



# **Solid State Storage (SSS) Performance Test Specification (PTS) Client**

Version 1.2

**ABSTRACT:** The SNIA has developed methods which enable manufacturers to set, and customers to compare, the performance specifications of Solid State Storage devices, which are evolving with the state of the technology. This specification defines a set of device level tests and methodologies which enable comparative testing of SSS devices for Client systems.

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**May 29, 2015**

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## Revision History

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# 1 Introduction

## 1.1 Preamble

This Client Performance Test Specification (PTS-C) 1.1 is a companion specification to the SNIA Solid State Storage Enterprise Performance Test Specification (PTS-E) 1.1. Both Performance Test Specifications (PTS) are intended to be used to obtain reliable and comparative measurement of NAND Flash based solid state storage devices. In both PTS in their present form, the tests and methodologies are designed to use a synthetic, or known and repeatable, test stimulus applied to a solid state storage product at the device level. In these PTS, "device level" refers to measurement of block IO at the physical device level as opposed to file system IO in the host Operating System.

Both of these PTS are based on test and preparation methodologies developed by the SNIA SSS TWG for performance test of NAND based solid state storage. NAND Flash based solid state storage (SSS) performance tends to be highly dependent on the write history of the SSS device, the type of stimulus applied to the SSS device, as well as the test environment (both hardware and software) in which the test stimulus is applied and measurements taken. Much of the preconditioning, test condition set up and parameters take these SSS behaviors into consideration.

These PTS do not require the use a specific test environment, but test tool requirements, capabilities and examples are set forth in the specifications. Care should be taken by the test operator to ensure that the test hardware does not bottleneck the SSS device performance, that the OS or test software tool has minimal contribution to test measurements, and that the same hardware and software test combination is used when comparing performance results of different SSS devices.

This Client PTS-C 1.1 differs from its companion Enterprise PTS-E 1.1 in the preparation of the Device Under Test (DUT) for steady state performance measurement and in the amount and type of test stimulus applied to the DUT. For example, preconditioning LBA ranges may be limited in the Client PTS-C to less than 100% of the available LBAs while the test stimulus Active Range may be limited to a reduced number of uniquely touched LBAs (see Client PTS-C Specification Section 2 Definitions). The use of limited preconditioning and test active ranges are meant to provide a test stimulus that share more characteristics with a typical Client user workload.

Readers and industry members are encouraged to participate in the further SNIA SSS TWG works and can contact the TWG at its website portal at <http://www.snia.org/feedback/>.

## 1.2 Purpose

Manufacturers need to set, and customers need to compare, the performance of Solid State Storage (SSS) devices. This Specification defines a set of device level tests and methodologies intended to enable comparative testing of SSS devices in Client (see 2.1.6) systems.

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Note: While the tests defined in this specification could be applied to SSS devices based on any technology (RAM, NAND, etc.), the emphasis in this specification, in particular regarding Preconditioning and Steady State, is oriented towards NAND.

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## 1.3 Background

A successful device level performance test isolates the device being tested from the underlying test platform (HW, OS, Tools, Applications) so the only limiting variable in the test environment is the device being tested. To achieve this goal with NAND-based SSS devices, in addition to typical system/device isolation issues, the test, and test methodologies, must address attributes unique to NAND-based flash media.

NAND-based SSS device controllers map Logical Block Addresses (LBA) to Physical Block Addresses (PBA) on the NAND media in order to achieve the best NAND performance and endurance. The SSS device manages this LBA-to-PBA mapping with internal processes that operate independently of the host. The sum of this activity is referred to as "flash management".

The performance of the flash management during a test, and hence the overall performance of the SSS device during the test, depends critically on:

- 1) Write History and Preconditioning: The state of the device prior to the test
- 2) Workload Pattern: Pattern of the I/O (r/w mix, block size, etc.) written to device during test
- 3) Data Pattern: The actual bits in the data payload written to the device

The methodologies defined in the SSS Performance Test Specification (SSS PTS) attempt to create consistent conditions for items 1-3 so that the only variable is the device under test.

Note: Descriptive notes precede each test section to explain the test rationale and examples of possible interpretations of test results. These notes are **informative only** and are set forth as “Descriptive Note” for the reader’s convenience.

The importance of the SSS PTS methodologies on SSS performance measurement is shown in Figure 1-1. A typical SSS device, taken Fresh Out of the Box (FOB), and exposed to a workload, experiences a brief period of elevated performance, followed by a transition to Steady State performance. The SSS PTS ensures that performance measurements are taken in the Steady State region, representing the device’s performance during its normal working life.

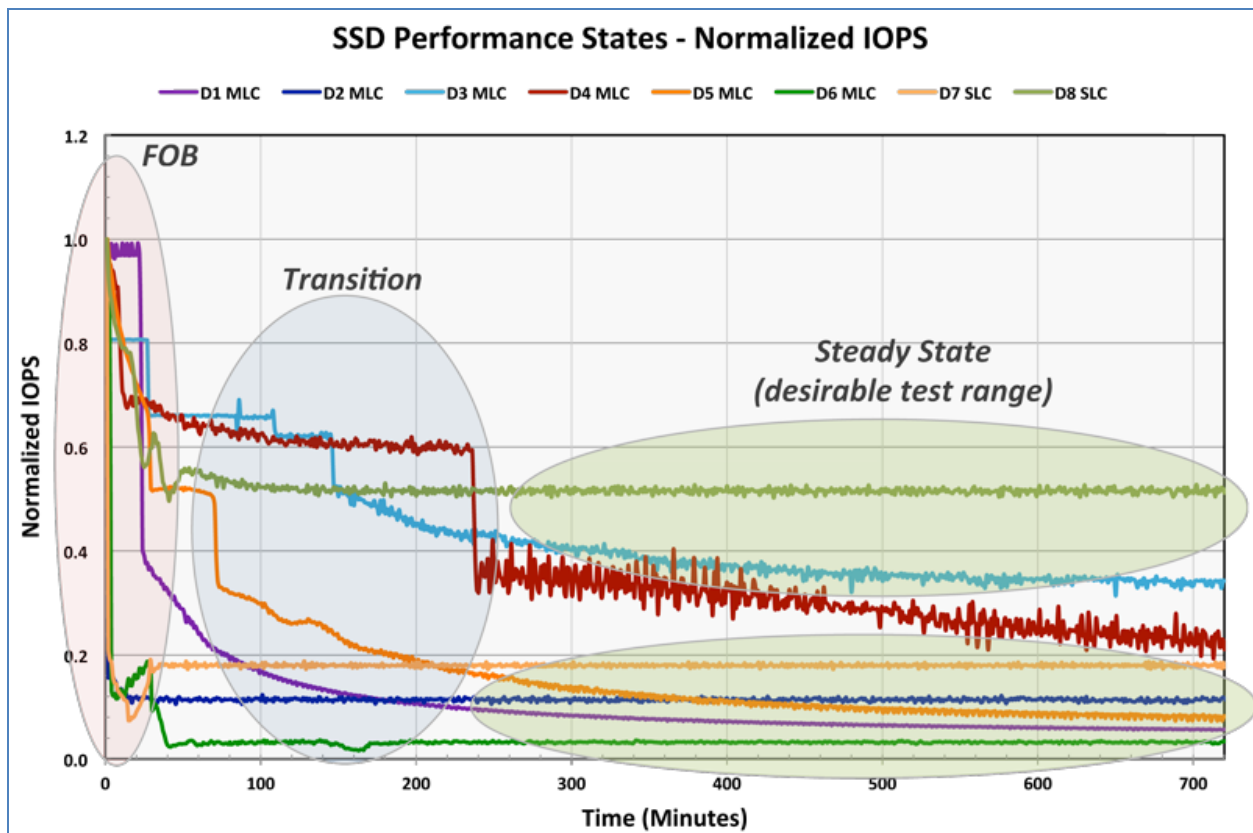


Figure 1-1 – NAND-based SSS Performance States (RND 4KiB Writes)

## 1.4 Scope

- 1) Preconditioning methods
- 2) Performance tests
- 3) Test reporting requirements

## 1.5 Not in Scope

- 1) Application Workload Tests
- 2) Test Platform (HW/OS/Tools)
- 3) Certification/Validation procedures for this specification
- 4) Device reliability, availability, or data integrity

## **1.6 Disclaimer**

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## **1.7 Normative References**

### **1.7.1 Approved references**

These are the standards, specifications and other documents that have been finalized and are referenced in this specification.

- IDEMA Document LBA1-02 -- LBA Count for IDE Hard Disk Drives Standard
- JEDEC JESD218 – Solid-State Drive (SSD) Requirements and Endurance Test Method
- JEDEC JESD219 – Solid-State Drive (SSD) Endurance Workloads

### **1.7.2 References under development**

- ATA/ATAPI Command Set - 2 (ACS-2) – INCITS/T13 2015-D

### **1.7.3 Other references**

- TBD

## 2 Definitions, symbols, abbreviations, and conventions

### 2.1 Definitions

- 2.1.1 **ActiveRange:** The range of LBA's that can be used for a given Test Code or Preconditioning Code (expressed as a percent of the total addressable LBAs as set forth in section 3.4)
- 2.1.2 **ActiveRange Amount:** The sum of the capacity referenced by the LBA's that are accessed for a given Test or Preconditioning Code equal to, or less than the capacity referenced by the ActiveRange LBAs (such as 8GiB or 16GiB ActiveRange Amount set forth in Section 3.5).
- 2.1.3 **ActiveRange Segments:** A collection of contiguous and equal sized LBA ranges within the ActiveRange where the Test Code and Preconditioning Codes are allowed to access. The starting LBA of each ActiveRange Segment is randomly distributed across the entire ActiveRange. The set of ActiveRange segments spans the ActiveRange. Note that ActiveRange segments shall not touch to form a single segment.
- 2.1.4 **ActiveRange Segment Size:** The size of a single ActiveRange Segment is determined by taking the ActiveRange Amount and dividing by the number of ActiveRange Segments as prescribed in the Test Code or Preconditioning Code.
- 2.1.5 **Cache:** A volatile or non-volatile data storage area outside the User Capacity that may contain a subset of the data stored within the User Capacity.
- 2.1.6 **Client:** Single user desktop or laptop system used in home or office.
- 2.1.7 **Enterprise:** Servers in data centers, storage arrays, and enterprise wide / multiple user environments that employ direct attached storage, storage attached networks and tiered storage architectures.
- 2.1.8 **Fresh Out of the Box (FOB):** State of SSS prior to being put into service.
- 2.1.9 **IO Demand:** Measured # of OIOs executing in the host.
- 2.1.10 **Logical Block Address (LBA):** The address of a logical block, i.e., the offset of the block from the beginning of the logical device that contains it.
- 2.1.11 **Latency:** The time between when the workload generator makes an IO request and when it receives notification of the request's completion.
- 2.1.12 **MaxUserLBA:** The maximum LBA # addressable in the User Capacity.
- 2.1.13 **Measurement Window:** The interval, measured in Rounds, during which test data is collected, bounded by the Round in which the device has been observed to have maintained Steady State for the specified number of Rounds (Round x), and five Rounds previous (Round x-4).
- 2.1.14 **Nonvolatile Cache:** A cache that retains data through power cycles.
- 2.1.15 **Outstanding IO (OIO):** The number of IO operations issued by a host, or hosts, awaiting completion.
- 2.1.16 **OIO/Thread:** The number of OIO allowed per Thread (Worker, Process)
- 2.1.17 **Over-Provisioned Capacity:** LBA range provided by the manufacturer for performance and endurance considerations, but not accessible by the host file system, operating system, applications, or user.
- 2.1.18 **Preconditioning:** The process of writing data to the device to prepare it for Steady State measurement consisting of two (2) Preconditioning steps as follows:
  - 18.1. **Workload Independent Preconditioning (WIPC):** The first Preconditioning step comprised of a prescribed workload, unrelated to the test workload, as a means to facilitate convergence to Steady State.
  - 18.2. **Workload Dependent Preconditioning (WDPC):** The second Preconditioning step comprised of running the test workload itself, after Workload Independent

Preconditioning, as a means to put the device in a Steady State relative to the dependent variable being tested.

- 2.1.19 **Preconditioning Code:** Refers to the Preconditioning steps set forth in this Specification.
- 2.1.20 **Purge:** 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.
- 2.1.21 **Round:** A complete pass through all the prescribed test points for any given test.
- 2.1.22 **Steady State:** A device is said to be in Steady State when, for the dependent variable (y) being tracked:
  - a) Range(y) is less than 20% of Ave(y): Max(y)-Min(y) within the Measurement Window is no more than 20% of the Ave(y) within the Measurement Window; and
  - b) Slope(y) is less than 10%: Max(y)-Min(y), where Max(y) and Min(y) are the maximum and minimum values on the best linear curve fit of the y-values within the Measurement Window, is within 10% of Ave(y) value within the Measurement Window.
- 2.1.23 **Test Code:** Refers to the measurement steps set forth in the test sections contained in this Specification.
- 2.1.24 **Thread:** Execution context defined by host OS/CPU (also: Process, Worker)
- 2.1.25 **Thread Count (TC):** Number of Threads (or Workers or Processes) specified by a test.
- 2.1.26 **Transition Zone:** A performance state where the device's performance is changing as it goes from one state to another (such as from FOB to Steady State).
- 2.1.27 **Total OIO:** Total outstanding IO Operations specified by a test = (OIO/Thread) \* (TC)
- 2.1.28 **User Capacity:** LBA range directly accessible by the file system, operating system and applications, not including Over-Provisioned Capacity.
- 2.1.29 **WSAT Steady State:** The state of performance during the WSAT test that follows the Transition Zone when measurements of the dependent variable (RND 4KiB Writes) are relatively time invariant. WSAT Steady State is determined by test operator inspection and is different from the Steady State determination as defined in 2.1.22.
- 2.1.30 coincidence, to the test workload, as a means to facilitate convergence to Steady State.
- 2.1.31 **Volatile Cache:** A cache that does not retain data through power cycles.

## 2.2 Acronyms and Abbreviations

- 2.2.1 **IOPS:** I/O Operations per Second
- 2.2.2 **DUT:** Device Under Test
- 2.2.3 **FOB:** Fresh Out of Box
- 2.2.4 **OIO:** Outstanding IO
- 2.2.5 **R/W:** Read/Write
- 2.2.6 **SSSI:** Solid State Storage Initiative
- 2.2.7 **SSS TWG:** Solid State Storage Technical Working Group
- 2.2.8 **TC:** Thread Count
- 2.2.9 **QD:** Queue Depth

## 2.3 Keywords

The key words “shall”, “required”, “shall not”, “should”, “recommended”, “should not”, “may”, and “optional” in this document are to be interpreted as:

- 2.3.1 **Shall:** This word, or the term "required", means that the definition is an absolute requirement of the specification.
- 2.3.2 **Shall Not:** This phrase means that the definition is an absolute prohibition of the specification.
- 2.3.3 **Should:** This word, or the adjective "recommended", means that there may be valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and weighed before choosing a different course.
- 2.3.4 **Should Not:** This phrase, or the phrase "not recommended", means that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
- 2.3.5 **May:** This word, or term "optional", indicates flexibility, with no implied preference.

## 2.4 Conventions

### 2.4.1 Number Conventions

Numbers that are not immediately followed by lower-case b or h are decimal values.

Numbers immediately followed by lower-case b (xxb) are binary values.

Numbers immediately followed by lower-case h (xxh) are hexadecimal values.

Hexadecimal digits that are alphabetic characters are upper case (i.e., ABCDEF, not abcdef).

Hexadecimal numbers may be separated into groups of four digits by spaces. If the number is not a multiple of four digits, the first group may have fewer than four digits (e.g., AB CDEF 1234 5678h).

Storage capacities and data transfer rates and amounts shall be reported in Base-10. IO transfer sizes and offsets shall be reported in Base-2. The associated units and abbreviations used in this specification are:

- A kilobyte (KB) is equal to 1,000 ( $10^3$ ) bytes.
- A megabyte (MB) is equal to 1,000,000 ( $10^6$ ) bytes.
- A gigabyte (GB) is equal to 1,000,000,000 ( $10^9$ ) bytes.
- A terabyte (TB) is equal to 1,000,000,000,000 ( $10^{12}$ ) bytes.
- A petabyte (PB) is equal to 1,000,000,000,000,000 ( $10^{15}$ ) bytes
- A kibibyte (KiB) is equal to  $2^{10}$  bytes.
- A mebibyte (MiB) is equal to  $2^{20}$  bytes.
- A gibibyte (GiB) is equal to  $2^{30}$  bytes.
- A tebibyte (TiB) is equal to  $2^{40}$  bytes.
- A pebibyte (PiB) is equal to  $2^{50}$  bytes

### 2.4.2 Pseudo Code Conventions

The specification uses an informal pseudo code to express the test loops. It is important to follow the precedence and ordering information implied by the syntax. In addition to nesting/indentation, the main syntactic construct used is the "For" statement.

A "For" statement typically uses the syntax: For (variable = x, y, z). The interpretation of this construct is that the Test Operator sets the variable to x, then performs all actions specified in the indented section under the "For" statement, then sets the variable to y, and again performs the actions specified, and so on. Sometimes a "For" statement will have an explicit "End For" clause, but not always; in these cases, the end of the For statement's scope is contextual.

Take the following loop as an example:

```
For (R/W Mix % = 100/0, 95/5, 65/35, 50/50, 35/65, 5/95, 0/100)
  For (Block Size = 1024KiB, 128KiB, 64KiB, 32KiB, 16KiB, 8KiB, 4KiB, 0.5KiB)
    - Execute random IO, per (R/W Mix %, Block Size), for 1 minute
    - Record Ave IOPS(R/W Mix%, Block Size)
```

This loop is executed as follows:

- Set R/W Mix% to 100/0 >>>>> Beginning of Loop 1
- Set Block Size to 1024KiB
- Execute random IO...
- Record Ave IOPS...
- Set Block Size to 128KiB
- Execute...
- Record...
- ...
- Set Block Size to 0.5KiB
- Execute...
- Record... >>>>> End of Loop 1
- Set R/W Mix% to 95/5 >>>>> Beginning of Round Loop 2
- Set Block Size to 1024 KiB
- Execute...
- Record...
- ...



## 3 Key Test Process Concepts

The performance of an SSS device is highly dependent on its prior usage, the pre-test state of the device and test parameters. This section describes key SSS test methodology concepts.

### 3.1 Steady State

SSS devices that are Fresh Out of the Box (FOB), or in an equivalent state, typically exhibit a transient period of elevated performance, which evolves to a stable performance state relative to the workload being applied. This state is referred to as a Steady State (Definition 2.1.22).

It is important that the test data be gathered during a time window when the device is in Steady State, for two primary reasons:

- 1) To ensure that a device's initial performance (FOB or Purged) will not be reported as "typical", since this is transient behavior and not a meaningful indicator of the drive's performance during the bulk of its operating life.
- 2) To enable Test Operators and reviewers to observe and understand trends. For example, oscillations around an average are "steady" in a sense, but might be a cause for concern.

Steady State may be verified:

- by inspection, after running a number of Rounds and examining the data;
- programmatically, during execution; or
- by any other method, as long as the attainment of Steady State, per Definition 2.1.22 is demonstrated and documented.

Steady State as defined in Section 2.1.19 shall meet the Steady State Verification criteria as set forth in each test section except for the Optional Write Saturation (WSAT) test – see Definition 2.1.29). For WSAT, the test sponsor shall determine WSAT Steady State by inspection and shall be defined as the area following the Transition Zone (2.1.26) wherein the IOPS measurements remain relatively time invariant.

### 3.2 Purge

The purpose of the Purge process (Definition 2.1.20) is to put the device in a consistent state prior to preconditioning and testing, and to facilitate a clear demonstration of Steady State convergence behavior.

Purge shall be run prior to each preconditioning and testing cycle. If the device under test does not support any kind of Purge method, and the Test Operator chooses to run the PTS, the fact that Purge was not supported/run must be documented in the test report.

The Test Operator may select any valid method of implementing the Purge process, including, but not limited to, the following:

- a) ATA: SECURITY ERASE, SANITIZE DEVICE (BLOCK ERASE EXT)
- b) SCSI: FORMAT UNIT
- c) Vendor specific methods

The Test Operator shall report what method of Purge was used.

### 3.3 Preconditioning

The goal of preconditioning is to facilitate convergence to Steady State during the test itself.

The SSS PTS defines two (2) Preconditioning steps:

- Workload Independent Preconditioning (WIPC Definition 2.1.18.1); and
- Workload Dependent Preconditioning (WDPC Definition 2.1.18.2)

### 3.4 ActiveRange

It is desirable to be able to test the performance characteristics of workloads which issue IO across a wide range of the LBA space vs. those which issue IO across only a narrow range. To enable this, the SSS Performance Specification defines ActiveRange. (Definition 2.1.1)

The test scripts define required and optional settings for ActiveRange.

The figures below show two examples of ActiveRange.

