache from performance measurements.

Access patterns generated by software applications must traverse the “IO Stack” to get from the user space to the SSD and back again. This means

that the file system and various drivers will affect the IOs as they pass them up or down the IO Stack.



Examples of how IOs are affected by the IO Stack include: *coalescing* small IO data transfers into fewer larger IO data transfers, *splitting* large sequential IO data transfers into multiple concurrent random IO data transfers, and using the faster file system cache while deferring IO commits to the SSD.



By testing at the block IO interface, the test operator can achieve an “apples-to-apples” comparison of SSDs. The test operator can sort SSDs by their performance characteristics to specific workloads and thus optimize the overall storage system stack.

## 5. The Basic PTS Test Flow

The PTS test flow is comprised of six basic steps: PURGE, Parameter Setting, Pre-conditioning, Steady State Determination, Test Measurement and Test Reporting. This methodology is intended to provide a fair and repeatable test environment for the comparative performance testing of SSDs. The SNIA report format provides a standardized way to present PTS results and ensures that required test conditions and parameter settings are properly disclosed.

## 6. PURGE – A known and repeatable test starting point

PTS requires a PURGE at the start of each test. PURGE is used to ensure that there is a repeatable and known test starting point. PURGE is defined as either a SECURITY ERASE UNIT command for SATA, FORMAT UNIT command for SCSI, or a vendor specific command that puts the drive in a state “as if no writes had occurred.”

## 7. Test Parameters and Set-Up Conditions

The PTS requires disclosure of various test parameters. These settings can significantly affect test results. Some of the important parameters include:

**Data Pattern** - the degree of randomness, or entropy, of the data being read or written. The default setting uses 100% RND data by using binary data generated from a seedable, 48 bit random number generator.



**Access Pattern** - the block size, RW mix and RND or SEQ accesses of the test stimulus stream. Access pattern should not be confused with the “Data Pattern.” Access patterns are clearly specified for the various tests.

**Write Cache** - settings that can be set for Client (write cache enabled) or Enterprise (write cache disabled) tests. In the PTS, DUT write cache and write buffer are synonymous and used interchangeably.

**Demand Intensity** - the Total Outstanding IOs (TOIO) that the host test system can generate.  $TOIO = \text{Thread Count} \times \text{Queue Depth}$ .

**Active Range (AR)** - the LBA range accessed during a test step. An AR setting is required for both the Pre-conditioning steps and test measurement steps. In Client tests, AR may be limited in order to emulate Client user workloads that have smaller footprints, or to emulate TRIM commands in operating systems that return previously written, but invalid, data for use (as opposed to Enterprise workloads that use the entire LBA space).

**Segmentation** - the distribution of test stimuli in segments across the AR. The default Client setting is for 2048 segments to be randomly distributed across the available AR with no adjacent segments.

**Steady State (SS)** - SS conditions and determination criteria are specifically prescribed by each test case. IOPS, Throughput and Latency share a common “5 Round Window Formula,” while WSAT has three ways to determine WSAT Steady State. Proposed PTS-E 1.1 tests also have special Pre-conditioning methodology and Steady State determination criteria.

**Test Environment** - Test hardware affects performance at each step in the data path and can have significant impact on performance. Software tools also significantly impact performance. For example, IOPS and response times may vary between software tools based on how they are architected to manage multiple streams of outstanding asynchronous IOs.

For these, and other reasons, the test operator should take care to only compare SSD performance on test environments of known characteristics and to make sure that comparisons are made using identical hardware, software tools and test procedures (and set-up conditions and parameter settings).