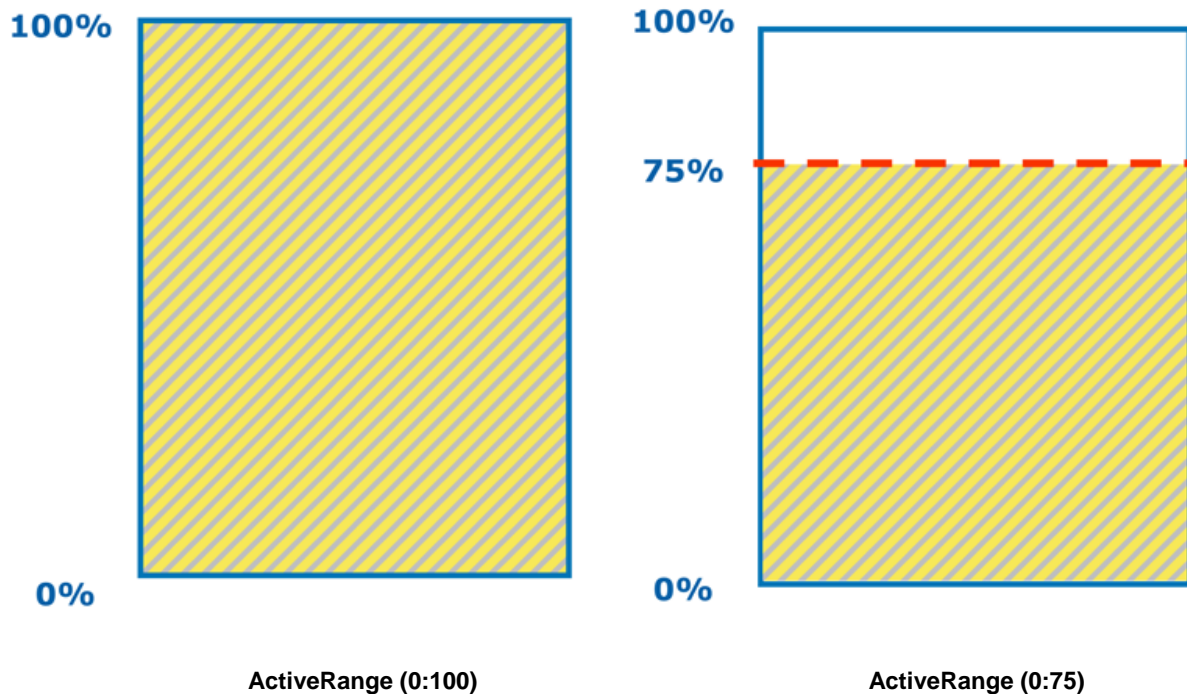
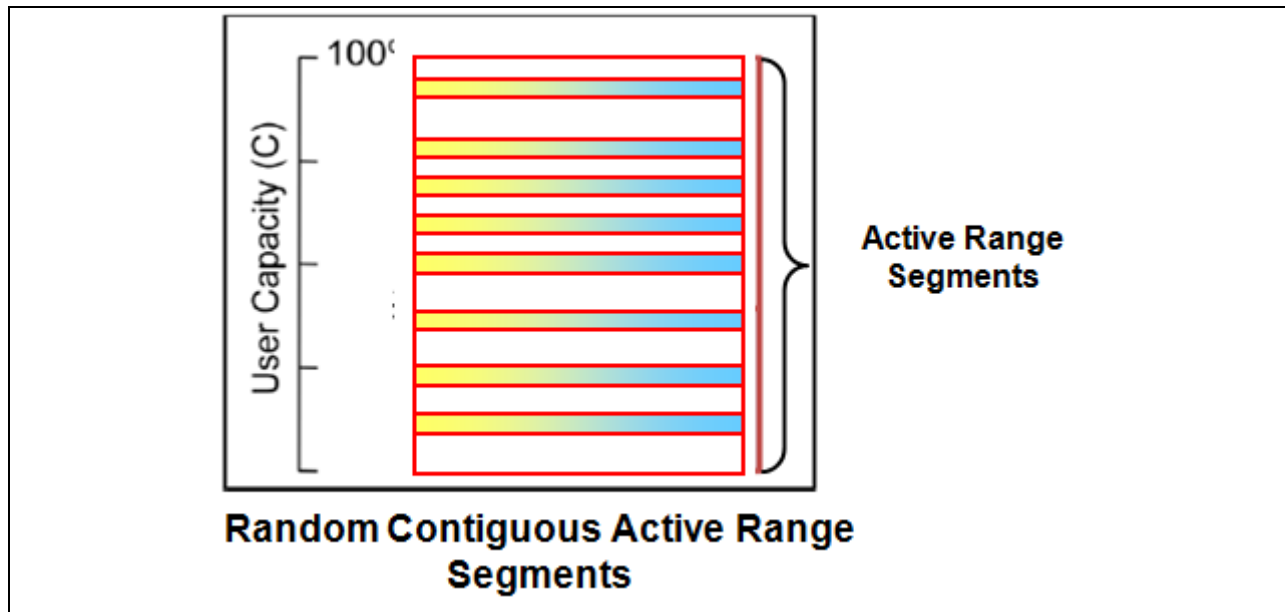


Figure 3-1 – ActiveRange Diagram

### 3.5 ActiveRange Segmentation

The Limited ActiveRange as set forth in this specification shall be segmented into segments as defined and prescribed. The following illustration shows the alignment of Random Contiguous Segments.



**Figure 3-2 – ActiveRange Segmentation Diagram**

### 3.6 Data Patterns

All tests shall be run with a random data pattern. The Test Operator may execute additional runs with non-random data patterns. If non-random data patterns are used, the Test Operator must report the data pattern.

---

Note: Some SSS devices look for and optimize certain data patterns in the data written to the device. It is not feasible to test for all possible kinds of optimizations, which are vendor specific and often market segment specific. The SSS TWG is still trying to characterize “how random is random enough” with respect to data patterns.

---

### 3.7 Multiple Thread Guideline

If the Test Operator wishes to run a test using multiple Threads, it is recommended that OIO/Thread for all Threads be equal, so Total OIO is equal to (OIO/Thread) \* (Thread Count). This will enable more direct comparisons.

While the Test Operator may select a given OIO for a test, the Test Operator shall use the same Thread Count and OIO/Thread for all steps of a given test.

### 3.8 Caching

All tests shall be run with all volatile write caches enabled. The cache state shall be reported for drives that cannot have write cache enabled. The test operator may optionally run tests with Write Caches disabled provided that the Cache Flush command is also disabled and that the method and frequency by which the flush buffer commands are issued are disclosed.

## 4 Overview of Common Test Flow

The Steady State tests in the SSS PTS (IOPS, Throughput and Latency) use the same general steps and flow, described below. Test-specific parameter settings, reports, and other requirements are documented in the test sections themselves.

Basic Test Flow:

For (ActiveRange = the specified values)

### 1) Purge the device

Note: Test Operator may use any values for ActiveRange and Test Parameters for this step; no parameter reporting is required.

### 2) Run Workload Independent Preconditioning

Note: Test Operator shall use specified ActiveRange (“For ActiveRange =”), but may choose other Test Parameter values to optimize this step, and shall report them.

### 3) Run Test (includes Workload Dependent Preconditioning):

- a) Set Test Parameters (OIO/Thread, Thread Count, Data Pattern, etc.) as specified in the test script.
- b) Run test loop until Steady State reached, or a maximum of 25 Rounds. Accumulate/Record intermediate data, as specified in test, for each Round.

### 4) Post process & plot the Rounds data:

- a) If Steady State is reached by Round  $x=25$ , where the Measurement Window is Round  $(x-4):x$ , the Test Operator shall:
  - i) Plot Rounds  $1:x$  per “Steady State Convergence Plot”;
  - ii) Plot Rounds  $(x-4):x$  per “Steady State Verification Plot”; and
  - iii) Plot Rounds  $(x-4):x$  per “Measurement Plot”.
- b) If Steady State is not reached by Round  $x=25$ , the Test Operator shall either:
  - i) Continue at 3b until Steady State reached ( $x>25$ ), and then report per 4a(i-iii); or
  - ii) Stop at Round  $x$  and report per 4a(i-iii).

End “For ActiveRange”

The Test Operator may re-run the entire “For ActiveRange” loop with alternate test parameters, which may be optional or required, depending on the test.

End “Basic Test Flow”

**Figure 4-1 – Basic Test Flow**

Note: Steps (2) and (3) must each be run with no interruptions, and there must be no delay between Step (2) and Step (3), to maintain consistent test conditions for all devices.

Note: With respect to the reports in Step (4):

- The **Steady State Convergence Plot** shows general visual convergence to Steady State by plotting the dependent variable (IOPS, Throughput, etc.) for each Round.
- The **Steady State Verification Plot** shows, via either graph or table, that the device has reached Steady State per definition 2.1.22, by examining dependent variable behavior within the Measurement Window.
- The **Measurement Plot** is not one, but a set of, plots/reports, which summarize the test data in the Measurement Window, for the metric being measured.
- The content of these plots, and other test-specific reporting, is specified in each test.
- Examples of these plots are set forth in Normative Annex A: Sample Test Reports.

## 5 Common Reporting Requirements

The following items, common to all tests, shall be included in the final test report. These items only need to be reported once in the test report. Test-specific report items are defined in the relevant test sections themselves. A sample test report can be found in Normative Annex A.

### 5.0 General

- 1) Test Date
- 2) Report Date
- 3) Test Operator name
- 4) Auditor name, if applicable
- 5) Test Specification Version

### 5.1 Test System Hardware

- 1) Manufacturer/Model #
- 2) Mother Board/Model #
- 3) CPU
- 4) DRAM
- 5) Host Bus Adapter
- 6) Primary Storage
- 7) Peripherals

### 5.2 Test System Software

- 1) Operating System Version
- 2) File System and Version
- 3) Test Software

### 5.3 Device Under Test

- 1) Manufacturer
- 2) Model Number
- 3) Serial Number
- 4) Firmware Revision
- 5) User Capacity
- 6) Interface/Speed
- 7) Form Factor (e.g. 2.5")
- 8) Media Type (e.g. MLC NAND Flash)
- 9) Optional: Other major relevant features (e.g. NCQ, Hot plug, Sanitize support, etc.)

## 6 Test Tool Guidelines

The SSS PTS is platform (HW/OS/Tool) agnostic. A sample platform is outlined in Informative Annex B: Reference Test Platform Example. SW tools used to test SSS devices pursuant to this PTS-C shall have the ability to:

- 1) Act as workload stimulus generator as well as data recorder
- 2) Issue Random and Sequential block level I/O
- 3) Ability to access contiguous LBA ranges sequentially across test steps
- 4) Restrict LBA accesses to a particular range, or collection of ranges, within the available user LBA space
- 5) Test ActiveRange – shall be able to limit “total unique LBAs used” to a specific value
- 6) Ability to randomly distribute a number of equally sized LBA segments across the test ActiveRange.
- 7) Set R/W percentage mix %
- 8) Set Random/Sequential IO mix %
- 9) Set IO Transfer Size
- 10) Generate and maintain multiple outstanding IO requests. All test sequence steps shall be executed immediately one after the other. This ensures that drives are not given time to recover between processing steps, unless recovery is the explicit goal of the test.
- 11) Provide output, or output that can be used to derive, IOPS, MB/s, maximum latency and average response time (latency if OIO=1) within some measurement period.

The random function for generating random LBA #'s during random IO tests shall be:

- 1) seedable;
- 2) have an output  $\geq$  48-bit; and
- 3) deliver a uniform random distribution independent of capacity.

## 7 IOPS Test

### 7.1 IOPS Descriptive Note

---

#### General Purpose:

Client IOPS test is intended to measure the test SSD IOPS at a range of Random Block Sizes and Read/Write mixes using a limited preconditioning and limited Test ActiveRange. This Client IOPS test is intended to emulate characteristics of Client workloads that are limited in the ways in which the LBAs are accessed compared to Enterprise workloads. PTS-E Enterprise workload tests use 100% LBAs and have no restrictions on Test ActiveRange (see conditions set forth in the PTS-E specification).

#### Test Flow:

The Client IOPS test makes use of:

- 1) a limited preconditioning LBA range (section 2.1);
- 2) a two step Workload Independent PC (section 2.1.18.1) consisting of
  - a) 128KiB SEQ W for 2X (twice) the user capacity; and
  - b) application of the IOPS loop over the PC LBA range (100% or 75%) until steady state, as defined, is achieved;
- 3) a one step Workload Dependent PC (WDPC) (section 2.1.18.2) consisting of the IOPS loop using the ActiveRange Amount (8GiB or 16GiB) within the ActiveRange until Steady State, as defined, is achieved.

#### Test Results:

The test results captured during steady state measurement window shall be tabulated and plotted as specified in section 7 and are intended to present the IOPS performance over the 56 element matrix of (7) Read/Write Mixes (aka the "outer loop") and (8) Block Sizes (aka the "inner loop").

#### Test Interpretation:

A higher value (more IOPS) is better.

---

### 7.2 IOPS Pseudo Code

For (ActiveRange=(0:100) and ActiveRange= (0:75)

For (ActiveRange Amount=8GiB and ActiveRange Amount=16GiB)

- 1 Purge the device. (Note: Active Range and other Test Parameters are not applicable to Purge step; any values can be used and none need to be reported.)
- 2 Workload Independent Preconditioning
  - 2.1 Run SEQ Workload Independent Preconditioning
    - 2.1.1 Set and record test conditions:
      - 2.1.1.1 Device volatile write cache = enabled
      - 2.1.1.2 OIO/Thread: Test Operator Choice
      - 2.1.1.3 Thread Count: Test Operator Choice
      - 2.1.1.4 Data Pattern: Required = Random, Optional = Test Operator
    - 2.1.2 Run SEQ Workload Independent Preconditioning - Write 2X User Capacity with 128KiB SEQ writes, writing to the entire ActiveRange without LBA restrictions.
      - 2.2 Run RND Workload Independent Preconditioning
        - 2.2.1 Set and record test conditions:
          - 2.2.1.1 Device volatile write cache = enabled

- 2.2.1.2 OIO/Thread: Same as in step 2.1 above.
  - 2.2.1.3 Thread Count: Same as in step 2.1 above.
  - 2.2.1.4 Data Pattern: Required = Random, Optional = Test Operator Choice
  - 2.2.2 For (R/W Mix % = 100/0, 95/5, 65/35, 50/50, 35/65, 5/95, 0/100)
    - 2.2.2.1 For (Block Size = 1024KiB, 128KiB, 64KiB, 32KiB, 16KiB, 8KiB, 4KiB, 0.5KiB)
      - 2.2.2.1.1 Execute **random IO**, per (R/W Mix %, Block Size), for 1 minute
      - 2.2.2.1.2 Record Ave IOPS (R/W Mix%, Block Size)
      - 2.2.2.1.3 Use IOPS(R/W Mix% = 0/100, Block Size = 4KiB) to detect Steady State.
      - 2.2.2.1.4 If Steady State is not reached by Round x=25, then the Test Operator shall either continue running the test until Steady State is reached, or may stop the test at Round x. The Measurement Window to determine WIPC termination is defined as Round x-4 to Round x.
    - 2.2.2.2 End (For Block Size) Loop
  - 2.2.3 End (For R/W Mix %) Loop
- 3 Run Workload Dependent Preconditioning and Test stimulus. Set test parameters and record for later reporting
  - 3.1 Set and record test conditions:
    - 3.1.1 Device volatile write cache = Disabled
    - 3.1.2 OIO/Thread: Same as in step 2.1 above.
    - 3.1.3 Thread Count: Same as in step 2.1 above.
    - 3.1.4 Data Pattern: Required= Random, Optional = Test Operator Choice.
    - 3.1.5 Active Range Segmentation Configuration:
      - 3.1.5.1 Required setting: No Segmentation
      - 3.1.5.2 Optional Setting: Segmentation Enabled as follows:
        - 3.1.5.2.1 Number of ActiveRange Segments = 2048
        - 3.1.5.2.2 ActiveRange Segment Size = ActiveRange Amount divided by 2048
        - 3.1.5.2.3 Distribution of ActiveRange Segments: randomly distributed within the entire ActiveRange. The ActiveRange Segments are not allowed to touch.
  - 3.2 Run the following test loop until Steady State is reached, or maximum of 25 Rounds:
    - 3.2.1 For (R/W Mix % = 100/0, 95/5, 65/35, 50/50, 35/65, 5/95, 0/100)
      - 3.2.1.1 For (Block Size = 1024KiB, 128KiB, 64KiB, 32KiB, 16KiB, 8KiB, 4KiB, 0.5KiB)
        - 3.2.1.1.1 Execute **RND IO**, per (R/W Mix %, Block Size), for 1 minute
        - 3.2.1.1.2 Record Ave IOPS (R/W Mix%, Block Size)
        - 3.2.1.1.3 Use IOPS (R/W Mix% = 0/100, Block Size = 4KiB) to detect Steady State.
        - 3.2.1.1.4 If Steady State is not reached by Round x=25, then the Test Operator may either continue running the test until Steady State is reached, or may stop the test at Round x. The Measurement Window is defined as Round x-4 to Round x.



3.2.1.2 End "For Block Size" Loop  
3.2.2 End "For R/W Mix%" Loop

- 4 Process and plot the accumulated Rounds data, per report guidelines in next section.

End (For ActiveRange Amount) loop

End (For ActiveRange) loop

Note: It is important to adhere to the nesting of the loops as well as the sequence of R/W Mixes and Block Sizes.

### 7.3 Test Specific Reporting for IOPS Test

The following sub-sections list the reporting requirements specific to the IOPS test. Reporting requirements common to all tests are documented in Section 5

If Steady State was reached at Round x, the Test Operator shall:

- Plot Rounds 1:x per "IOPS Steady State Convergence Plot";
- Plot Rounds (x-4):x per "IOPS Steady State Verification Plot"; and
- Plot Rounds (x-4):x per "IOPS Measurement Plot."

If Steady State was not reached then the Test Operator may report results per above, picking the last Round run as Round x. **In the case where Steady State was not reached, the Test Operator must state this fact in the final report.**

#### 7.3.1 Purge Report

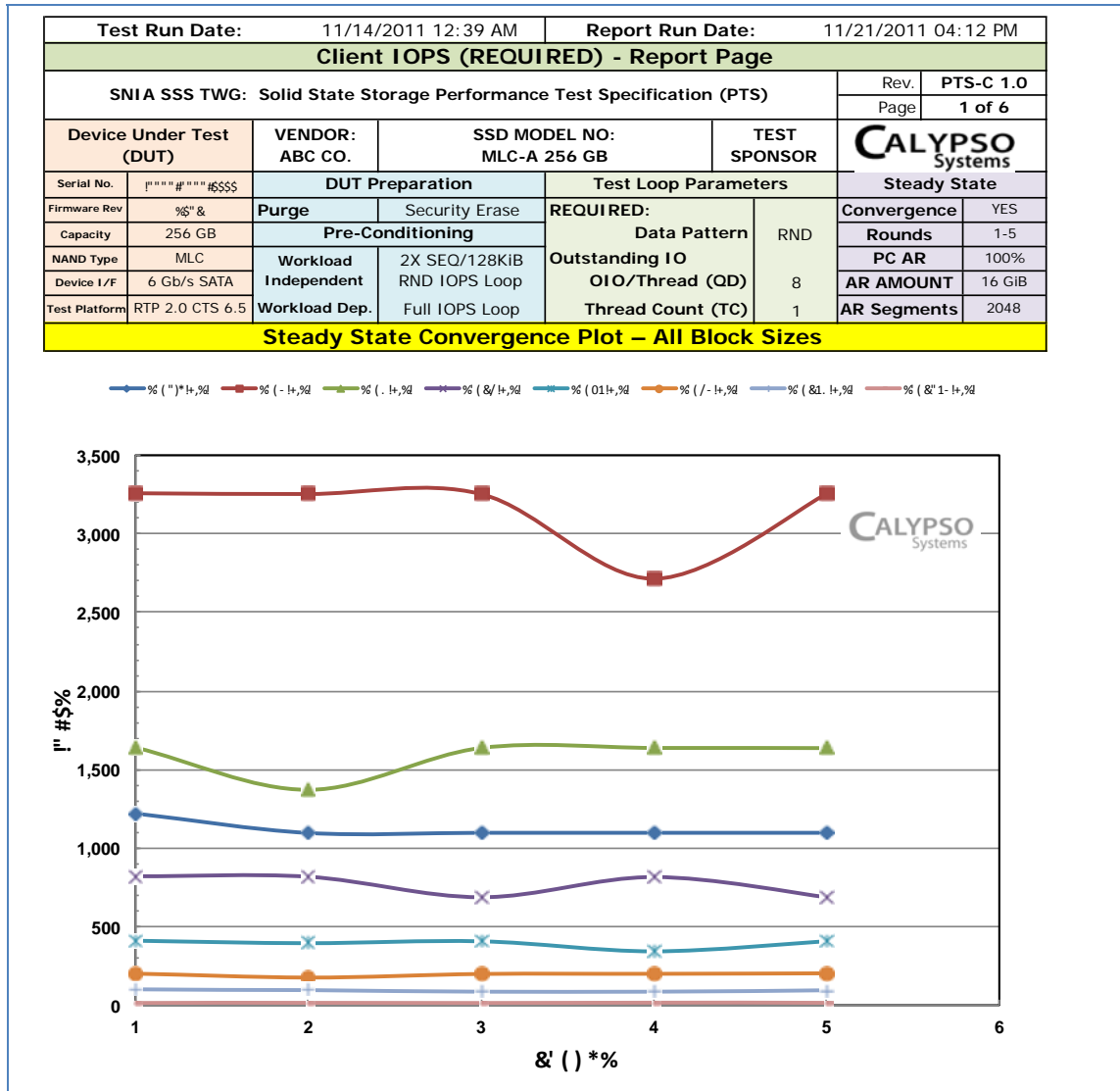
The Test Operator shall report the method used to run the Purge operation.

#### 7.3.2 Preconditioning Report

The Test Operator shall report both Workload Independent and Workload Dependent preconditioning information as shown in the Report Headers that follow.