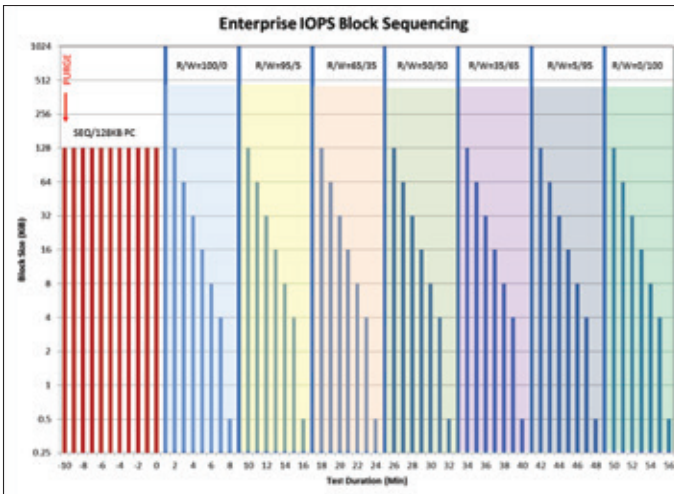


## 8. Pre-conditioning & Steady State

The PTS has a prescribed methodology to put the DUT into a specific and repeatable Steady State for the intended performance measurement. IOPS, TP and LAT share a common Pre-conditioning and Steady State determination procedure. Other tests have variants of this process.

IOPS, TP and LAT PTS tests begin with a device PURGE followed by a two-step Pre-conditioning (PC) regime until the DUT enters Steady State - or until 25 Rounds have occurred at which point the test is terminated. Test parameters and condition settings (such as data pattern, write cache setting, OIO, AR and segmentation) should be set for each test step.

After the PURGE step, Workload Independent Pre-conditioning (WIPC) is applied to the DUT. WIPC consists of writing twice the user capacity in SEQ 128KiB Ws followed immediately, without delay, by the Workload Dependent Pre-conditioning (WDPC) step.



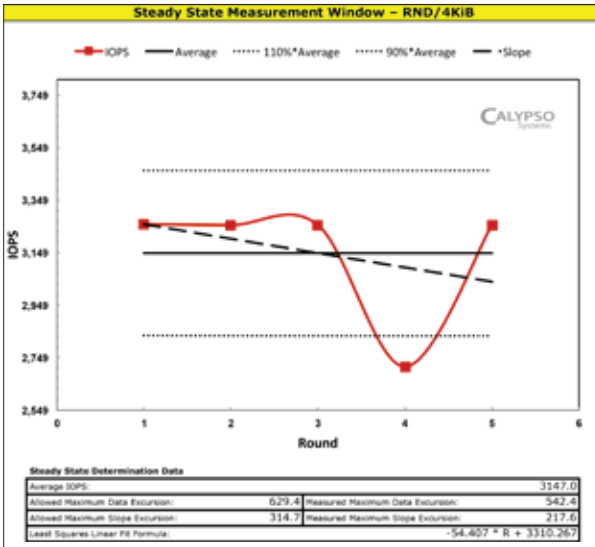
WDPC consists of applying the workload of interest to the device (such as the IOPS loop for the IOPS test) until the workload tracking variable meets the SS determination criteria (e.g. the RND 4KiB 100%W for IOPS).

In the case of the PTS-E 1.1 IOPS test, the IOPS block size sequencing for WDPC will iterate through the IOPS test loop of 8 block sizes by 7 RW



mixes, testing each BS/RW mix for one minute. This results in a “Round” of 56 one-minute segments or a 56-minute Round. See Enterprise IOPS Block Sequencing chart on preceding page.

The tracking variable for PTS-E I.I IOPS is RND 4KiB 100% W. The RND 4KiB Ws are averaged for each of the one-minute RND 4KiB 100% W Rounds and used to calculate the Steady State window. All test measurement data is extracted from the Steady State window.



The SNIA report format presents Steady State window calculations with the required Steady State window plot as illustrated above.

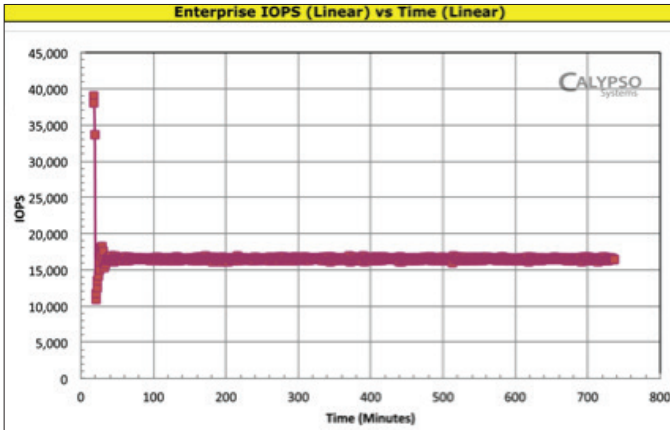
## 9. PTS I.I - Basic Tests: WSAT, IOPS, TP & LAT

The following summary test descriptions are simplifications of the test pseudo code contained in the PTS. The summary and notes in this User Guide are intended to provide the reader with a concise and simplified test flow. Readers are urged to refer to the PTS for actual test steps and procedures.



## Write Saturation (WSAT)

Continuous RND 4KiB Ws after a Purge for a period of Time, TGBW or until Steady State is determined by five Round Formula.



### Test Flow:

1. Set Parameters: *Note: This step is parameter determination only*
  - a. Data Pattern: RND
  - b. QD & TC (user choice)
  - c. Write cache setting - WCD (Enterprise)
  - d. AR - default=100%
  - e. Run time (default 24hrs) or SS
  - f. Set SS window (default - see notes below)
2. PURGE DUT
3. Apply continuous RND 4KiB 100% W
4. Measure every 1 minute
5. Run to SS Formula, Time or Total GB Written
6. Record measurements from SS window

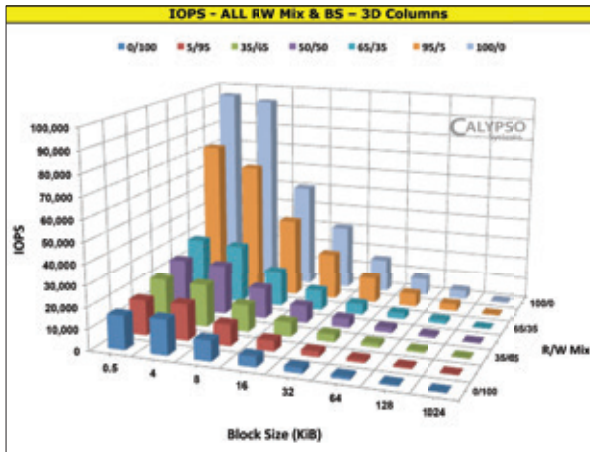
### Notes:

1. This test runs after PURGE without Pre-conditioning
2. Default stimulus is RND 4KiB 100% W
3. Default time is 24 hours; default TGBW is 4X user capacity
4. SS Formula is 5 one-minute Rounds separated by 30 minutes of Ws
5. Output is both IOPS v Time and IOPS v TGBW



## Input Output Operations Per Second (IOPS)

Applying IOPS loop of BS x RW mix until SS after a PURGE, WIPC and WDPC to generate IOPS measurements for each BS RW combination.



### Test Flow:

1. Set parameters & conditions
  - a. Data pattern: RND
  - b. Pre-conditioning WIPC: AR (100%), TC/QD (user choice)
  - c. Pre-conditioning WDPC: AR (100%), TC/QD (user choice)
  - d. Write cache setting: WCD (Enterprise)
  - e. Segmentation - Off
  - f. Set SS window (default 5 Round Formula)
2. PURGE
3. WIPC - 2X SEQ 128KiB W
4. WDPC - IOPS loop in one-minute periods (56 minutes per Round)
5. Tracking variable - RND 4KiB W for each Round
6. RND 4KiB rolling consecutive 5 Round values until SS reached
7. Record measurements from SS window