### 7.3.3 Steady State Convergence Report

The Test Operator shall generate a Steady State Convergence plot as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 7-1: IOPS SS Convergence Report

### 7.3.4 Steady State Verification

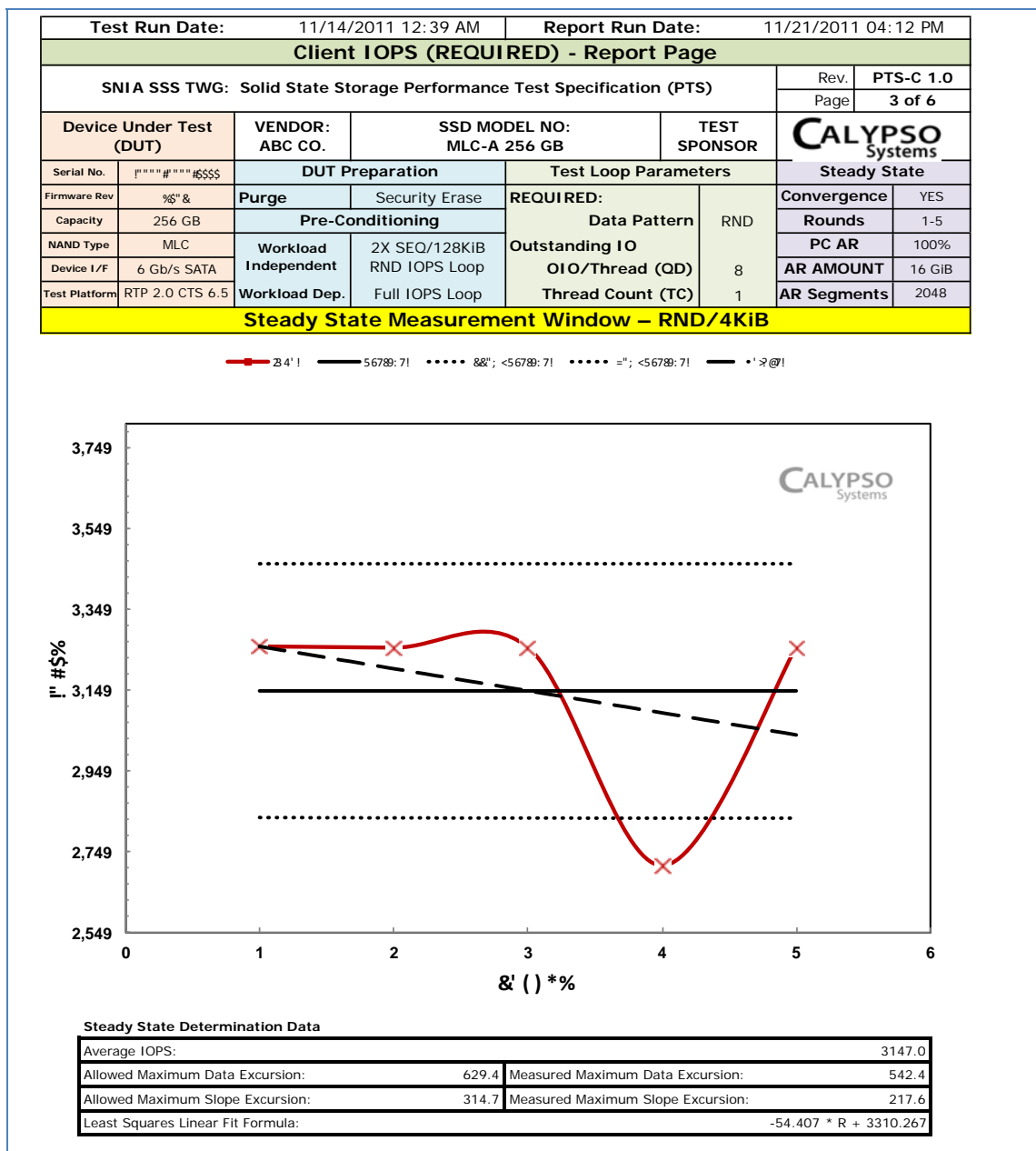
The Test Operator shall document the following for Steady State Verification, using Ave 4KiB Random Write IOPS as the dependent variable:

**IOPS Test - Steady State Verification**  
**Dependent Variable = Ave 4KiB Random Write IOPS**  
**ActiveRange = (x,y); OIO/Thread = x; Thread Count = x; Data Pattern = x**

- Measurement Window: Start \_\_\_; End \_\_\_
- Ave. value in Measurement Window: \_\_\_
- Calculated allowed range in Measurement Window (+-10% of Ave.): Max\_\_\_; Min \_\_\_
- Measured range in Measurement Window: Max \_\_\_; Min \_\_\_ (pass/fail)
- Slope of best linear fit in Measurement Window (must be <= 10%): \_\_\_% (pass/fail)
- Correlation coefficient for best linear fit: \_\_\_

### 7.3.5 Steady State Measurement Window

The Test Operator shall include a plot showing the Steady State Measurement Window. as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 7-2: IOPS SS Measurement Window

### 7.3.6 Measurement Window Report

The results for the test shall be reported in the following series of tables and graphs which record and report the data from the Steady State Measurement Window.

#### 7.3.6.1 IOPS Measurement Window Tabular Data

The Test Operator shall include a plot showing an IOPS Tabular Data as follows including the test set up and parameters set forth in the Report Header (see Annex A).

Test Run Date:		11/14/2011 12:39 AM		Report Run Date:		11/21/2011 04:12 PM	
<b>Client IOPS (REQUIRED) - Report Page</b>							
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)						Rev.	PTS-C 1.0
						Page	4 of 6
Device Under Test (DUT)		VENDOR:	SSD MODEL NO:	TEST SPONSOR		<b>CALYPSO</b> Systems	
		ABC CO.	MLC-A 256 GB				
Serial No.	#####6SS\$	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	%" &	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	256 GB	Pre-Conditioning		Data Pattern	RND	Rounds	1-5
NAND Type	MLC	Workload Independent	2X SEQ/128KiB RND IOPS Loop	Outstanding IO		PC AR	100%
Device I/F	6 Gb/s SATA		Workload Dep.	Full IOPS Loop	OIO/Thread (QD)	8	AR AMOUNT
Test Platform	RTP 2.0 CTS 6.5			Thread Count (TC)	1	AR Segments	2048
<b>Client IOPS - ALL RW Mix &amp; BS – Tabular Data</b>							
Block Size (KiB)	Read / Write Mix %						
	0/100	5/95	35/65	50/50	65/35	95/5	100/0
0.5	1,122.3	1,162.2	1,654.6	1,965.6	2,717.7	11,970.0	29,860.1
4	3,147.0	2,896.6	3,044.4	3,454.4	3,779.3	13,005.8	29,876.3
8	1,584.9	1,589.7	2,055.0	2,238.9	2,898.1	11,568.2	21,723.1
16	765.8	786.3	1,028.1	1,272.6	1,604.9	6,208.3	12,482.5
32	392.7	401.0	525.8	652.7	963.8	4,129.6	7,011.6
64	196.4	205.9	291.3	352.3	565.4	2,372.7	3,791.5
128	92.5	97.1	139.9	185.4	377.9	1,410.2	2,015.3
1024	16.4	16.5	23.3	27.3	90.8	191.4	266.7

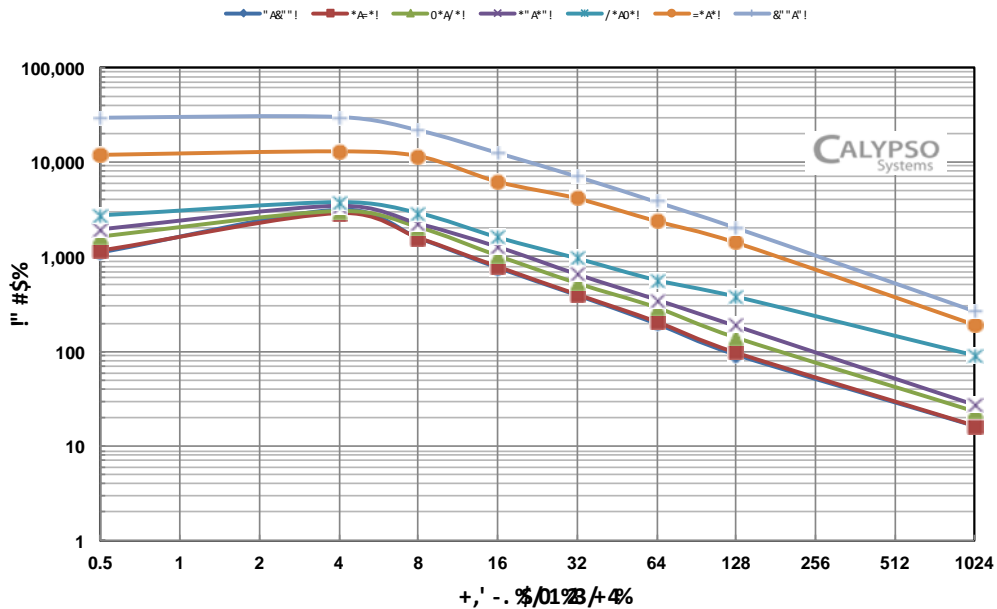
**Plot 7-3: IOPS Measurement Window Tabular Data**

Each entry in the table is the average of the values in the five Rounds comprising the Steady State Measurement Window, for the selected (R/W Mix%, Block Size) element.

### 7.3.6.2 IOPS Measurement Plot – 2D

The Test Operator shall include a plot showing an IOPS 2D Plot as follows including the test set up and parameters set forth in the Report Header (see Annex A):

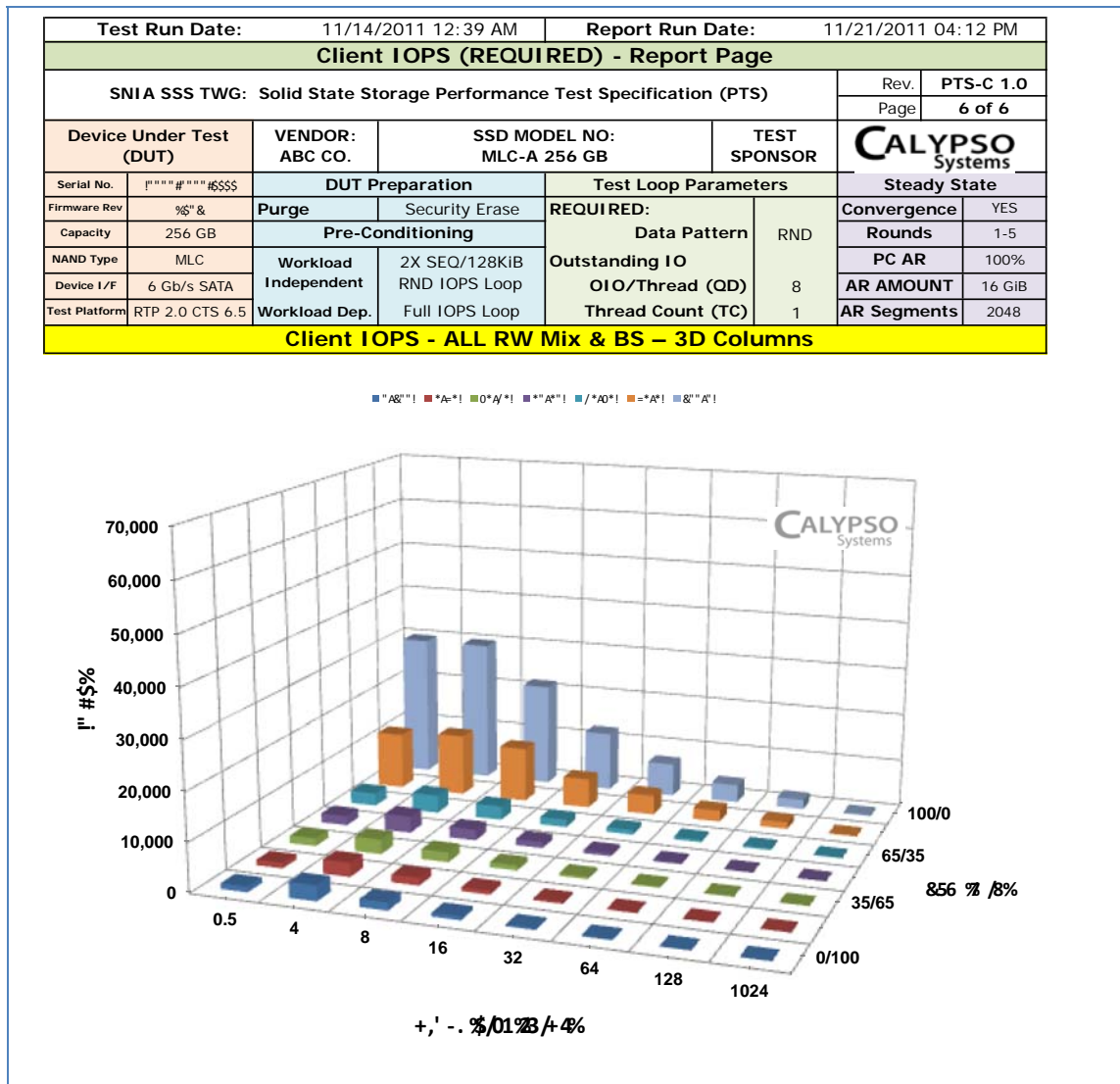
Test Run Date: 11/14/2011 12:39 AM		Report Run Date: 11/21/2011 04:12 PM	
<b>Client IOPS (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 5 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR: CALYPSO Systems
Serial No. *****#*****#SSSS	DUT Preparation		Steady State
Firmware Rev %&	Purge	Security Erase	Convergence YES
Capacity 256 GB	Pre-Conditioning		Rounds 1-5
NAND Type MLC	Workload Independent	2X SEQ/128KiB RND IOPS Loop	PC AR 100%
Device I/F 6 Gb/s SATA	Workload Dep.	Full IOPS Loop	AR AMOUNT 16 GiB
Test Platform RTP 2.0 CTS 6.5			AR Segments 2048
<b>Client IOPS - ALL RW Mix &amp; BS - 2D Plot</b>			



Plot 7-4: IOPS Measurement Plot – 2D

### 7.3.6.3 IOPS Measurement Plot – 3D

The Test Operator shall include a plot showing an IOPS 3D Plot as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 7-5: IOPS Measurement Plot – 3D

## 8 Throughput Test

### 8.1 Throughput Descriptive Note

---

#### General Purpose:

Client Throughput test is intended to measure the test SSD Throughput (TP) in large block (1024KiB) Sequential Read/Write (100/0, 0/100) during Steady State. This Client TP test is intended to present the test SSD data transfer rate in MB/s at 100% R and 100% W in 1024KiB blocks. The intent of the TP test is to determine how fast the test SSD can transfer Sequential data without limitation from the IO Bus.

#### Test Flow:

The Client TP test makes use of:

- 1) a limited preconditioning LBA range (section 2.1);
- 2) a two step Workload Independent PC (section 2.1.18.1) consisting of
  - a) 128KiB SEQ W for 2X (twice) the user capacity; and
  - b) application of the TP stimulus (1024KiB) over the PC LBA ActiveRange (100% or 75%) until Steady State, as defined, is achieved;
- 3) a one step Workload Dependent PC (WDPC) (section 2.1.18.2) consisting of the TP stimulus using the ActiveRange Amount (8GiB or 16GiB) within the ActiveRange until Steady State, as defined, is achieved.

#### Test Results:

The test results captured during steady state measurement window shall be tabulated and plotted as specified in section 8.

#### Test Interpretation:

A higher value (greater MB/s) is better.

---

### 8.2 Throughput Pseudo Code

For (ActiveRange=(0:100) and ActiveRange= (0:75)

For (ActiveRange Amount=8GiB and ActiveRange Amount=16GiB)

1. Purge the device. (Note: ActiveRange Amount and other Test Parameters are not applicable to Purge step; any values can be used and none need to be reported.)
2. Workload Independent Preconditioning
  - 2.1. Set and record parameters for later reporting.
    - 2.1.1. Volatile Write cache: disabled
    - 2.1.2. Thread Count: Test Operator Choice
    - 2.1.3. OIO/Thread: Test Operator Choice
    - 2.1.4. Data Pattern: Required = Random, Optional = Test Operator Choice
  - 2.2. Run SEQ Workload Independent Preconditioning - Write 2X User Capacity w/ 1024KiB SEQ writes to the entire ActiveRange without any LBA restrictions
3. Run Workload Dependent Preconditioning and Test Stimulus
  - 3.1. Set parameters and record for later reporting
    - 3.1.1. Volatile Write cache: disabled
    - 3.1.2. Thread Count: Same as in step 2.1 above.
    - 3.1.3. OIO/Thread: Same as in step 2.1 above.
    - 3.1.4. Data Pattern: Required = Random, Optional = Test Operator Choice
    - 3.1.5. ActiveRange Segmentation Configuration:
      - 3.1.5.1. Number of ActiveRange Segments = 2048

- 3.1.5.2. ActiveRange Segment Size = ActiveRange Amount divided by 2048
  - 3.1.5.3. Distribution of ActiveRange Segments: randomly distributed within the entire ActiveRange. The ActiveRange Segments are not allowed to touch.
- 3.2. Run the following until Steady State is reached, or maximum of 25 Rounds
- 3.2.1. For (R/W Mix % = 100/0, 0/100)
    - 3.2.1.1. Execute **SEQ IO**, per (R/W Mix%) at 1024KiB Block Size, for 1 minute
    - 3.2.1.2. Record Ave MB/s (R/W Mix%)
    - 3.2.1.3. Use Ave MB/s(RW Mix%) to detect Steady State.
    - 3.2.1.4. If Steady State is not reached by Round x=25, then the Test Operator may either continue running the test until Steady State is reached, or may stop the test at Round x. The Measurement Window is defined as Round x-4 to Round x.
    - 3.2.1.5. Note that the sequential accesses shall be continuous and use the entire ActiveRange between test steps
  - 3.2.2. End (For R/W Mix%) Loop
4. Process and plot the accumulated Rounds data, per report guidelines in next section, based on current values of ActiveRange etc.

End (For ActiveRange Amount) loop

End (For ActiveRange) loop

### 8.3 Test Specific Reporting for Throughput Test

The following sub-sections list the reporting requirements specific to the Throughput test. Reporting requirements common to all tests are documented in Section 5, Common Reporting Requirements. See also Normative Annex A – Sample Test Report.

If Steady State was reached at Round x, the Test Operator shall:

- Plot Rounds 1:x per “Throughput Steady State Convergence Plot”;
- Plot Rounds (x-4):x per “Throughput Steady State Verification Plot”; and
- Plot Rounds (x-4):x per “Throughput Measurement Plot.”

If Steady State was not reached then the Test Operator may report results per above, picking the last Round run as Round x. **In the case where Steady State was not reached, the Test Operator must state this fact in the final report.**

#### 8.3.1 Purge Report

The Test Operator shall report the method used to run the Purge operation.

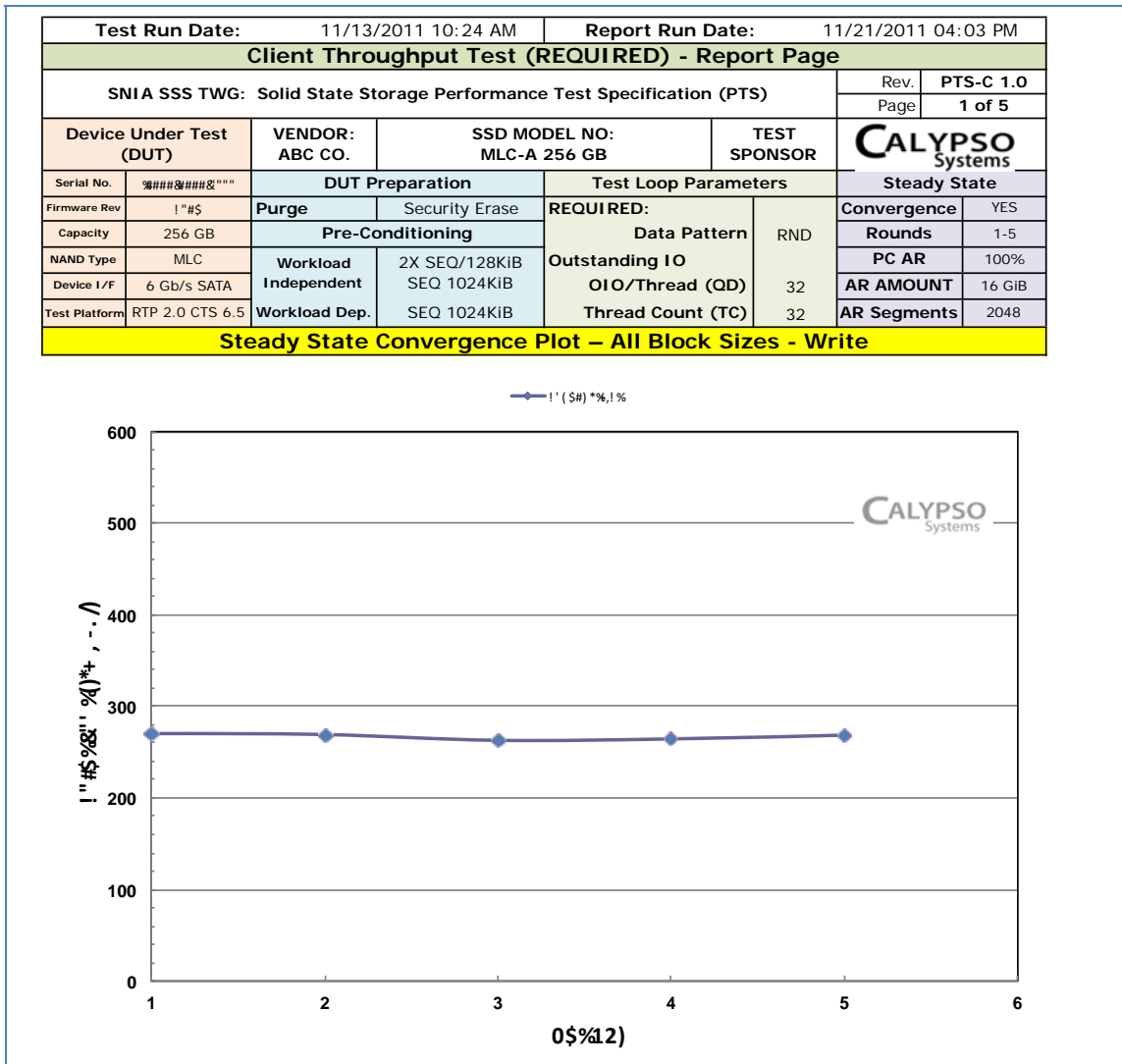
#### 8.3.2 Preconditioning Report

The Test Operator shall report both Workload Independent and Workload Dependent preconditioning information as shown in the Report Headers that follow.



### 8.3.3 Steady State Convergence Report Write

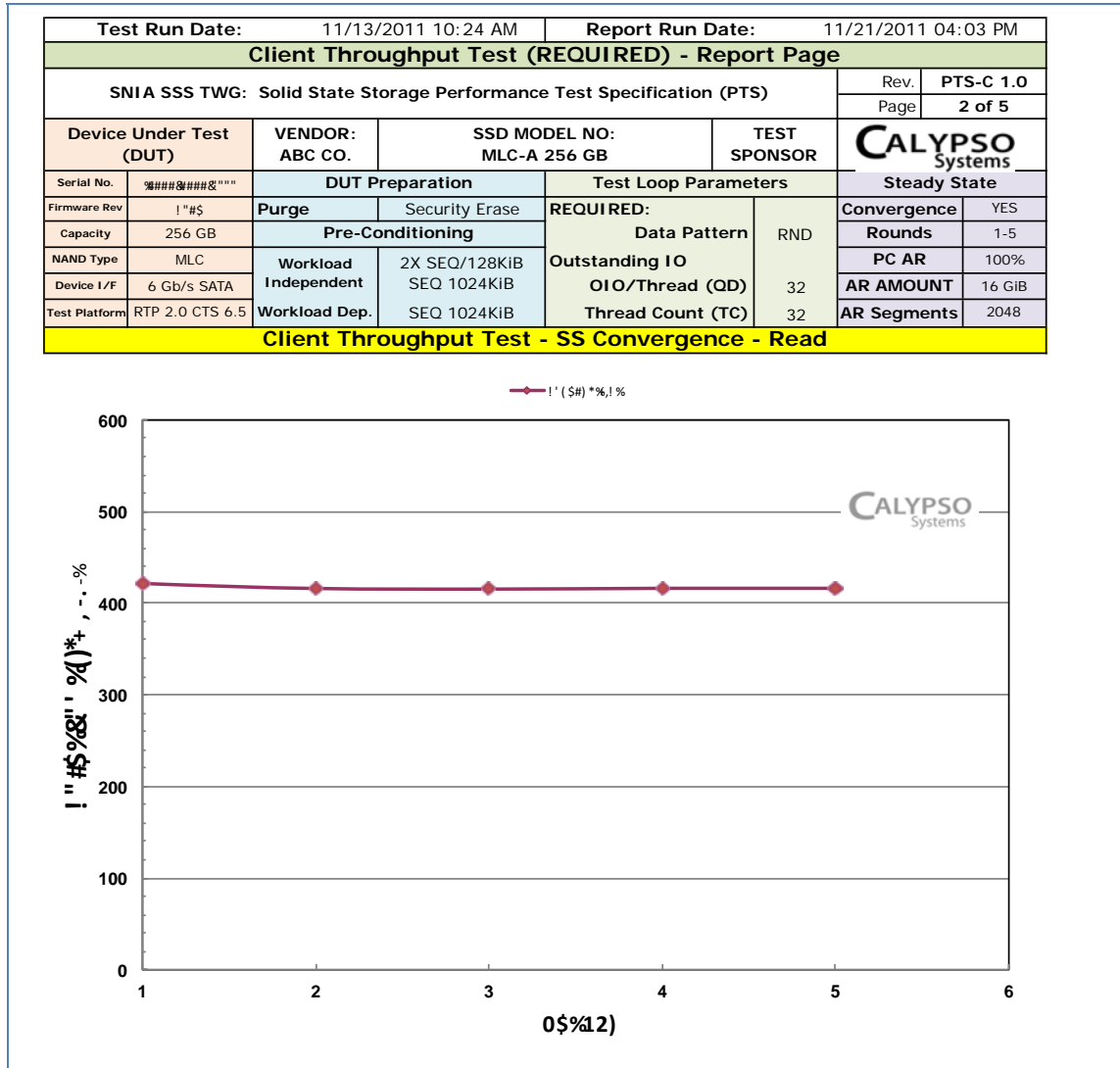
The Test Operator shall generate a Steady State Convergence Report WRITE as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 8-1: TP SS Convergence Report WRITE

### 8.3.4 Steady State Convergence Report - Read

The Test Operator shall include a plot showing the Steady State Convergence Report Read as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 8-2: TP SS Convergence Report Read

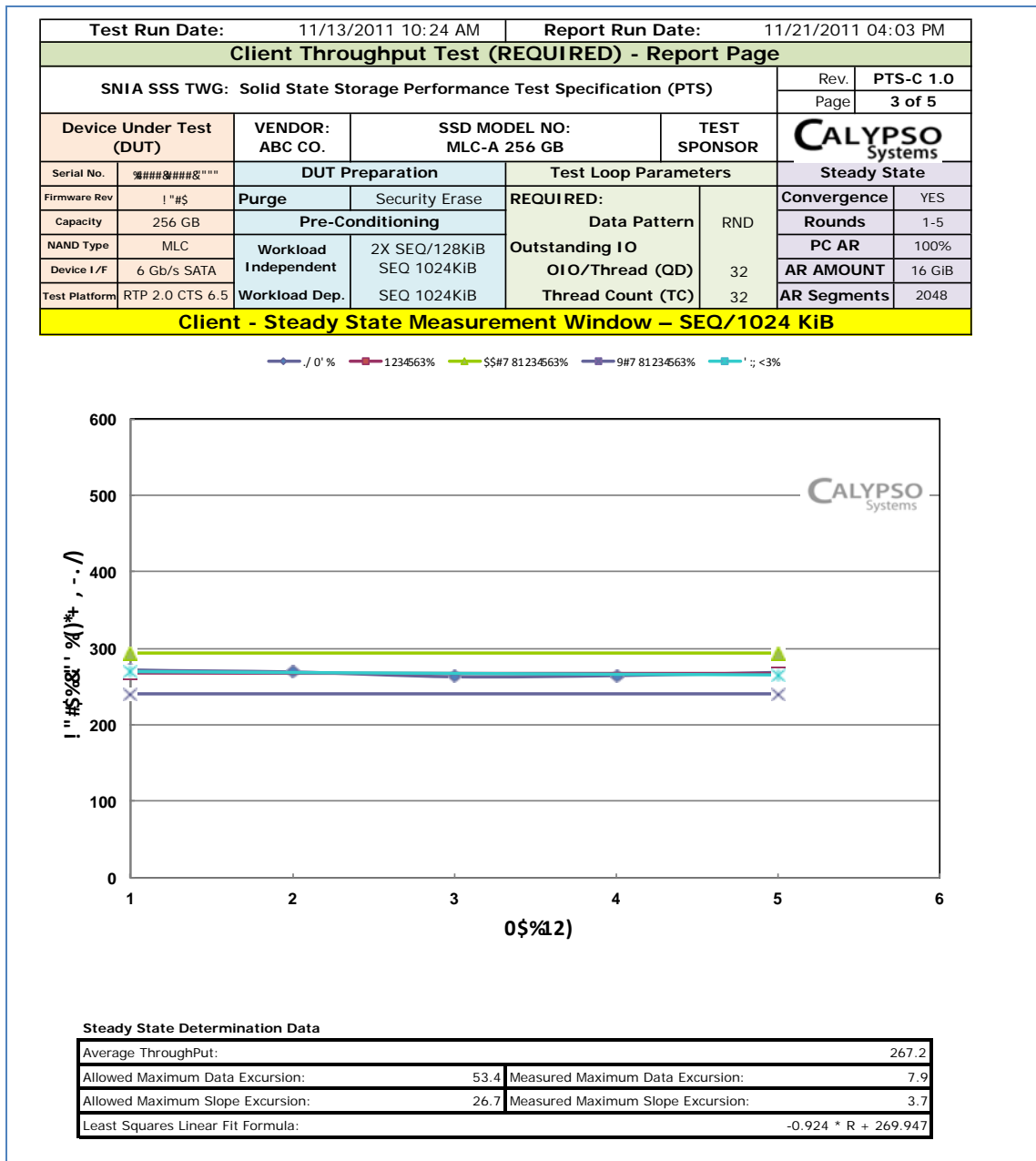
### 8.3.5 Steady State Verification Report

The Test Operator shall document the following for Steady State Verification, using Ave 1024KiB Sequential Write MB/s as the dependent variable:

- Measurement Window: Start \_\_; End \_\_
- Ave. value in Measurement Window: \_\_
- Calculated allowed range in Measurement Window (+-10% of Ave.): Max \_\_; Min \_\_
- Measured range in Measurement Window: Max \_\_; Min \_\_ (pass/fail)
- Slope of best linear fit in Measurement Window (must be <= 10%): \_\_% (pass/fail)
- Correlation coefficient for best linear fit: \_\_

### 8.3.6 Steady State Measurement Window

The Test Operator shall include a plot showing the Steady State Measurement Window. as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 8-3: TP SS Measurement Window

### 8.3.7 Measurement Window Report

The results for the test must be reported in the following series of tables and graphs which record and report the data from the Steady State Measurement Window.

#### 8.3.7.1 TP Measurement Window Tabular Data

The Test Operator shall include a plot showing a Throughput Tabular Data as follows including the test set up and parameters set forth in the Report Header (see Annex A).

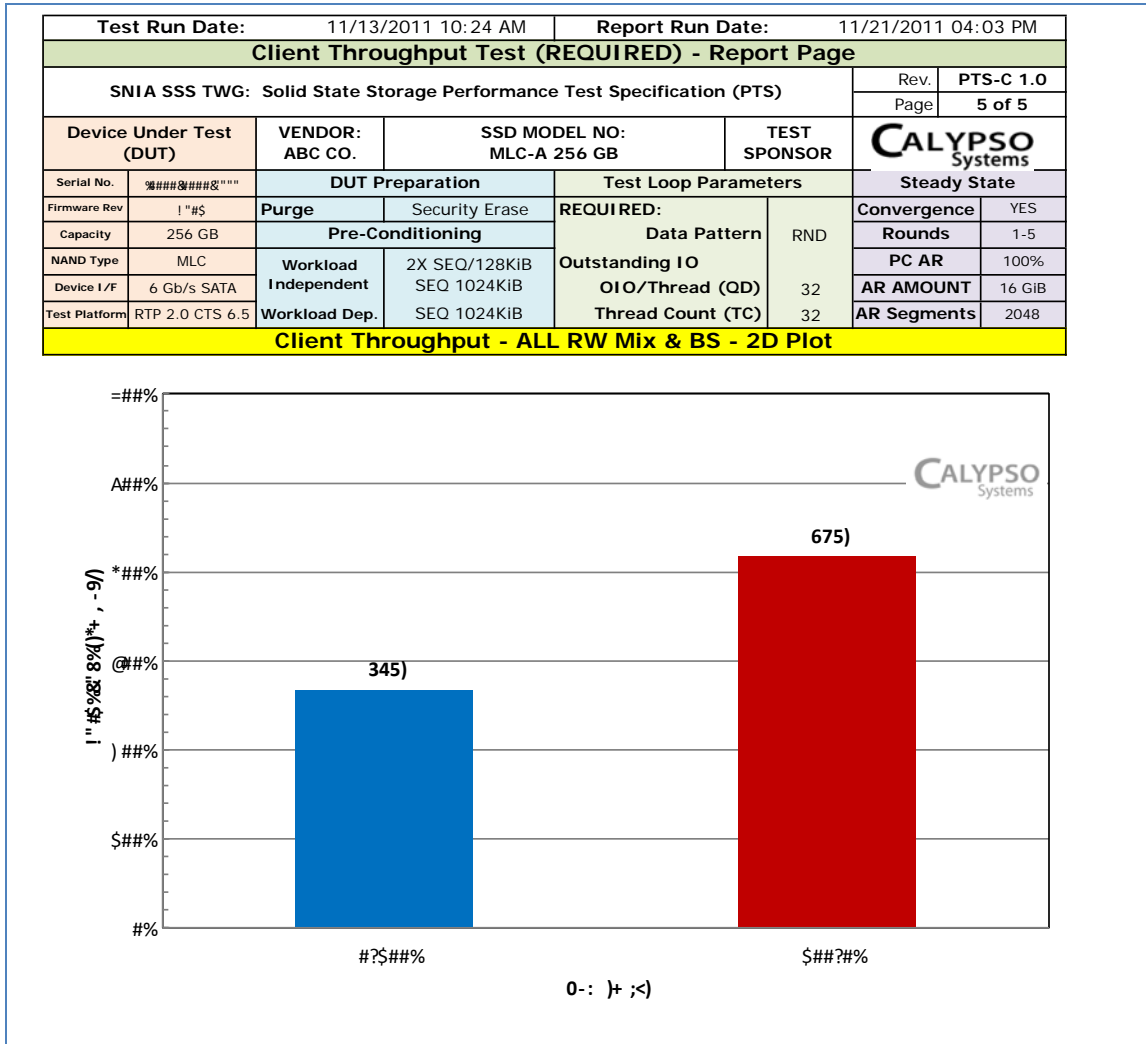
Test Run Date:		11/13/2011 10:24 AM		Report Run Date:		11/21/2011 04:03 PM	
<b>Client Throughput Test (REQUIRED) - Report Page</b>							
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)						Rev.	PTS-C 1.0
						Page	4 of 5
Device Under Test (DUT)		VENDOR:	SSD MODEL NO:		TEST SPONSOR	<b>CALYPSO</b> Systems	
		ABC CO.	MLC-A 256 GB				
Serial No.	#####	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	! "#\$	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	256 GB	Pre-Conditioning		Data Pattern	RND	Rounds	1-5
NAND Type	MLC	Workload	2X SEQ/128KIB	Outstanding IO		PC AR	100%
Device I/F	6 Gb/s SATA	Independent	SEQ 1024KIB	OIO/Thread (OD)	32	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	SEQ 1024KIB	Thread Count (TC)	32	AR Segments	2048
<b>Client Throughput - ALL RW Mix &amp; BS – Tabular Data</b>							
		Block Size (KiB)	Read / Write Mix %				
			0/100	100/0			
		1024	267.2	416.9			

**Plot 8-4: TP Measurement Window Tabular Data**

Each entry in the table is the average of the values in the five Rounds comprising the Steady State Measurement Window, for the selected (R/W Mix%, Block Size) element.

### 8.3.7.2 TP Measurement Plot – 2D

The Test Operator shall include a plot showing a Throughput 2D Plot as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 8-5: TP Measurement Plot – 2D

## 9 Latency Test

### 9.1 Latency Descriptive Note

---

#### General Purpose:

Client Latency test is intended to measure the test SSD response time at 3 Block Sizes (8KiB, 4KiB and 0.5KiB) and 3 Read/Write mixes (100/0, 65/35, 0/100) using a limited preconditioning and limited Test ActiveRange Amount. This Latency test is intended to observe how well the test SSD handles a single OIO without the benefit of queueing.

This Client Latency test is intended to present Average and Maximum Response Times (Latency) at a total outstanding IO of 1 (one Thread at a single OIO/Thread (Queue Depth)). The Latency measurement is inherently dependent on the treatment of the outstanding IOs by the host hardware and software test platform. An OIO of 1 is set to normalize the impact of the test system (as OIO >1 may be treated differently by different test hardware).

#### Test Flow:

The Client Latency test makes use of:

- 1) a limited preconditioning LBA range (section 2.1);
- 2) a two step Workload Independent PC (section 2.1.18.1) consisting of
  - a) 128KiB SEQ W for 2X (twice) user capacity; and
  - b) application of the Latency loop over ActiveRange (100% or 75%) until steady state, as defined, is achieved;
- 3) a one step Workload Dependent PC (WDPC) (section 2.1.18.2) consisting of the Latency loop using the ActiveRange Amount (8GiB or 16GiB) within the ActiveRange until Steady State, as defined, is achieved.

#### Test Results:

The test results captured during steady state measurement window shall be tabulated and plotted as specified in section 9.1.

#### Test Interpretation:

A lower value (lower msec) is better.

---

### 9.2 Latency Pseudo Code

For (ActiveRange=100% and ActiveRange= 75%)

For (ActiveRange Amount=8GiB and ActiveRange Amount=16GiB)

1. Purge the device. (Note: ActiveRange and other Test Parameters are not applicable to Purge step; any values can be used and none need to be reported.)
2. Workload Independent Preconditioning
  - 2.1. Run SEQ Workload Independent Preconditioning
    - 2.1.1. Set and record test conditions:
      - 2.1.1.1. Device volatile write cache = disabled
      - 2.1.1.2. OIO/Thread: 1
      - 2.1.1.3. Thread Count: 1
      - 2.1.1.4. Data Pattern: Required = Random, Optional = Test Operator Choice
    - 2.1.2. Run SEQ Workload Independent Preconditioning - Write 2X User Capacity w/ 128KiB sequential writes, writing to the entire ActiveRange without other LBA restrictions.
  - 2.2. Run RND WIPC –
    - 2.2.1. Set and record test parameters:

- 2.2.1.1. Device volatile write cache = disabled
  - 2.2.1.2. Thread Count: 1
  - 2.2.1.3. OIO/Thread: 1
  - 2.2.1.4. Data Pattern: Required = Random, Optional = Test Operator Choice
  - 2.2.2. For (R/W% = 100/0, 65/35, 0/100)
    - 2.2.2.1. For (Block Size = 8KiB, 4KiB, 0.5KiB)
      - 2.2.2.1.1. Execute random IO per (R/W%, Block Size), for 1 minute
      - 2.2.2.1.2. Record Max and Ave Latency (R/W%, Block Size)
      - 2.2.2.1.3. Use Ave Latency (R/W Mix%=0/100, Block Size=4KiB) to detect Steady State.
      - 2.2.2.1.4. If Steady State is not reached by Round x=25, then the Test Operator may either continue running the test until Steady State is reached, or may stop the test at Round x. The Measurement Window to determine WIPC termination is defined as Round x-4 to Round x
    - 2.2.2.2. End (For Block Size) Loop
  - 2.2.3. End (For R/W%) Loop
3. Run Workload Dependent Preconditioning and Test stimulus
- 3.1. Set test parameters and record for later reporting.
    - 3.1.1. Device volatile write cache = disabled
    - 3.1.2. OIO/Thread: 1
    - 3.1.3. Thread Count: 1.
    - 3.1.4. Data Pattern: Required = Random, Optional = Test Operator Choice
    - 3.1.5. Active Range Segmentation Configuration:
      - 3.1.5.1. Number of ActiveRange Segments = 2048
      - 3.1.5.2. ActiveRange Segment Size = ActiveRange Amount divided by 2048
      - 3.1.5.3. Distribution of ActiveRange Segments: randomly distributed within the entire ActiveRange. The ActiveRange Segments are not allowed to touch.
  - 3.2. Run the following test loop until Steady State is reached, or maximum of 25 Rounds:
    - 3.2.1. For (R/W Mix % = 100/0, 65/35, 0/100)
      - 3.2.1.1. For (Block Size = 0.5 KiB, 4KiB, 8KiB)
        - 3.2.1.1.1. Execute **RND IO**, per (R/W Mix %, Block Size), for 1 minute
        - 3.2.1.1.2. Record Max and Ave Latency (R/W Mix%, Block Size)
        - 3.2.1.1.3. Use AVE Latency(R/W Mix% = 0/100, Block Size = 4KiB) to detect Steady State.
        - 3.2.1.1.4. If Steady State is not reached by Round x=25, then the Test Operator may either continue running the test until Steady State is reached, or may stop the test at Round x. The Measurement Window is defined as Round x-4 to Round x.
      - 3.2.1.2. End (For Block Size) Loop
    - 3.2.2. End (For R/W Mix %) Loop
- End (For ActiveRange Amount) Loop

End (For ActiveRange) Loop

- Process and plot the accumulated Rounds data, per report guidelines in next section, based on current values of ActiveRange etc.

### 9.3 Test Specific Reporting for Latency Test

The following sub-sections list the reporting requirements specific to the Latency test. Reporting requirements common to all tests are documented in Section 5, General Reporting Requirements.

#### 9.3.1 Purge

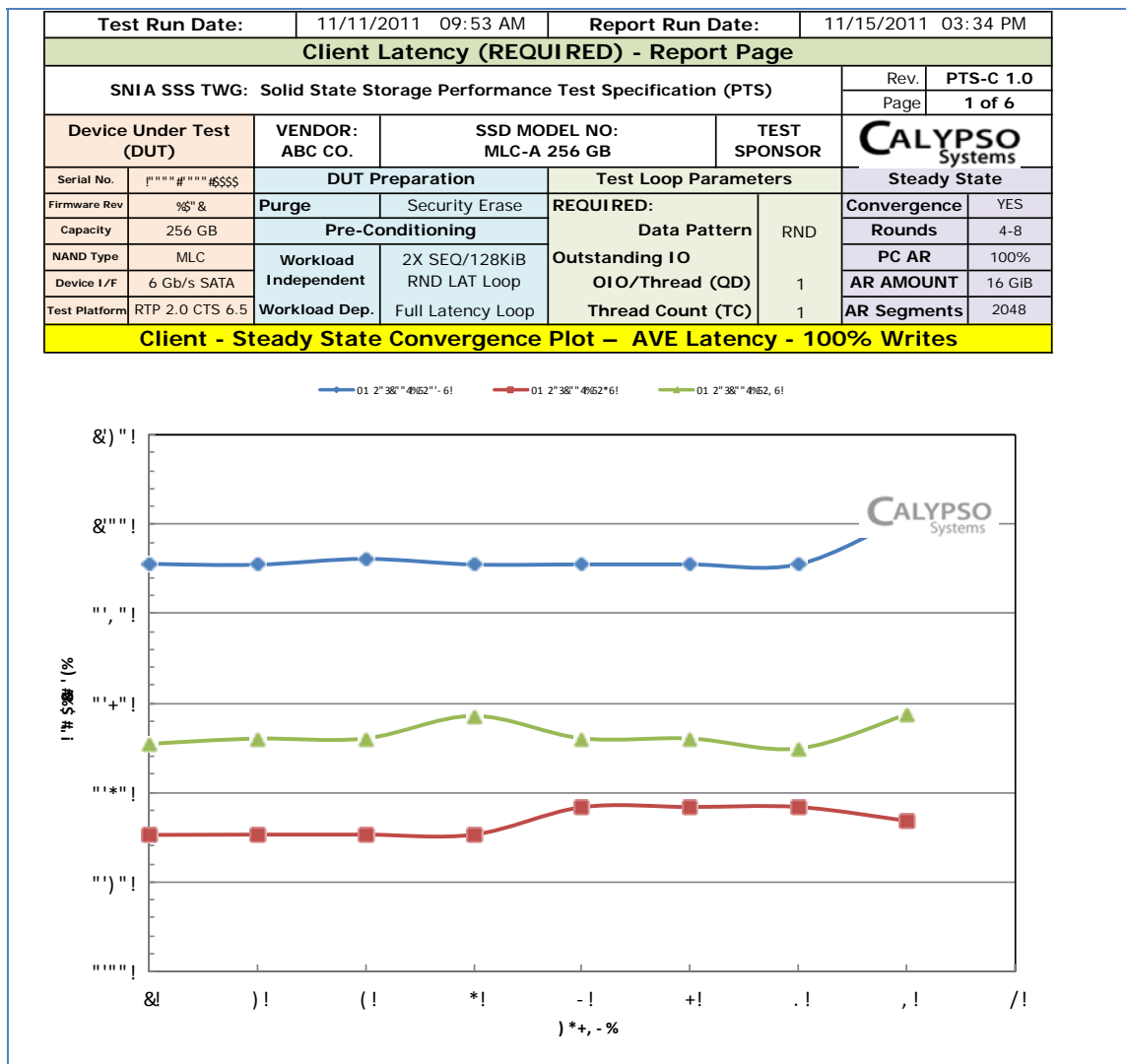
The Test Operator shall report the method used to run the Purge operation.