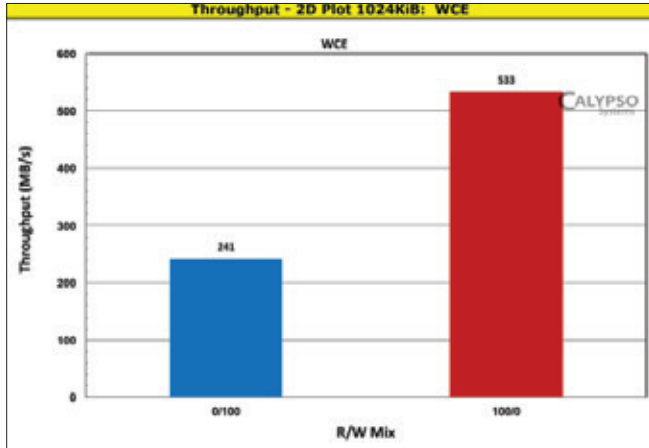
### Notes:

1. Apply the SS Formula or 25 Rounds, whichever comes first
2. Results can be shown as a 3D bar plot, 2D plot or tabular form
3. There should be no time delay between any of the steps
4. See "Sample SNIA IOPS Report" for required reporting disclosures



## Throughput (TP)

Applying SEQ 1024KiB R & W after PURGE, WIPC and WDPC until SS to generate throughput in MB/s.



Test Flow:

1. Set parameters & conditions
  - a. Data pattern: RND
  - b. Pre-conditioning WIPC: AR (100%), TC/QD (user choice)
  - c. Pre-conditioning WDPC: AR (100%), TC/QD (user choice)
  - d. WCD (Enterprise setting)
  - e. Segmentation - Off
  - f. Set SS window
2. PURGE
3. WIPC - 2X SEQ 128KiB W
4. WDPC - SEQ 1024KiB W for one-minute periods
5. Tracking variable - SEQ 1024KiB W from each Round
6. Plot SEQ 1024KiB W consecutive 5 Round values until SS reached
7. Record values from SS window

Notes:

1. Client test BS=1024KiB; Enterprise BS=128KiB and BS=1024KiB
2. Enterprise WIPC workload can be 1024KiB for Test=1024KiB
3. Client tests can set PC AR to 80% and Test AR to 8GiB or 16GiB
4. Note SNIA report header: Write cache settings, OIO, and other parameters disclosed





## Latency (LAT)

Applying RND .5, 4 & 8K W by 100%R, 65:35 R/W and 100%W at an OIO of one - after PURGE, WIPC and WDPC until SS - to generate single IO response times and measurements for average and maximum latencies.

Average and Maximum Response Time - ALL RW Mix & BS - Tabular Data			
Average Latency (ms)			
Read / Write Mix %			
Block Size (KIB)	0/100	65/35	100/0
0.5	0.20	0.24	0.13
4	0.19	0.24	0.14
8	0.29	0.42	0.19
Maximum Latency (ms)			
Read / Write Mix %			
Block Size (KIB)	0/100	65/35	100/0
0.5	38.92	9.31	0.79
4	19.10	9.37	0.79
8	34.43	9.38	6.25

### Test Flow:

1. Set parameters & conditions
  - a. Data pattern: RND
  - b. Pre-conditioning WIPC: AR (100%), TC/QD (user choice)
  - c. Pre-conditioning WDPC: AR (100%), TC/QD (user choice)
  - d. WCD (Enterprise setting)
  - e. Segmentation - Off
  - f. Set SS window
2. PURGE
3. WIPC - 2X SEQ 128KiB W
4. WDPC - RND .5, 4 & 8KiB W by RW 100:0, 65:35, 0:100
5. Tracking variable - RND 4KiB W from each Round
6. Plot all RND 4KiB W consecutive 5 Round values until SS reached
7. Record values from SS window

### Notes:

1. Response times for IOs with a total OIO of one will provide latency measurements
2. Latency histograms can be plotted from LAT results
3. Confidence Plots can be plotted from LAT results
4. See "Sample SNIA LAT Report" for required reporting disclosures

## 10. SNIA Report Format

Each PTS 1.1 test has a required SNIA report format that ensures proper disclosure of test environment, test set-up conditions and parameters and measurements to be presented. SNIA reports allow the reader to see test data in a familiar structure to enhance drive-to-drive comparisons.