#### 9.3.2 Preconditioning Report

The Test Operator shall report both Workload Independent and Workload Dependent preconditioning information as shown in the Report Headers that follow.

#### 9.3.3 Steady State Convergence Report

The Test Operator shall generate a Steady State Convergence plot as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 9-1: LAT SS Convergence Report



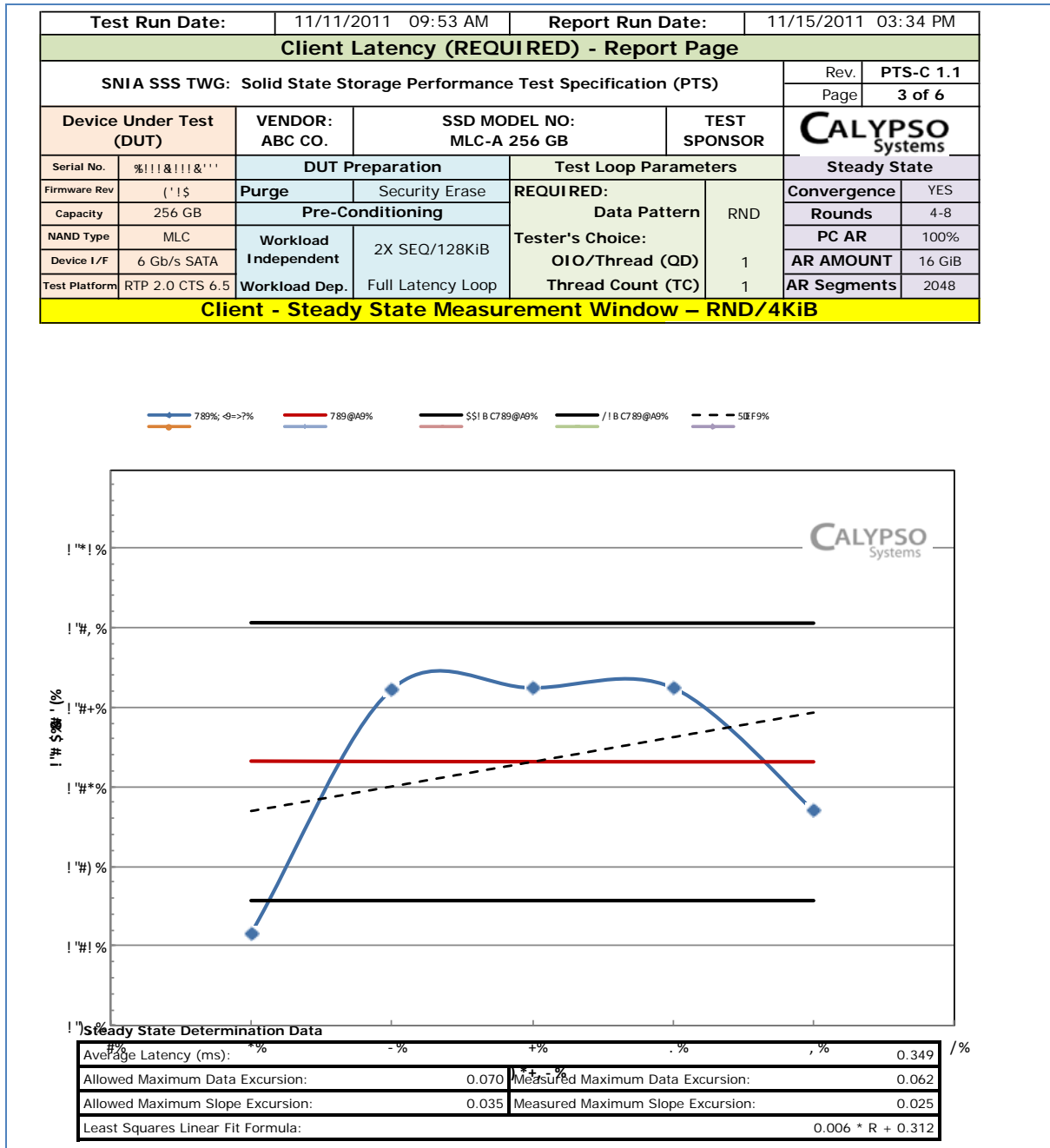
### 9.3.4 Steady State Verification Report

The Test Operator shall document the following for Steady State Verification, using *Ave 4KiB Random Write Latency (ms)* as the dependent variable:

- Measurement Window: Start \_\_; End \_\_
- Ave. value in Measurement Window: \_\_
- Calculated allowed range in Measurement Window (+-10% of Ave.): Max \_\_; Min \_\_
- Measured range in Measurement Window: Max \_\_; Min \_\_ (pass/fail)
- Slope of best linear fit in Measurement Window (must be  $\leq 10\%$ ): \_\_% (pass/fail)
- Correlation coefficient for best linear fit: \_\_

### 9.3.5 Steady State Measurement Window

The Test Operator shall include a plot showing the Steady State Measurement Window, as follows including the test set up and parameters set forth in the Report Header (see Annex A):



Plot 9-2: LAT SS Measurement Window

### 9.3.6 Measurement Window Report

The results for the test must be reported in the following series of tables and graphs which record and report the data from the Steady State Measurement Window.

#### 9.3.6.1 LAT Measurement Window Tabular Data

The Test Operator shall include a plot showing a Latency Tabular Data as follows including the test set up and parameters set forth in the Report Header (see Annex A).

Test Run Date:		11/11/2011 09:53 AM		Report Run Date:		11/15/2011 03:34 PM	
<b>Client Latency (REQUIRED) - Report Page</b>							
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)						Rev.	PTS-C 1.0
						Page	4 of 6
Device Under Test (DUT)		VENDOR:	SSD MODEL NO:		TEST SPONSOR	<b>CALYPSO</b> Systems	
		ABC CO.	MLC-A 256 GB				
Serial No.		DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	%* &	Purge	Security Erase	REQUIRED:	RND	Convergence	YES
Capacity	256 GB	Pre-Conditioning		Data Pattern		Rounds	4-8
NAND Type	MLC	Workload Independent	2X SEQ/128KiB RND LAT Loop	Outstanding IO OIO/Thread (OD)	1	PC AR	100%
Device I/F	6 Gb/s SATA	Workload Dep.	Full Latency Loop	Thread Count (TC)	1	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5					AR Segments	2048
<b>Client - AVE and MAX Response Time - ALL RW Mix &amp; BS – Tabular Data</b>							

Average Latency (ms)			
Read / Write Mix %			
Block Size (KiB)	0/100	65/35	100/0
0.5	0.932	0.449	0.196
4	0.349	0.332	0.203
8	0.537	0.432	0.240

Maximum Latency (ms)			
Read / Write Mix %			
Block Size (KiB)	0/100	65/35	100/0
0.5	52.1	50.2	1.0
4	51.0	50.0	1.6
8	52.8	53.3	39.5

**Plot 9-3: LAT Measurement Window Tabular Data**

Each entry in the Average table is the average values in the five Rounds comprising the Average Latency Steady State Measurement Window, for the selected (R/W Mix%, Block Size) element.

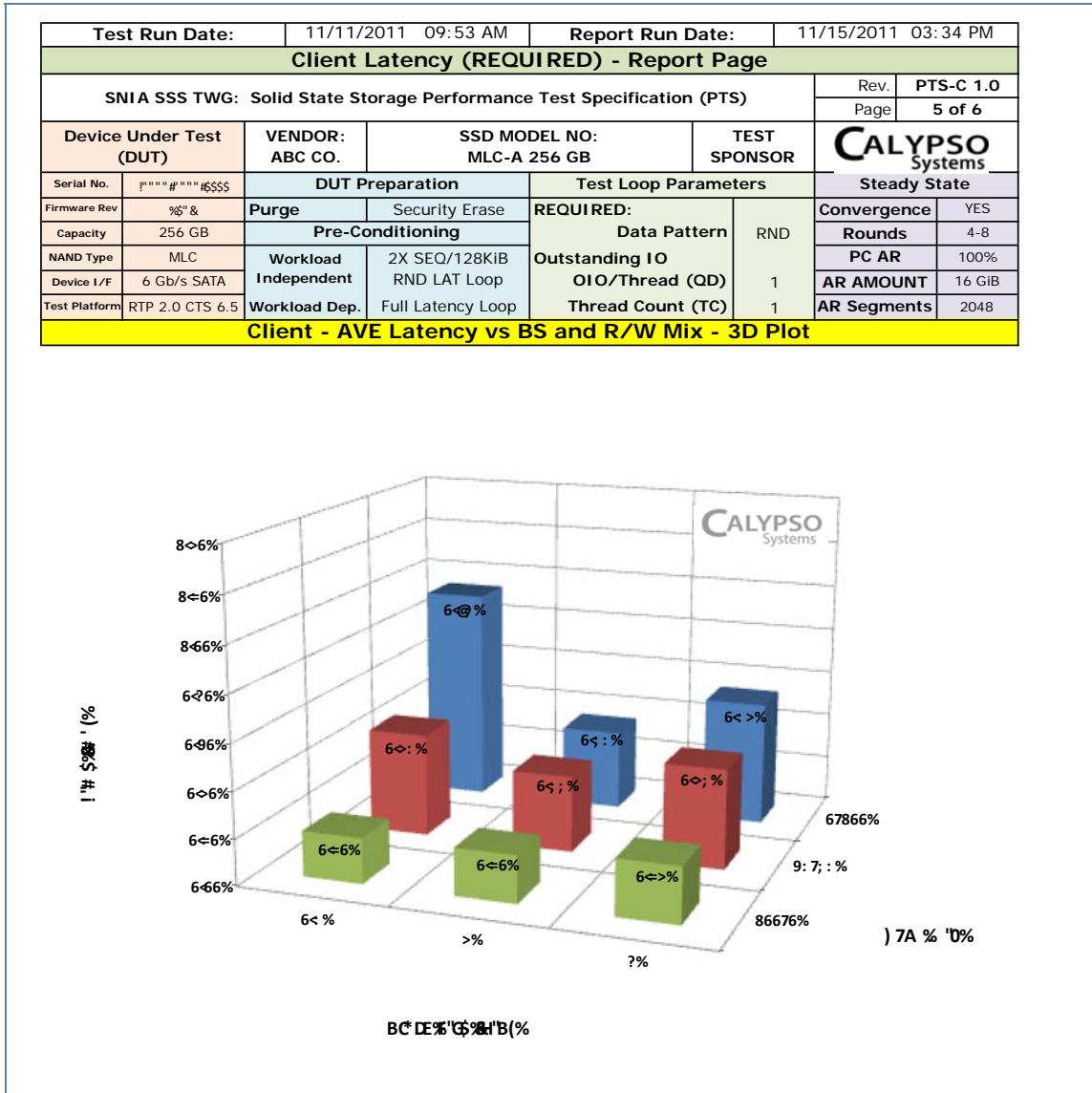
Each entry in the Maximum table is the maximum value in the five Rounds comprising the Maximum Latency Steady State Measurement Window, for the selected (R/W Mix%, Block Size) element.

- 

### 9.3.6.2 LAT Measurement Window Plots

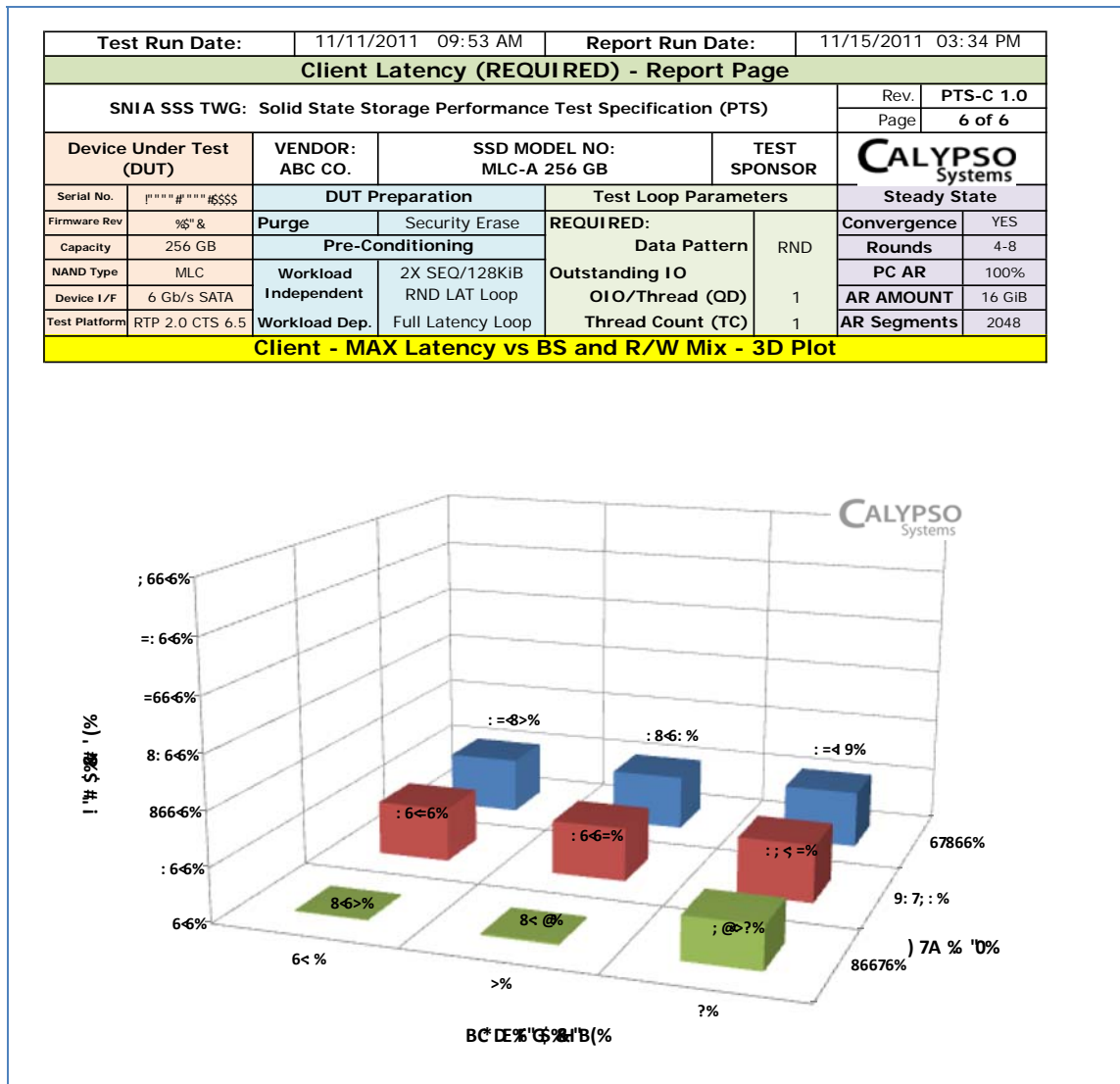
The Test Operator shall include a plot showing a Latency 3D Plot for Average and Maximum Latency as follows including the test set up and parameters set forth in the Report Header (see Annex A):

### 9.3.6.3 Average Latency - 3D Plot



Plot 9-4: AVE LAT – 3D Plot

### 9.3.6.4 Maximum Latency - 3D Plot



Plot 9-5: MAX LAT - 3D Plot

## 10 Write Saturation Test - Optional

### 10.1 WSAT Descriptive Note

---

#### General Description:

Client WSAT test is intended to measure the test SSD IOPS at a 4KiB Block Size at 100% Write Read/Write mix using a limited preconditioning and limited Test ActiveRange Amount. This Client WSAT test is intended to emulate characteristics of Client workloads that are limited in the ways in which the LBAs are accessed compared to Enterprise workloads.

#### Test Flow:

The Client WSAT test makes use of:

- 1) a limited preconditioning LBA range (section 2.1);
- 2) a one step Workload Dependent PC (WDPC) (section 2.1.18.2) consisting of RND 4KiB 100% Writes using the ActiveRange Amount (8GiB or 16GiB) within the ActiveRange until specified termination conditions are met (4X, or four times, the user capacity or 24 hours, whichever occurs first).

#### Test Results:

The test results captured during the WSAT test shall be tabulated and plotted as specified in section 10 and are intended to present the IOPS performance over Time and Total Gigabytes Written.

#### Test Interpretation:

The test operator is encouraged to observe the initial peak IOPS values, the shape and length of the Transition Zones, and the level of IOPS at the “WSAT Steady State.” Less drop off from peak FOB IOPS and a more level WSAT Steady State (see definitions) with a smaller amplitude variation is better.

---

### 10.2 WSAT Pseudo Code

For (ActiveRange(0:75), optional ActiveRange(Test Operator Choice))

For (ActiveRange Amount=8GiB and ActiveRange Amount=16GiB)

- 1 Purge the device. (Note: Active Range and other Test Parameters are not applicable to Purge step; any values can be used and none need to be reported.)
- 2 Run Test stimulus. Set test parameters and record for later reporting
  - 2.1 Set and record test conditions:
    - 2.1.1 Device volatile write cache = Disabled
    - 2.1.2 OIO/Thread: Test Operator Choice.
    - 2.1.3 Thread Count: Test Operator Choice.
    - 2.1.4 Data Pattern: Required= Random, Optional = Test Operator Choice.
    - 2.1.5 Active Range Segmentation Configuration:
      - 2.1.5.1 Number of ActiveRange Segments = 2048
      - 2.1.5.2 ActiveRange Segment Size = ActiveRange Amount divided by 2048
      - 2.1.5.3 Distribution of ActiveRange Segments: randomly distributed within the entire ActiveRange. The ActiveRange Segments are not allowed to touch.
  - 2.2 Run the following test stimulus until 4X User Capacity is written, or 24 hours, whichever occurs first.
    - 2.2.1 Execute **RND IO** (R/W Mix 100% W, Block Size 4KiB), for 1 minute
    - 2.2.2 Record Ave IOPS, Max and Ave Latency

2.3 Process and plot the accumulated Rounds data, per report guidelines in next section.

End "For ActiveRange Amount" loop

End "For ActiveRange" loop

After generating report data for current parameter values, the Test Operator may re-run "For ActiveRange" loop with alternate Test Parameters.

## **10.3 Test Specific Reporting for Write Saturation Test**

The following sub-sections list the reporting requirements specific to the Write Saturation test. Reporting requirements common to all tests are documented in Section 5, Common Reporting Requirements. See also Normative Annex A: Sample Test Report.

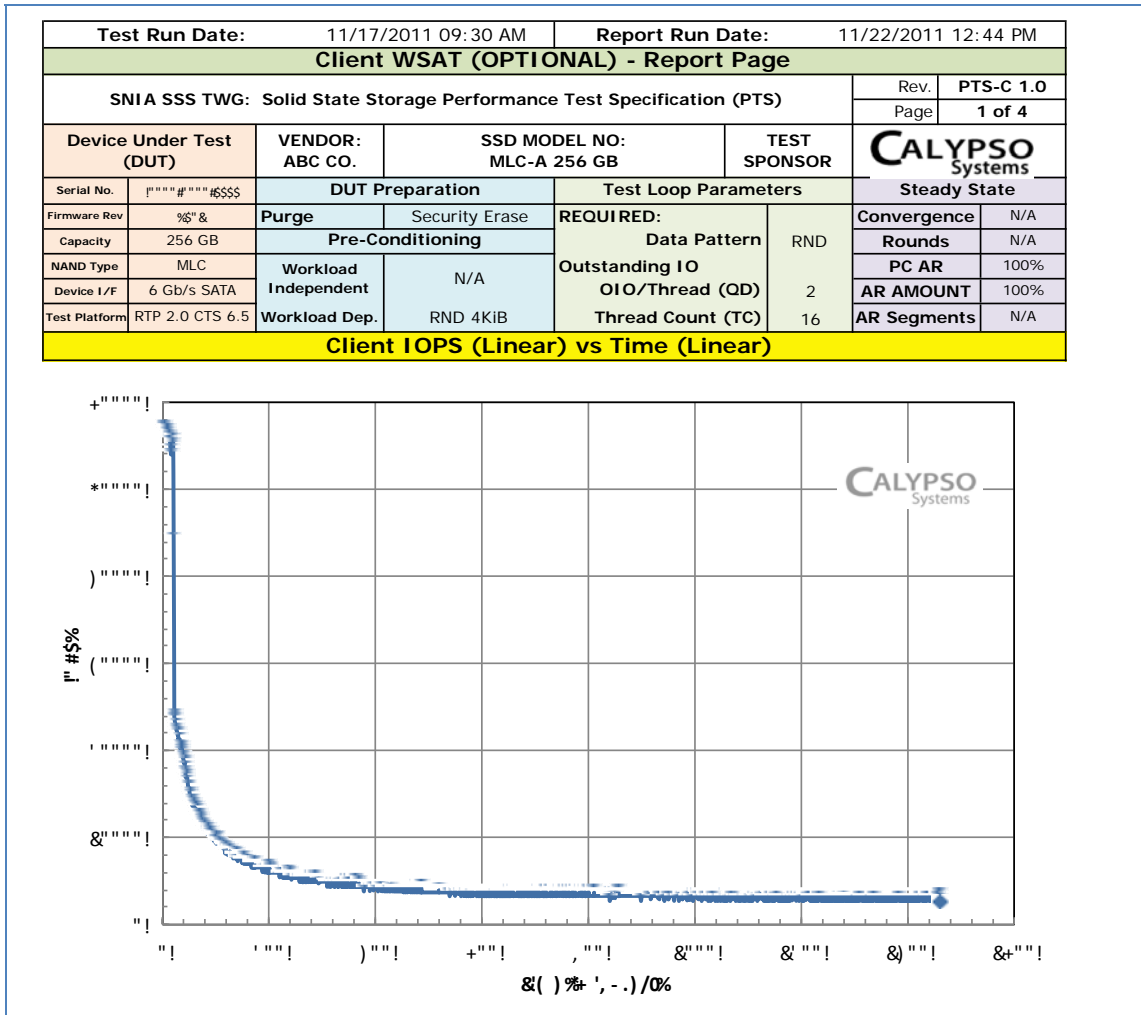
### **10.3.1 Purge Report**

The Test Operator shall report the method used to run the Purge operation.