Each report page includes a report header with required and optional information relevant to the test data reported. Note: not all report headers contain identical information as the headers list information specific to the particular test. Headers will also vary between Client and Enterprise test settings.

Test Run Date:		03/02/2013 03:30 PM		Report Run Date:		05/13/2013 05:48 PM	
IOPS Test (REQUIRED) - Report Page							
SNIA	Solid State Storage		IOPS - Block Size x RW Mix Matrix			Rev.	PTS-C 1.1
SSS TWG	Performance Test Spec (PTS)					Page	4 of 6
Vendor:	ABC Co.	SSD Model:	ABC Co. MLC-A 250		TEST SPONSOR	CALYPSO systems	
Test Platform		Device Under Test		Set Up Parameters		Test Parameters	
Ref Test Platform	Calypso RFP 2.0	Model	ABC Co.	Data Pattern	RND	Data Pattern	RND
Motherboard	Intel U320AC	Model No.	MLC-A	AR	100%	AR & Amount	100%
CPU	Intel XEON 5500W	S/N	123 456	AR Segments	N/A	Test Stimulus 1	QPS Loop
Memory	8 GB PC1600 2DR2	Firmware ver	FFFF	Pre Condition 1	500 128K W	RW Mix	Outer Loop
Operating System	CentOS 6.3	Capacity	250 GB	T000 - TC/QD	TC 2/ QD 16	Block Size	Inner Loop
Test SW	CTS 6.5.1.13.8	Interface	SATA 6Gb/s	Duration	Twice User Capacity	T000 - TC/QD	TC 4/QD 16
Test SW Auth	1.00.7/1.9.16	MAND Type	MLC	Pre Condition 2	IOPS Loop	Steady State	1 - 5
Test ID No.	830-5146	PCIe NVM	N/A	T000 - TC/QD	TC 4/ QD 16	Test Stimulus 2	N/A
HBA	LSI 9212-4e6	Purge Method	Security Erase	SS Rounds	1 - 5	T000 - TC/QD	N/A
PCIe	Gen 2 x 8	Write Cache	WCE	Note	-	Steady State	N/A

Report Headers as shown above contain the following information:

### Administrative Data

Each report header provides administrative data that includes: Test run date, report run date, PTS test name, PTS revision level, report page number, vendor name, SSD model number and the test sponsor.

### Test Platform Information

The Test Platform information block lists the test hardware platform and details of the motherboard, CPU, RAM and OS along with HBA or PCIe connection (if relevant). Test software information is also listed along with the individual raw test data report number.



### **Device Under Test (DUT)**

The DUT information block discloses the DUT manufacturer, model number, serial number, firmware version, capacity and NAND type, interface, PURGE method and write cache setting.

### **Set-Up Parameters**

The Set-up parameters information block lists the data pattern, active range settings, Pre-conditioning workloads (with OIO and duration or TGBW) and steady state rounds for Pre-conditioning workloads (if applicable).

### **Test Parameters**

The Test parameters information block discloses the data pattern and AR amount, the test stimulus and workload dependent test loops, block sizes, OIO and rounds to steady state.

## **II. Best Practices for Comparative Analysis**

As stated at the outset, the PTS provides a way to conduct comparative performance testing of Solid State Storage products. Every effort has been made to eliminate the non-DUT attributes of performance measurement. However, a few simple and obvious precautions should be considered when comparing SSDs.

The reader should consider which of the various tests best represent the environment in which these devices will be deployed. The design of SSDs, like any other emerging technology, requires some degree of design trade-offs. Certain devices will perform better than others on some workloads.

Although performance measurement and comparison is the main objective of the PTS, there are other device attributes that are exposed in the results. One should consider the consistency of the IO, Throughput rates, device Latency and Write Saturation behavior in deciding which device is best for a particular application.