### **10.3.2 Measurement Report**

The Test Operator shall generate Measurement Plots for WSAT plotting IOPS v Time and IOPS v TGBW and should follow the following format:

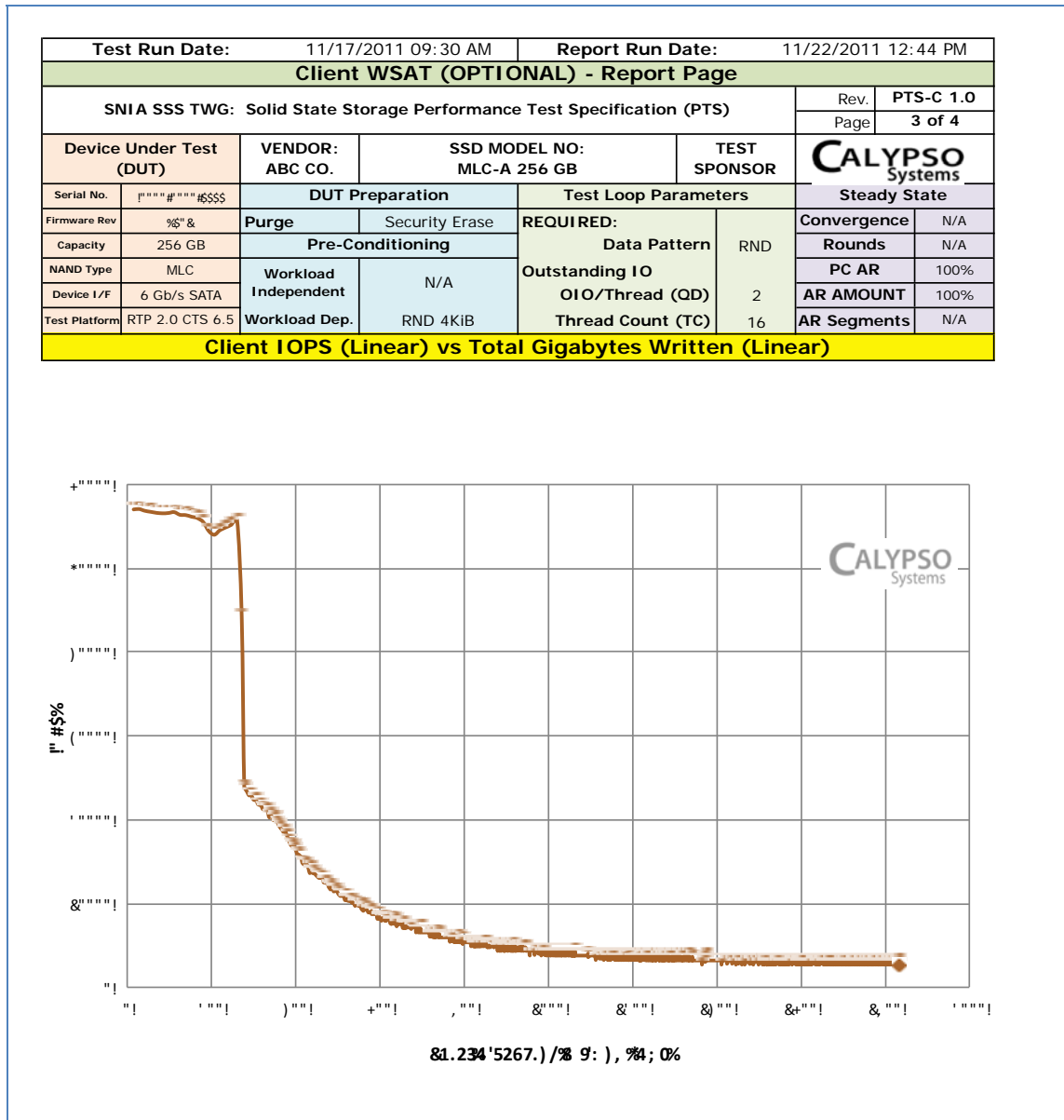
### 10.3.2.1 WSAT IOPS v Time



Plot 10-1: WSAT IOPS v Time



### 10.3.2.2 WSAT IOPS v TGBW



Plot 10-2: WSAT IOPS v TGBW


## **11 Normative Annex A – Sample Test Report**

The following is a sample PTS-C SNIA Test Report which includes Informative Summary Pages (Summary Page – All Tests and Summary Page – Individual Report (WSAT, IOPS, Throughput, Latency)) and Normative Individual Reports (Optional WSAT test and Required IOPS, Throughput and Latency test reports).

Informative Summary Pages contain information compiled for the convenience of the test sponsor. Normative Individual Report Pages contain mandatory Report Headers on each page that set forth required reporting information pertinent to the tests presented on the particular page(s).



# MLC-A Test Report Summary Report Page - WSAT

<b>SNIA Solid State Storage Performance Test Specification (PTS)</b>			Rev.	<b>PTS 1.0</b>			
			Page	<b>2 of 26</b>			
Device Under Test (DUT)	<b>MLC-A</b>	<b>SNIA SSS PTS Summary Report</b>	<b>Calypso Systems, Inc.</b>				
DEVICE INFORMATION		TEST HARDWARE PLATFORM	TEST SOFTWARE		REPORT DATE		
SERIAL NO.	0000-0000-FFFF	SYSTEM	Calypso RTP 2.0	SYS OS	CENT OS 5.6	Report	06DEC11
FIRMWARE REV.	BFO I	Motherboard/ cpu	Intel 5520HC / W5580	SW TOOL	Calypso CTS 6.5	Test Run	01NOV - 04DEC11
USER CAPACITY	MLC 256 GB	RAM	12GB ECC DDR3	SW Rev	1.19.10	Test Sponsor	Calypso
DEVICE INTERFACE	6 Gb/s SATAII	Device Interface	LSA 9212-e 6Gb/s HBA	Release	Nov. 2011	Auditor	N/A

### Test Description

<b>Purpose</b>	To observe the drive's performance evolution from a PURGED state to that of SETTLED state
<b>Test Outline</b>	Uses total outstanding IO settings that maximizes RND 4KiB Writes, first PURGE the drive, followed by immediate continuous RND 4KiB (4K-aligned) writes for lesser of 4 x User Capacity or 24 Hours
<b>Preconditioning</b>	!"#\$%&'()*@, -./:;, 0%1234\$ 6 7* - \$95*;/&' / #* ; / \$ ? 9\$*#@ \$, 0*)\$ )96 //, 0\$% ,)C

### Test Set Up

PTS-C	TEST	Purge	DP	OIO	WIPC		WDPC		STEADY STATE	
					PC AR	TEST AR	AR AMT	SEGMENTS	WORKLOAD	TIME/ GB
7.0	WSAT - OPTIONAL	Security Erase	RND	TC 1 QD 16	100%	100%	N/A	N/A	RND 4KIB W	24 Hrs 1.9 TB

### Select Performance Data

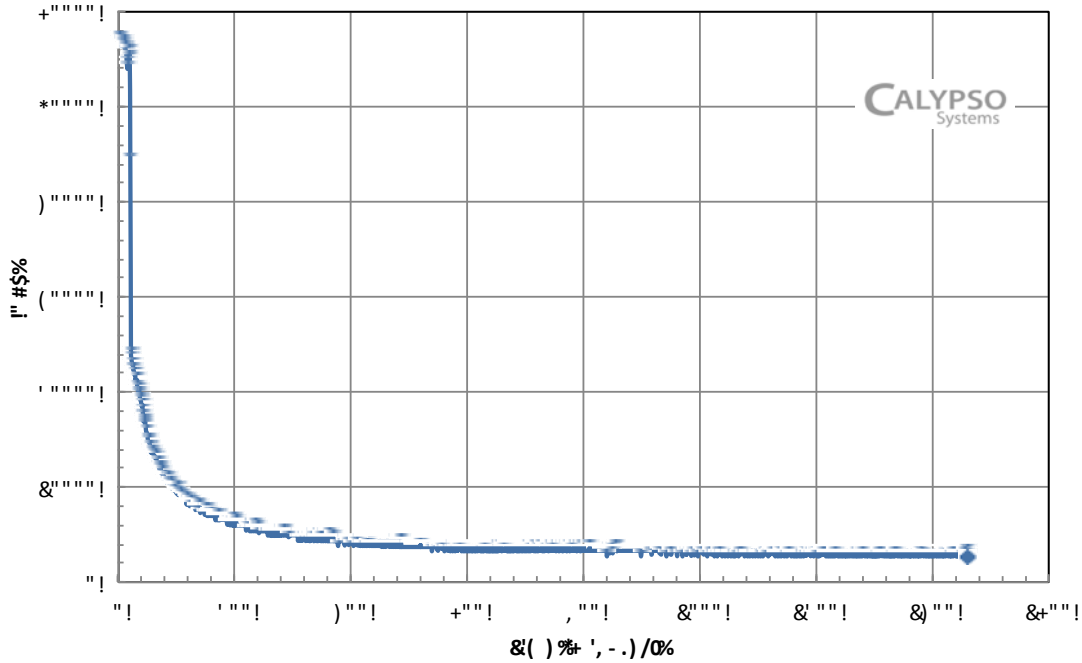
FOB IOPS	Steady State IOPS	Time	Total GB Written
56,896	2,714	20 Hours	18 TB

### Test Sponsor – Special Notes

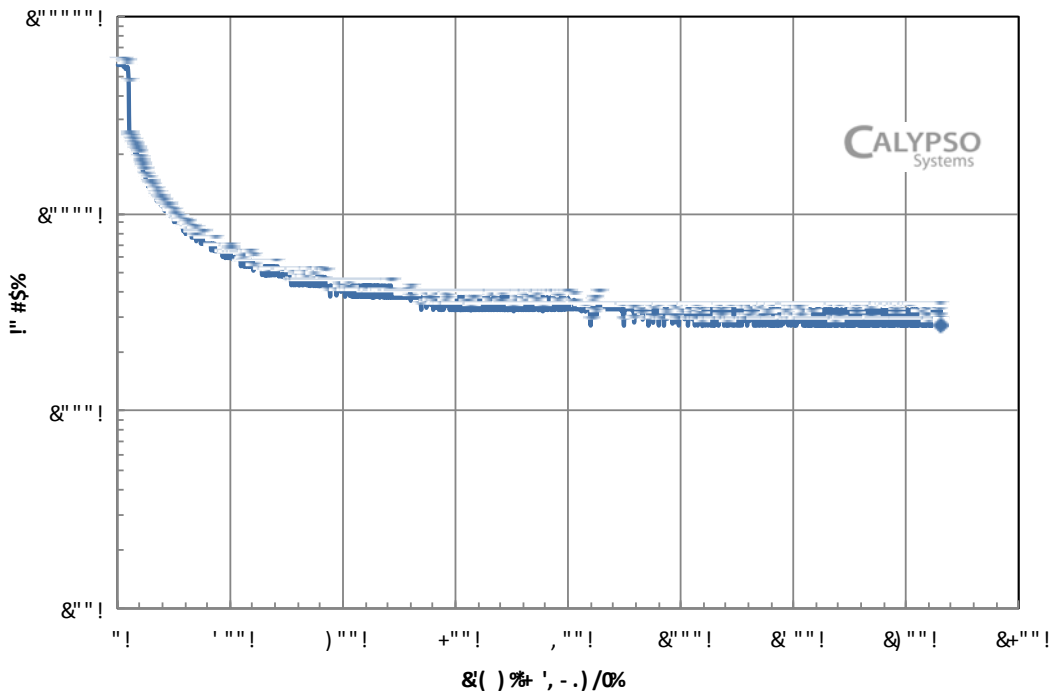
ITEM	NOTATION	COMMENTS

!  
!

<b>Test Run Date:</b> 11/17/2011 09:30 AM		<b>Report Run Date:</b> 11/22/2011 12:44 PM	
<b>Client WSAT (OPTIONAL) - Report Page</b>			
<b>SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)</b>			Rev. <b>PTS-C 1.0</b>
			Page <b>1 of 4</b>
<b>Device Under Test (DUT)</b>	<b>VENDOR:</b> ABC CO.	<b>SSD MODEL NO:</b> MLC-A 256 GB	<b>TEST SPONSOR</b> <b>CALYPSO Systems</b>
Serial No.	<b>DUT Preparation</b>		<b>Steady State</b>
Firmware Rev	<b>Purge</b>	Security Erase	<b>Convergence</b> N/A
Capacity	<b>Pre-Conditioning</b>		<b>Rounds</b> N/A
NAND Type	<b>Workload Independent</b>	N/A	<b>PC AR</b> 100%
Device I/F	<b>Workload Dep.</b>	RND 4KiB	<b>AR AMOUNT</b> 100%
Test Platform	RTP 2.0 CTS 6.5		<b>AR Segments</b> N/A
<b>Client IOPS (Linear) vs Time (Linear)</b>			

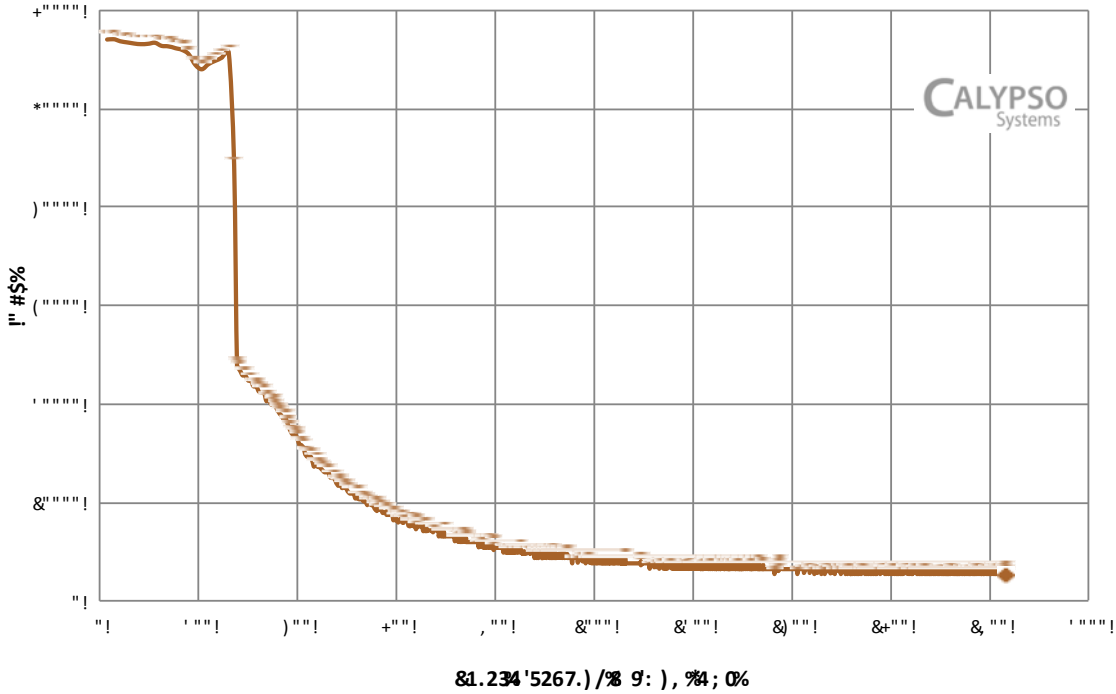



<b>Test Run Date:</b> 11/17/2011 09:30 AM		<b>Report Run Date:</b> 11/22/2011 12:44 PM	
<b>Client WSAT (OPTIONAL) - Report Page</b>			
<b>SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)</b>			Rev. <b>PTS-C 1.0</b>
			Page <b>2 of 4</b>
<b>Device Under Test (DUT)</b>	<b>VENDOR:</b> ABC CO.	<b>SSD MODEL NO:</b> MLC-A 256 GB	<b>TEST SPONSOR</b> <b>CALYPSO Systems</b>
Serial No.	<b>DUT Preparation</b>		<b>Steady State</b>
Firmware Rev	<b>Purge</b>	Security Erase	<b>Convergence</b> N/A
Capacity	<b>Pre-Conditioning</b>		<b>Rounds</b> N/A
NAND Type	<b>Workload Independent</b>	N/A	<b>PC AR</b> 100%
Device I/F	<b>Workload Dep.</b>	RND 4KiB	<b>AR AMOUNT</b> 100%
Test Platform	RTP 2.0 CTS 6.5		<b>AR Segments</b> N/A
<b>Client IOPS (Log10) vs Time (Linear)</b>			

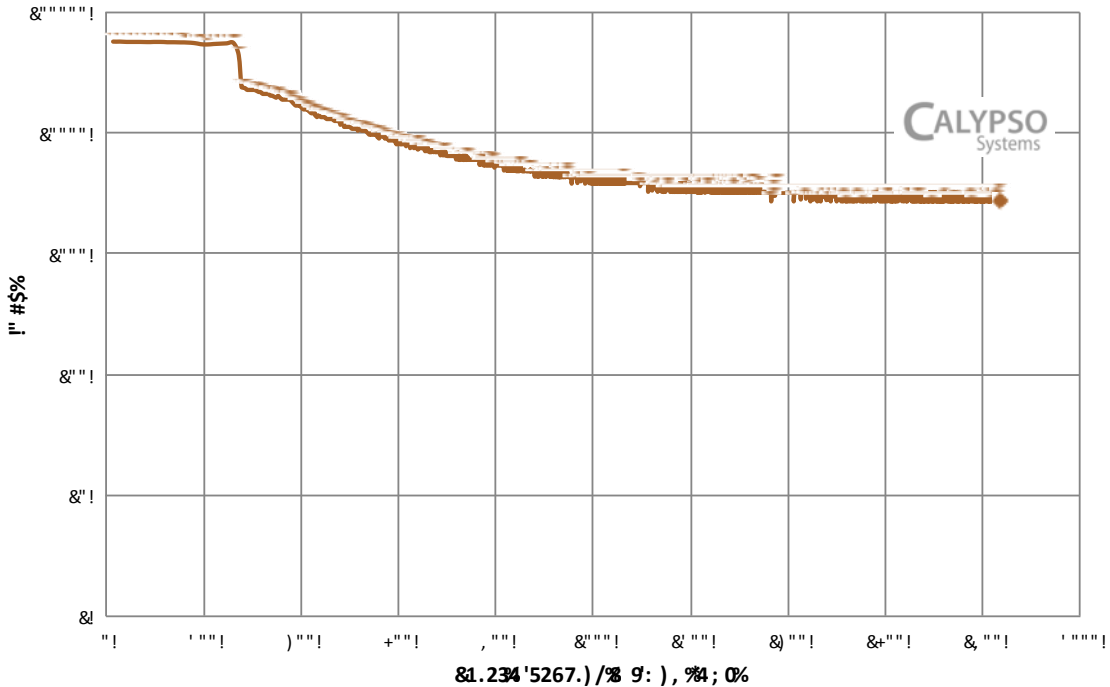


Test Run Date: 11/17/2011 09:30 AM		Report Run Date: 11/22/2011 12:44 PM	
<b>Client WSAT (OPTIONAL) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 3 of 4
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR
<b>CALYPSO Systems</b>			
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	Convergence
Capacity	Pre-Conditioning		Rounds
NAND Type	Workload Independent	N/A	PC AR
Device I/F	Workload Dep.	RND 4KiB	AR AMOUNT
Test Platform			AR Segments
		REQUIRED: Data Pattern RND	
		Outstanding IO	
		OIO/Thread (QD) 2	
		Thread Count (TC) 16	