Lastly, although absolute measures of IOPS and Throughput are cited in the results, the reader is cautioned that these values are for comparison only. Very rarely, if ever, will an SSD experience the exact environment under which these tests were conducted and therefore produce the same results.



Rather, the performance of the devices should be considered in the relative rank order of the results. In general, a device that exhibits better performance than another under these test conditions will also perform better in the actual applications. For application environments having critical performance requirements, PTS results should never be a substitute for disciplined customer application benchmarking.

## 12. What's Next?

PTS 1.0 was developed over three years by the SNIA Solid State Storage Technical Working Group (SSS TWG). The SSS TWG is comprised of 56 member companies from throughout the SSS industry and includes major SSD OEMs, NAND flash OEMs, controller developers, test houses, academia and end-users.

PTS 1.0 tests utilized a mixed Pre-conditioning workload (e.g. IOPS 56 point matrix of BS & RW) applied as an uninterrupted series of stimuli. The intent was to put the drive in a used state not necessarily due to a specific workload and because, at the time, it was difficult to identify and agree upon a single Pre-conditioning workload.

The pending PTS 1.1 – scheduled to be released in Q3 2013 - moves to using test stimuli that are emulating aspects of specific real world workloads. This includes single stream SEQ or RND workloads as well as multiple stream composite workloads that allow the test operator to combine access patterns.

Additional work is being done to further characterize user workloads to help develop more accurate synthetic test workloads. See SNIA SSSI Workload IO Capture Program or WIOCP ([www.snia.org/forums/sssi/wiocp](http://www.snia.org/forums/sssi/wiocp)). The PTS can then be used to insert these updated access patterns to more closely emulate specific use cases and workloads.

PTS 1.1 has default settings for commonly used composite workloads as well as more complex tests that allow the user to “plug in” different test stimuli (and adjust the set-up conditions and parameters) to allow testing to targeted workloads of interest.



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## Conclusion

The PTS is an accurate, reliable and repeatable test methodology that allows users to fairly compare NAND flash based SSD device performance. Use of the PTS test scripts provide a standard performance benchmark that results in an ordinal ranking of different SSDs and can be used to establish an industry standard SSD performance baseline.

The PTS can also now be used as a powerful analytic tool to investigate SSD performance behaviors by changing set up conditions, test parameters and test workloads that are of interest to the test sponsor. With release of PTS I.1, users can generate test patterns that more closely emulate specific real world end-user workloads.

For more information on the SNIA PTS go to:

[www.snia.org/tech\\_activities/standards/curr\\_standards/pts](http://www.snia.org/tech_activities/standards/curr_standards/pts)



## About the Authors

### **Eden Kim, Calypso Systems, Inc.**

Eden Kim is CEO of Calypso Systems, Inc., a solid state storage test and measurement company and the manufacturer of the Calypso RTP and CTS test software upon which the PTS and data contained herein were developed. The Calypso RTP/CTS was also used to develop, validate and run the PTS and is used in the SSSI Certified Test Lab for PTS test services. Calypso can be found at [www.calypstesters.com](http://www.calypstesters.com).

Eden is Chair of the SNIA Solid State Storage Technical Working Group which developed the PTS. Eden is also Chair of the SSSI PCIe SSD Committee, Chair of the SSSI TechDev Committee and a member of the SSSI Governing Board.

Eden is a graduate of the University of California.

### **Chuck Paridon, Hewlett Packard**

Chuck is 26 year veteran in computer system and storage subsystem performance analysis. He is currently responsible for the development and delivery of Hewlett-Packard Storage Performance collateral in the form of field performance troubleshooting training, HP Enterprise Services efficient storage technology deployment and pre-sales consulting.

Chuck is a member of the SNIA Solid State Storage Technical Workgroup, the SNIA Green Storage Technical Workgroup and the Storage Performance Council.

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## 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 [www.snia.org](http://www.snia.org).

# SSSI TECH NOTES

## About this Book

What is SSD performance?

How do I measure and compare SSD performance?

How do I use the SNIA Solid State Storage Performance Test Specification?

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