**Client IOPS (Linear) vs Total Gigabytes Written (Linear)**



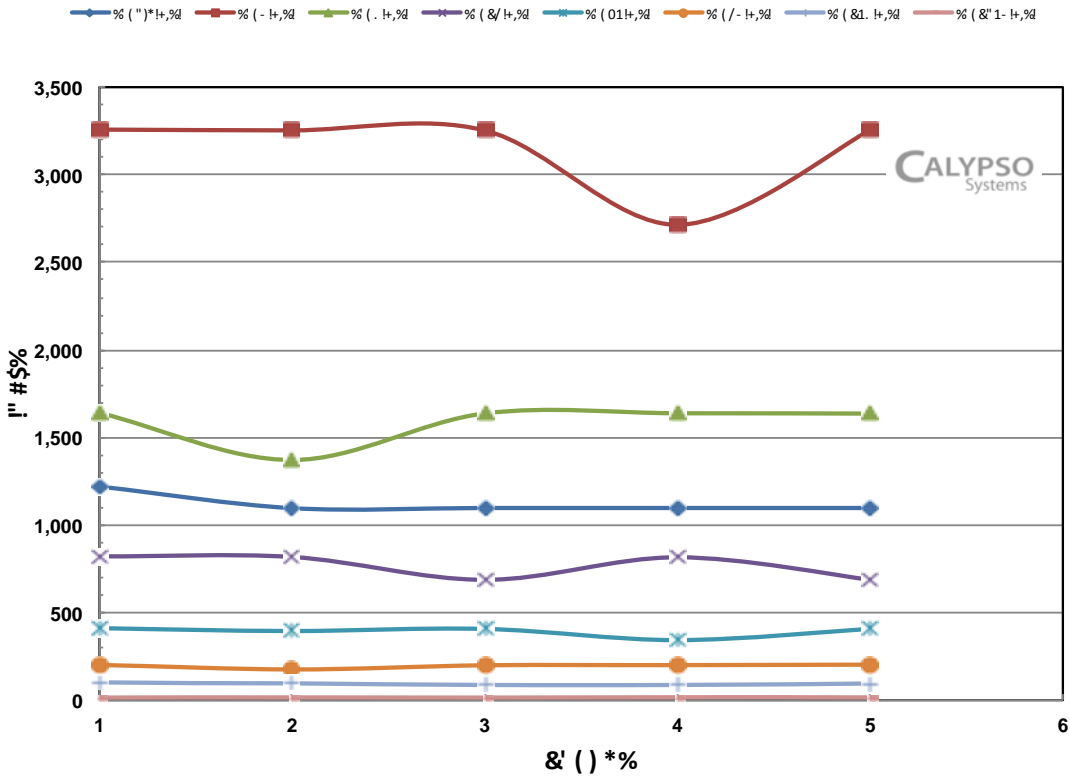
<b>Test Run Date:</b> 11/17/2011 09:30 AM		<b>Report Run Date:</b> 11/22/2011 12:44 PM	
<b>Client WSAT (OPTIONAL) - Report Page</b>			
<b>SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)</b>			Rev. <b>PTS-C 1.0</b>
			Page <b>4 of 4</b>
<b>Device Under Test (DUT)</b>	<b>VENDOR:</b> ABC CO.	<b>SSD MODEL NO:</b> MLC-A 256 GB	<b>TEST SPONSOR</b> 
<b>Serial No.</b>	<b>DUT Preparation</b>		<b>Test Loop Parameters</b>
<b>Firmware Rev</b>	<b>Purge</b>	Security Erase	<b>REQUIRED:</b>
<b>Capacity</b>	<b>Pre-Conditioning</b>		<b>Data Pattern</b> RND
<b>NAND Type</b>	<b>Workload Independent</b>	N/A	<b>Outstanding IO</b>
<b>Device I/F</b>			
<b>Test Platform</b>		RND 4KIB	<b>OIO/Thread (OD)</b> 2
			<b>Thread Count (TC)</b> 16
			<b>Steady State</b>
			<b>Convergence</b> N/A
			<b>Rounds</b> N/A
			<b>PC AR</b> 100%
			<b>AR AMOUNT</b> 100%
			<b>AR Segments</b> N/A
<b>Client IOPS (Log10) vs Total Gigabytes Written (Lin)</b>			



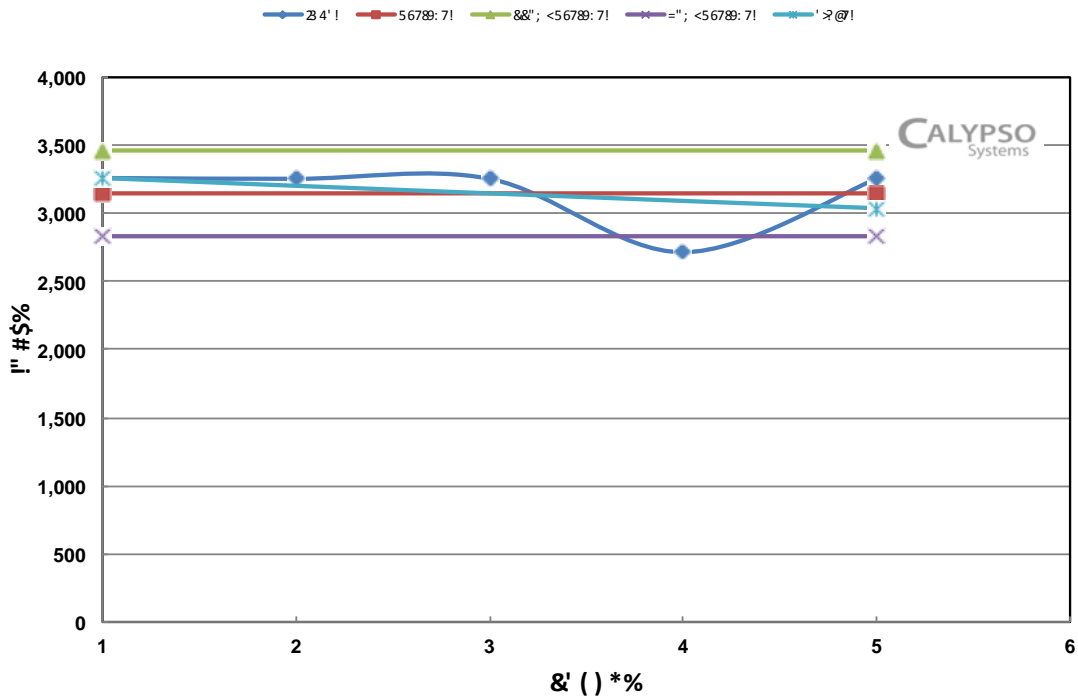




Test Run Date: 11/14/2011 12:39 AM		Report Run Date: 11/21/2011 04:12 PM	
<b>Client IOPS (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 1 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR
			<b>CALYPSO Systems</b>
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	Convergence YES
Capacity	Pre-Conditioning		Rounds 1-5
NAND Type	Workload Independent	2X SEQ/128KiB RND IOPS Loop	PC AR 100%
Device I/F	Workload Dep.	Full IOPS Loop	AR AMOUNT 16 GiB
Test Platform	RTP 2.0 CTS 6.5		AR Segments 2048
<b>Steady State Convergence Plot – All Block Sizes</b>			

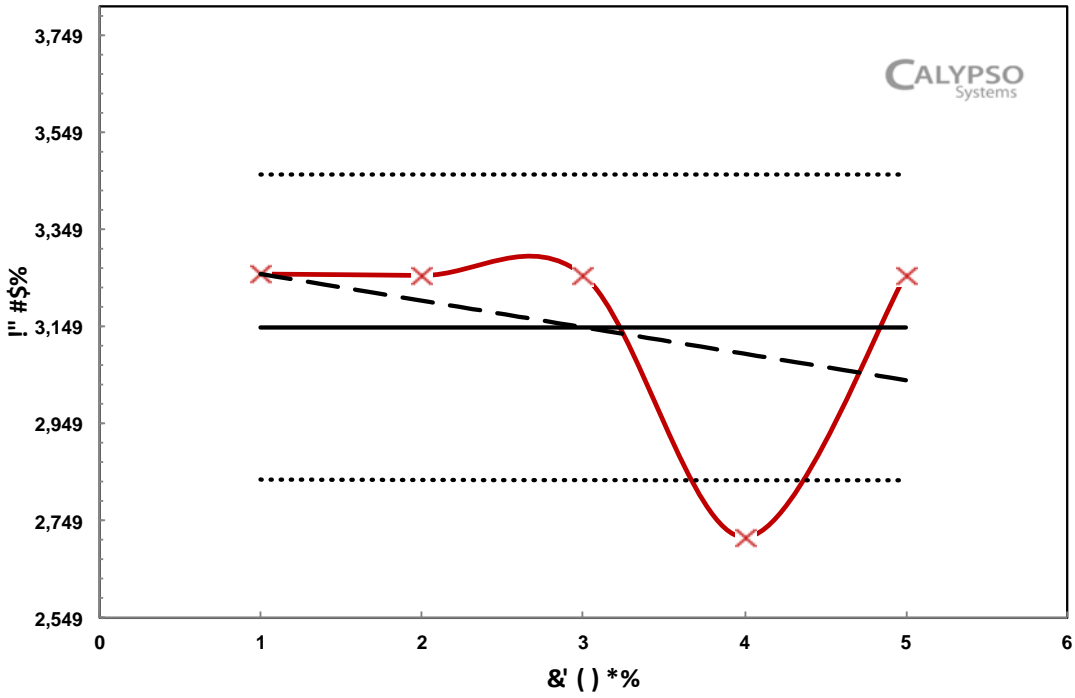


Test Run Date: 11/14/2011 12:39 AM		Report Run Date: 11/21/2011 04:12 PM	
<b>Client IOPS (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 2 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR
			<b>CALYPSO</b> Systems
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	REQUIRED:
Capacity	Pre-Conditioning		Data Pattern
NAND Type	Workload Independent	2X SEQ/128KiB RND IOPS Loop	RND
Device I/F	Workload Dep.	Full IOPS Loop	Outstanding IO
Test Platform			OIO/Thread (QD)
			Thread Count (TC)
			Convergence
			Rounds
			PC AR
			AR AMOUNT
			AR Segments
			YES
			1-5
			100%
			16 GiB
			2048
<b>Steady State Measurement Window</b>			




Test Run Date: 11/14/2011 12:39 AM		Report Run Date: 11/21/2011 04:12 PM	
<b>Client IOPS (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 3 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR: CALYPSO Systems
Serial No. #####	DUT Preparation		Steady State
Firmware Rev %&	Purge	Security Erase	REQUIRED: Convergence YES
Capacity 256 GB	Pre-Conditioning		Outstanding IO Data Pattern RND Rounds 1-5
NAND Type MLC	Workload Independent	2X SEQ/128KiB RND IOPS Loop	PC AR 100%
Device I/F 6 Gb/s SATA	Workload Dep.	Full IOPS Loop	AR AMOUNT 16 GiB
Test Platform RTP 2.0 CTS 6.5			AR Segments 2048
<b>Steady State Measurement Window – RND/4KiB</b>			

Legend: —●— 3147.0    — 3147.0    ..... 3147.0    ..... 3147.0    ..... 3147.0    —●— 3147.0



**Steady State Determination Data**

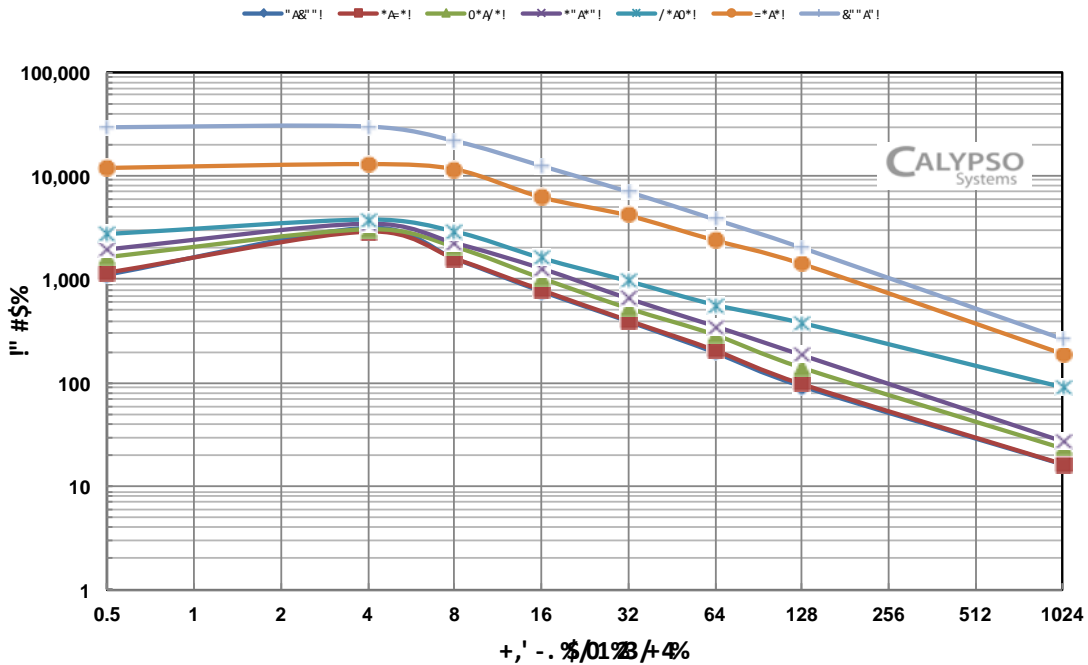
Average IOPS:	3147.0	
Allowed Maximum Data Excursion:	629.4	Measured Maximum Data Excursion: 542.4
Allowed Maximum Slope Excursion:	314.7	Measured Maximum Slope Excursion: 217.6
Least Squares Linear Fit Formula:	-54.407 * R + 3310.267	

<b>Test Run Date:</b> 11/14/2011 12:39 AM		<b>Report Run Date:</b> 11/21/2011 04:12 PM	
<b>Client IOPS (REQUIRED) - Report Page</b>			
<b>SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)</b>			Rev. <b>PTS-C 1.0</b>
			Page <b>4 of 6</b>
<b>Device Under Test (DUT)</b>	<b>VENDOR:</b> ABC CO.	<b>SSD MODEL NO:</b> MLC-A 256 GB	<b>TEST SPONSOR</b> 
<b>Serial No.</b>	<b>DUT Preparation</b>		<b>Test Loop Parameters</b>
<b>Firmware Rev</b>	<b>Purge</b>	<b>Security Erase</b>	<b>REQUIRED:</b>
<b>Capacity</b>	<b>Pre-Conditioning</b>		<b>Data Pattern</b>
<b>NAND Type</b>	<b>Workload Independent</b>	<b>2X SEQ/128KIB RND IOPS Loop</b>	<b>RND</b>
<b>Device I/F</b>	<b>Workload Dep.</b>	<b>Full IOPS Loop</b>	<b>Outstanding IO</b>
<b>Test Platform</b>			<b>OIO/Thread (QD)</b>
			<b>Thread Count (TC)</b>
			<b>Convergence</b>
			<b>Rounds</b>
			<b>PC AR</b>
			<b>AR AMOUNT</b>
			<b>AR Segments</b>

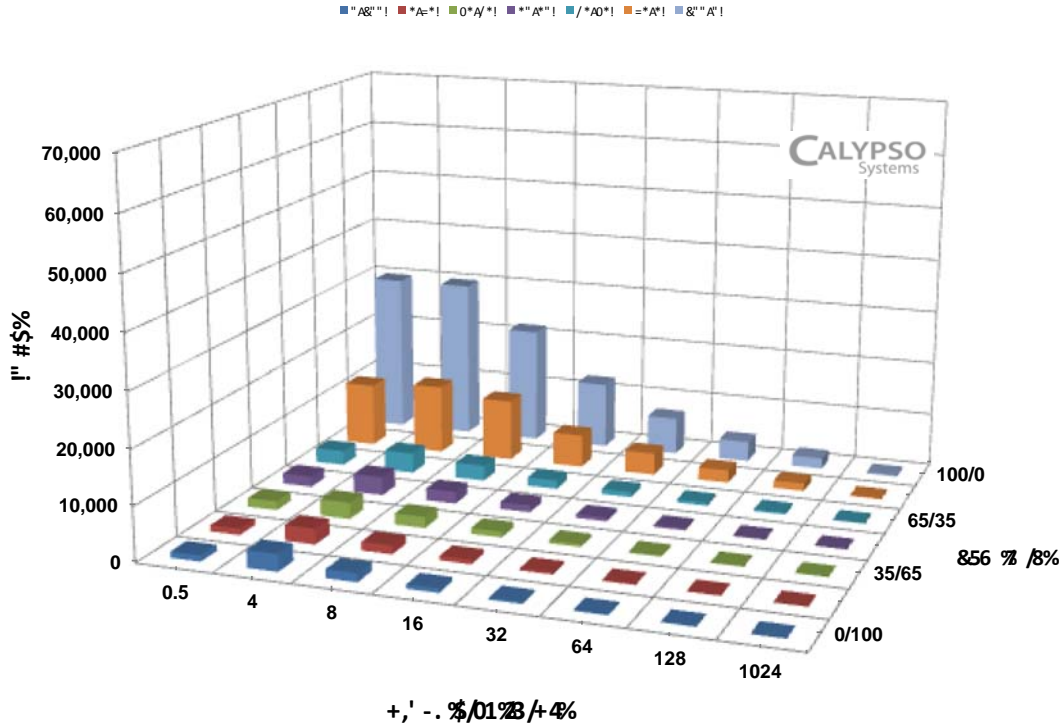
**Client IOPS - ALL RW Mix & BS – Tabular Data**

Block Size (KIB)	Read / Write Mix %						
	0/100	5/95	35/65	50/50	65/35	95/5	100/0
0.5	1,122.3	1,162.2	1,654.6	1,965.6	2,717.7	11,970.0	29,860.1
4	3,147.0	2,896.6	3,044.4	3,454.4	3,779.3	13,005.8	29,876.3
8	1,584.9	1,589.7	2,055.0	2,238.9	2,898.1	11,568.2	21,723.1
16	765.8	786.3	1,028.1	1,272.6	1,604.9	6,208.3	12,482.5
32	392.7	401.0	525.8	652.7	963.8	4,129.6	7,011.6
64	196.4	205.9	291.3	352.3	565.4	2,372.7	3,791.5
128	92.5	97.1	139.9	185.4	377.9	1,410.2	2,015.3
1024	16.4	16.5	23.3	27.3	90.8	191.4	266.7

Test Run Date: 11/14/2011 12:39 AM		Report Run Date: 11/21/2011 04:12 PM	
<b>Client IOPS (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 5 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR
			<b>CALYPSO Systems</b>
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	REQUIRED:
Capacity	Pre-Conditioning		Data Pattern RND
NAND Type	Workload Independent	2X SEQ/128KiB RND IOPS Loop	Outstanding IO
Device I/F	Workload Dep.	Full IOPS Loop	OIO/Thread (QD) 8
Test Platform			Thread Count (TC) 1
			Convergence YES
			Rounds 1-5
			PC AR 100%
			AR AMOUNT 16 GiB
			AR Segments 2048
<b>Client IOPS - ALL RW Mix &amp; BS - 2D Plot</b>			



Test Run Date: 11/14/2011 12:39 AM		Report Run Date: 11/21/2011 04:12 PM	
<b>Client IOPS (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 6 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR: CALYPSO Systems
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	Convergence YES
Capacity 256 GB	Pre-Conditioning		Rounds 1-5
NAND Type MLC	Workload Independent	2X SEQ/128KIB RND IOPS Loop	PC AR 100%
Device I/F 6 Gb/s SATA	Workload Dep.	Full IOPS Loop	AR AMOUNT 16 GiB
Test Platform RTP 2.0 CTS 6.5			AR Segments 2048
<b>Client IOPS - ALL RW Mix &amp; BS - 3D Columns</b>			



## MLC-A Test Report Summary Report Page - THROUGHPUT

<b>SNIA Solid State Storage Performance Test Specification (PTS)</b>				Rev. <b>PTS 1.0</b>			
				Page <b>14 of 26</b>			
Device Under Test (DUT)	<b>MLC-A</b>	<b>SNIA SSS PTS Summary Report</b>	<b>Calypso Systems, Inc.</b>	<b>CALYPSO Systems</b>			
<b>DEVICE INFORMATION</b>		<b>TEST HARDWARE PLATFORM</b>	<b>TEST SOFTWARE</b>	<b>REPORT DATE</b>			
<b>SERIAL NO.</b>	0000-0000-FFFF	<b>SYSTEM</b>	Calypso RTP 2.0	<b>SYS OS</b>	CENT OS 5.6	<b>Report</b>	06DEC11
<b>FIRMWARE REV.</b>	BFO1	<b>Motherboard/ cpu</b>	Intel 5520HC / W5580	<b>SW TOOL</b>	Calypso CTS 6.5	<b>Test Run</b>	01NOV – 04DEC11
<b>USER CAPACITY</b>	MLC 256 GB	<b>RAM</b>	12GB ECC DDR3	<b>SW Rev</b>	1.19.10	<b>Test Sponsor</b>	Calypso
<b>DEVICE INTERFACE</b>	6 Gb/s SATAII	<b>Device Interface</b>	LSA 9212-e 6Gb/s HBA	<b>Release</b>	Nov. 2011	<b>Auditor</b>	N/A

### Test Description

<b>Purpose</b>	To measure Large Block SEQ TP using different BS and R/W Mixes
<b>Test Outline</b>	PURGE, then apply preconditioning until Steady State is achieved according to the SNIA PTS
<b>Preconditioning</b>	PURGE followed by SNIA PTS prescribed WIPC & WDPC

### Test Set Up

PTS-C	TEST	Purge	DP	OIO	WIPC		WDPC		STEADY STATE	
9.0	<b>THROUGHPUT - REQUIRED</b>	Security Erase	RND	TC 32 QD 32	PC AR	TEST AR	AR AMT	SEGMENTS	WORKLOAD	ROUNDS
					100%	100%	16 GIB	2048	SEQ 1024KIB	1 - 5

### Select Performance Data

	SEQ 1024KiB R	SEQ 1024KiB W
	<b>417 MiB/ S</b>	<b>267 MiB/ S</b>

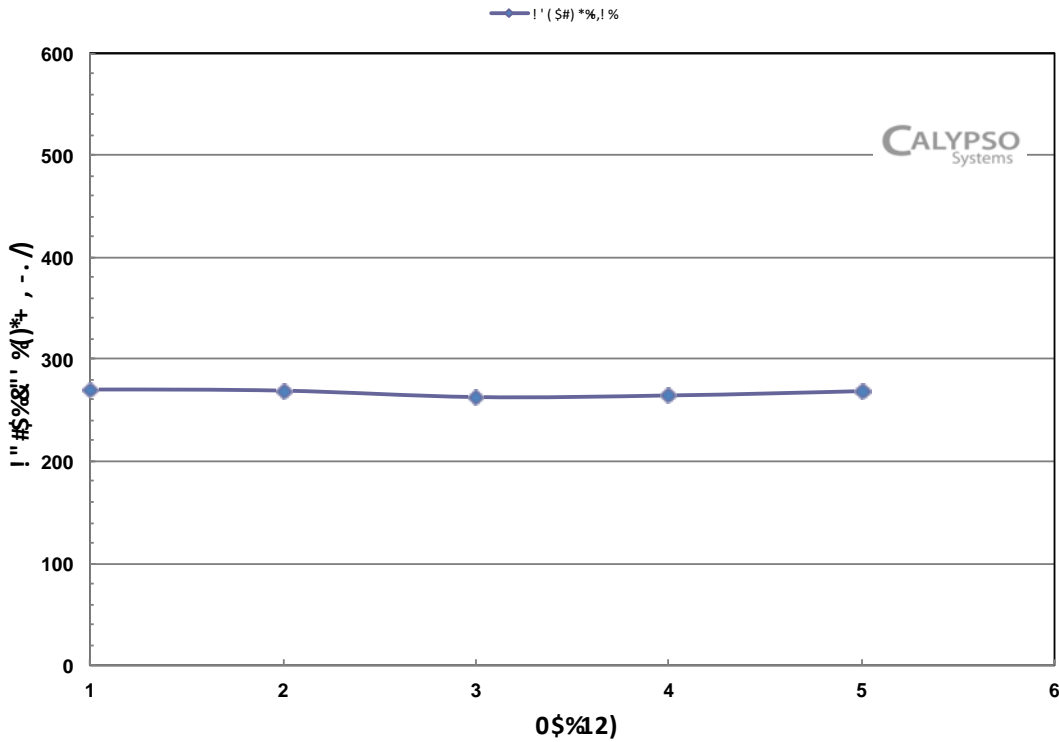
### Test Sponsor – Special Notes

ITEM	NOTATION	COMMENTS

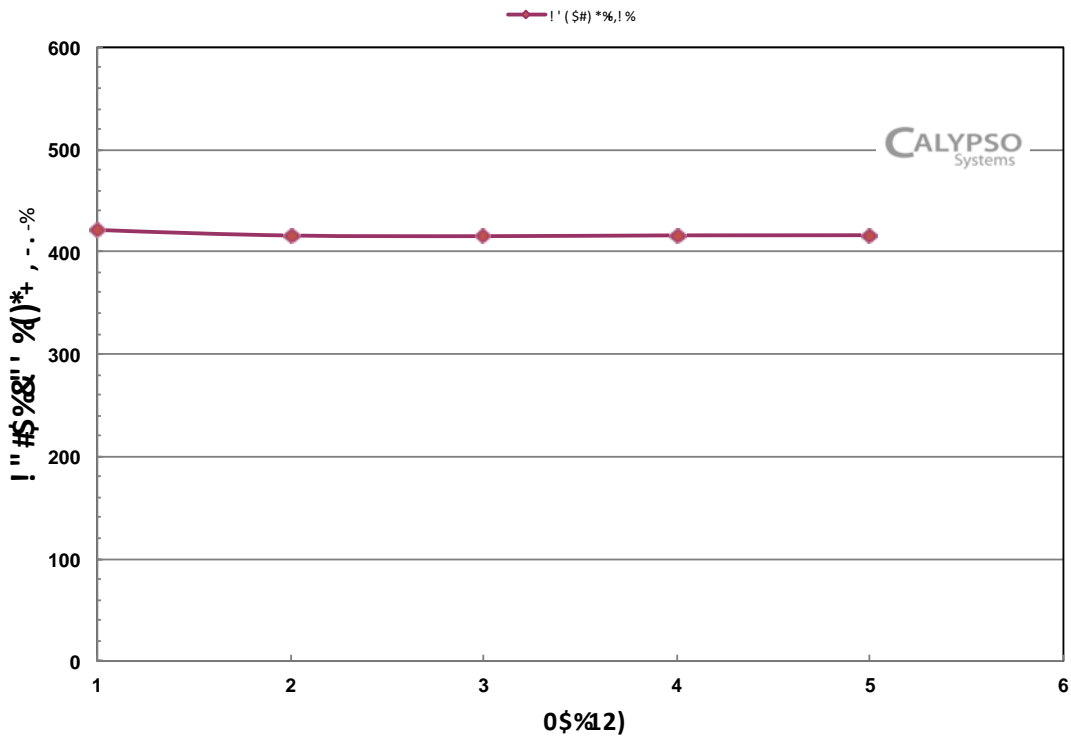
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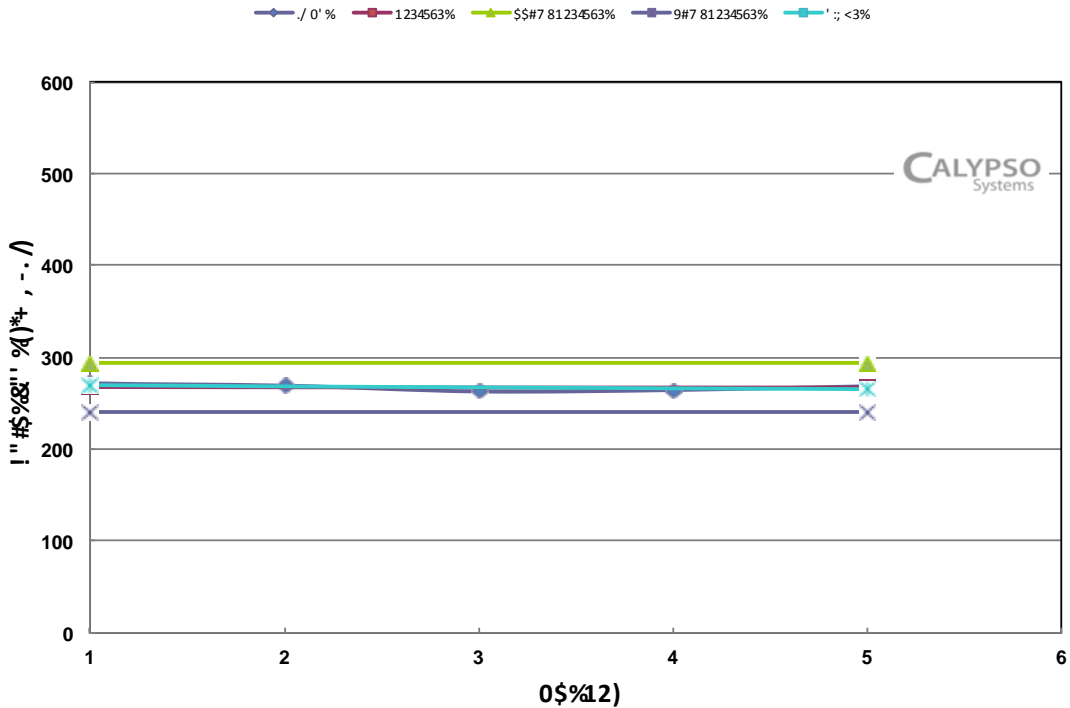
Test Run Date: 11/13/2011 10:24 AM		Report Run Date: 11/21/2011 04:03 PM	
<b>Client Throughput Test (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 1 of 5
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR: <b>CALYPSO Systems</b>
Serial No. #####&"	DUT Preparation		Steady State
Firmware Rev !"#	Purge	Security Erase	Convergence YES
Capacity 256 GB	Pre-Conditioning		Rounds 1-5
NAND Type MLC	Workload Independent	2X SEQ/128KIB	PC AR 100%
Device I/F 6 Gb/s SATA		SEQ 1024KIB	AR AMOUNT 16 GiB
Test Platform RTP 2.0 CTS 6.5	Workload Dep.	SEQ 1024KIB	AR Segments 2048
<b>Steady State Convergence Plot – All Block Sizes - Write</b>			




Test Run Date: 11/13/2011 10:24 AM		Report Run Date: 11/21/2011 04:03 PM	
<b>Client Throughput Test (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 2 of 5
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR <b>CALYPSO Systems</b>
Serial No. #####	DUT Preparation		Steady State
Firmware Rev !"#	Purge	Security Erase	REQUIRED:
Capacity 256 GB	Pre-Conditioning		Data Pattern RND
NAND Type MLC	Workload Independent	2X SEQ/128KIB SEQ 1024KIB	Outstanding IO
Device I/F 6 Gb/s SATA	Workload Dep.	SEQ 1024KIB	OIO/Thread (OD) 32
Test Platform RTP 2.0 CTS 6.5		Thread Count (TC) 32	Convergence YES
			Rounds 1-5
			PC AR 100%
			AR AMOUNT 16 GiB
			AR Segments 2048
<b>Client Throughput Test - SS Convergence - Read</b>			



Test Run Date: 11/13/2011 10:24 AM		Report Run Date: 11/21/2011 04:03 PM	
<b>Client Throughput Test (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 3 of 5
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR <b>CALYPSO Systems</b>
Serial No. #####	DUT Preparation		Steady State
Firmware Rev. !"#	Purge	Security Erase	REQUIRED: Convergence YES
Capacity 256 GB	Pre-Conditioning		Outstanding IO RND Rounds 1-5
NAND Type MLC	Workload Independent	2X SEQ/128KiB SEQ 1024KiB	PC AR 100%
Device I/F 6 Gb/s SATA	Workload Dep.	SEQ 1024KiB	AR AMOUNT 16 GiB
Test Platform RTP 2.0 CTS 6.5			AR Segments 2048
<b>Client - Steady State Measurement Window – SEQ/1024 KiB</b>			

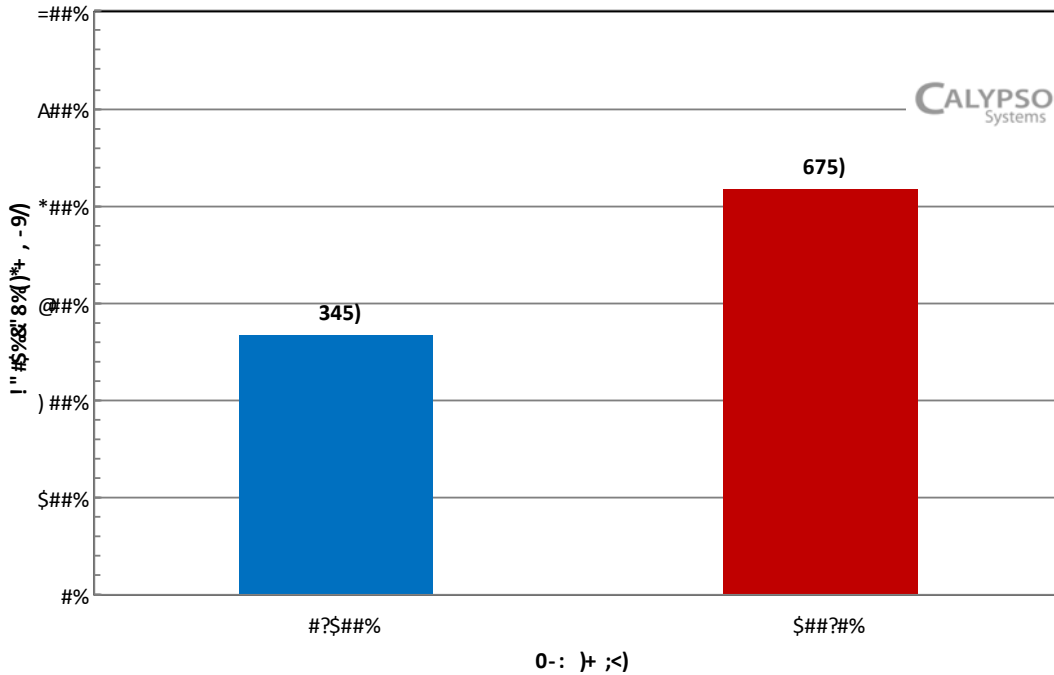


Steady State Determination Data	
Average ThroughPut:	267.2
Allowed Maximum Data Excursion:	53.4
Measured Maximum Data Excursion:	7.9
Allowed Maximum Slope Excursion:	26.7
Measured Maximum Slope Excursion:	3.7
Least Squares Linear Fit Formula:	-0.924 * R + 269.947

<b>Test Run Date:</b> 11/13/2011 10:24 AM		<b>Report Run Date:</b> 11/21/2011 04:03 PM	
<b>Client Throughput Test (REQUIRED) - Report Page</b>			
<b>SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)</b>			Rev. <b>PTS-C 1.0</b>
			Page <b>4 of 5</b>
<b>Device Under Test (DUT)</b>	<b>VENDOR:</b> ABC CO.	<b>SSD MODEL NO:</b> MLC-A 256 GB	<b>TEST SPONSOR</b> 
<b>Serial No.</b>	<b>DUT Preparation</b>		<b>Test Loop Parameters</b>
<b>Firmware Rev</b>	<b>Purge</b>	Security Erase	<b>REQUIRED:</b>
<b>Capacity</b>	<b>Pre-Conditioning</b>		<b>Data Pattern</b>
<b>NAND Type</b>	<b>Workload Independent</b>	2X SEQ/128KIB	RND
<b>Device I/F</b>		SEQ 1024KIB	
<b>Test Platform</b>	<b>Workload Dep.</b>	SEQ 1024KIB	<b>Outstanding IO</b>
			<b>OIO/Thread (QD)</b>
			<b>Thread Count (TC)</b>
			<b>Convergence</b>
			<b>Rounds</b>
			<b>PC AR</b>
			<b>AR AMOUNT</b>
			<b>AR Segments</b>
			<b>YES</b>
			<b>1-5</b>
			<b>100%</b>
			<b>16 GiB</b>
			<b>2048</b>
<b>Client Throughput - ALL RW Mix &amp; BS – Tabular Data</b>			

Block Size (KiB)	Read / Write Mix %	
	0/100	100/0
1024	267.2	416.9

Test Run Date: 11/13/2011 10:24 AM		Report Run Date: 11/21/2011 04:03 PM	
<b>Client Throughput Test (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 5 of 5
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR <b>CALYPSO Systems</b>
Serial No. #####	DUT Preparation		Steady State
Firmware Rev. !"#	Purge	Security Erase	REQUIRED:
Capacity 256 GB	Pre-Conditioning		Data Pattern RND
NAND Type MLC	Workload Independent	2X SEQ/128KiB SEQ 1024KiB	Outstanding IO
Device I/F 6 Gb/s SATA	Workload Dep.	SEQ 1024KiB	OIO/Thread (OD) 32
Test Platform RTP 2.0 CTS 6.5			Thread Count (TC) 32
			Convergence YES
			Rounds 1-5
			PC AR 100%
			AR AMOUNT 16 GiB
			AR Segments 2048
<b>Client Throughput - ALL RW Mix &amp; BS - 2D Plot</b>			



## MLC-A Test Report Summary Report Page - LATENCY

<b>SNIA Solid State Storage Performance Test Specification (PTS)</b>				Rev. <b>PTS 1.0</b>
				Page <b>20 of 26</b>
<b>Device Under Test (DUT)</b>	<b>MLC-A</b>	<b>SNIA SSS PTS Summary Report</b>	<b>Calypso Systems, Inc.</b>	<b>CALYPSO Systems</b>
<b>DEVICE INFORMATION</b>		<b>TEST HARDWARE PLATFORM</b>	<b>TEST SOFTWARE</b>	<b>REPORT DATE</b>
<b>SERIAL NO.</b>	0000-0000-FFFF	<b>SYSTEM</b>	Calypso RTP 2.0	<b>SYS OS</b>
<b>FIRMWARE REV.</b>	BFOI	<b>Motherboard/ cpu</b>	Intel 5520HC / W5580	CENT OS 5.6
<b>USER CAPACITY</b>	MLC 256 GB	<b>RAM</b>	12GB ECC DDR3	<b>SW TOOL</b>
<b>DEVICE INTERFACE</b>	6 Gb/s SATAII	<b>Device Interface</b>	LSA 9212-e 6Gb/s HBA	Calypso CTS 6.5
			<b>SW Rev</b>	1.19.10
			<b>Release</b>	Nov. 2011
			<b>Test Sponsor</b>	Calypso
			<b>Auditor</b>	N/A

### Test Description

<b>Purpose</b>	To measure AVE & MAX Response times at selected BS & RW Mixes measured in mSec
<b>Test Outline</b>	PURGE, then apply preconditioning until Steady State is achieved according to the SNIA PTS
<b>Preconditioning</b>	PURGE followed by SNIA PTS prescribed WIPC & WDPC

### Test Set Up

PTS-C	TEST	Purge	DP	OIO	WIPC		WDPC		STEADY STATE	
10.0	<b>LATENCY - REQUIRED</b>	Security Erase	RND	TC I QD I	PC AR	TEST AR	AR AMT	SEGMENTS	WORKLOAD	ROUNDS
					100%	100%	16 GIB	2048	LAT LOOP	4 - 8

### Select Performance Data

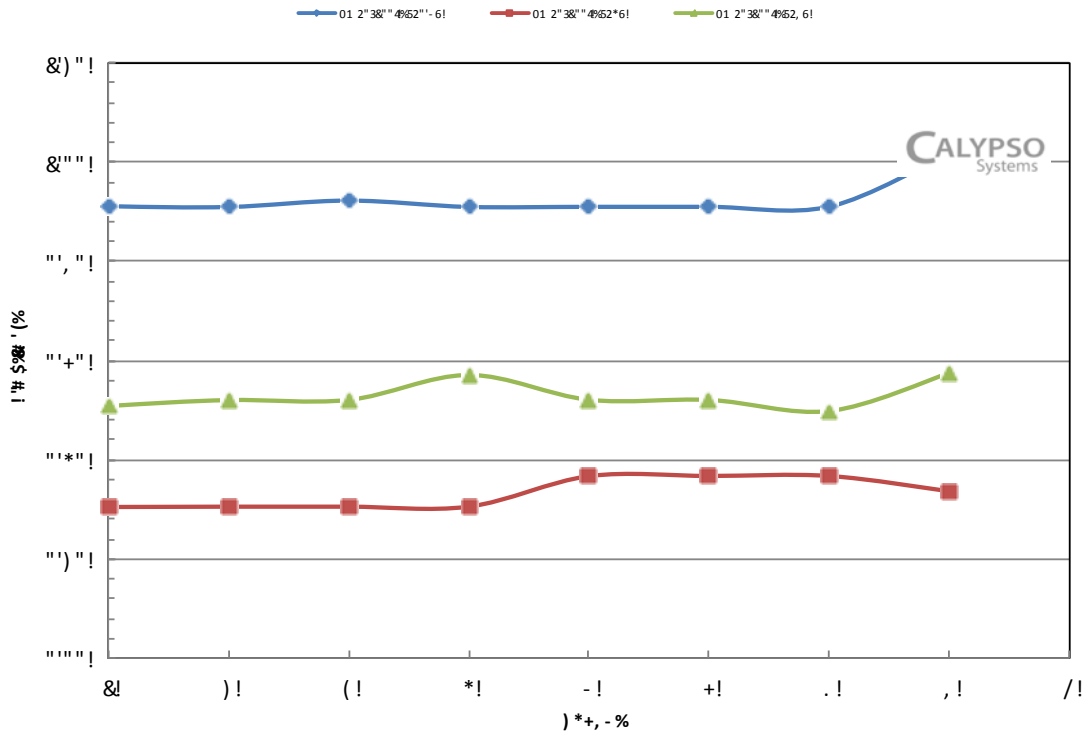
RND 4KiB R AVE	RND 4KiB W AVE	RND 4KiB R MAX	RND 4KiB W MAX
0.203 mSec	0.309 mSec	1.600 mSec	51.000 mSec

### Test Sponsor – Special Notes

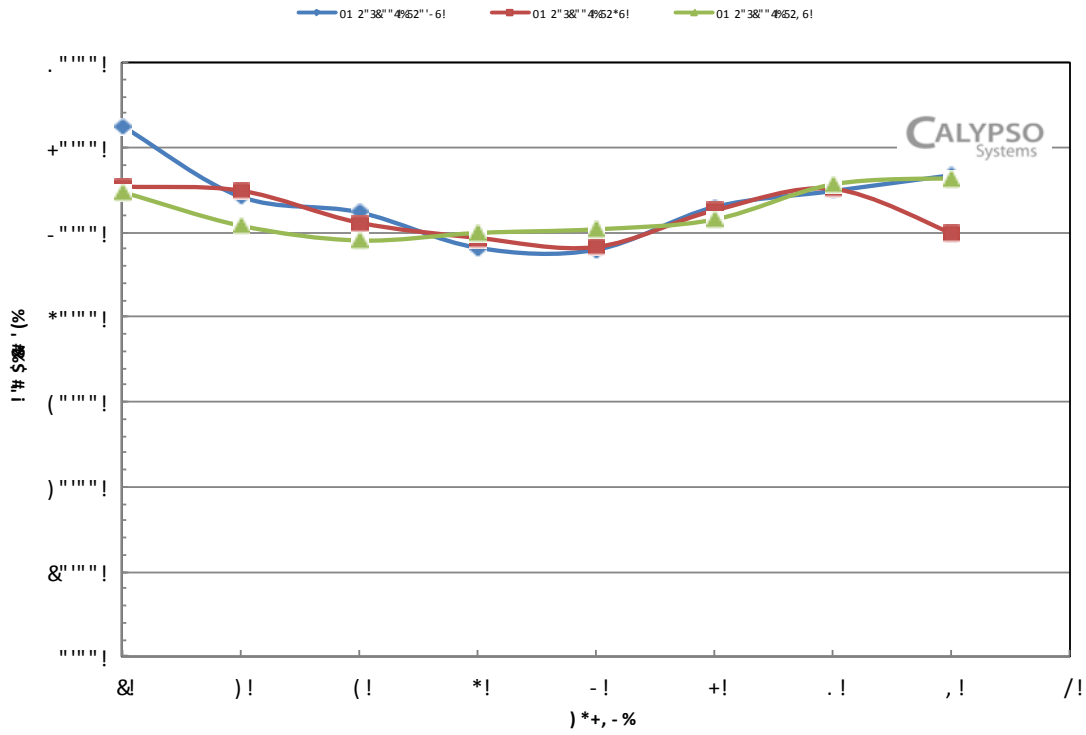
ITEM	NOTATION	COMMENTS

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Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM
<b>Client Latency (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 1 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR: CALYPSO Systems
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	REQUIRED: Convergence YES
Capacity	Pre-Conditioning		Data Pattern RND Rounds 4-8
NAND Type	Workload Independent	2X SEQ/128KiB RND LAT Loop	Outstanding IO PC AR 100%
Device I/F	Workload Dep.	Full Latency Loop	OIO/Thread (QD) 1 AR AMOUNT 16 GiB
Test Platform			Thread Count (TC) 1
<b>Client - Steady State Convergence Plot – AVE Latency - 100% Writes</b>			

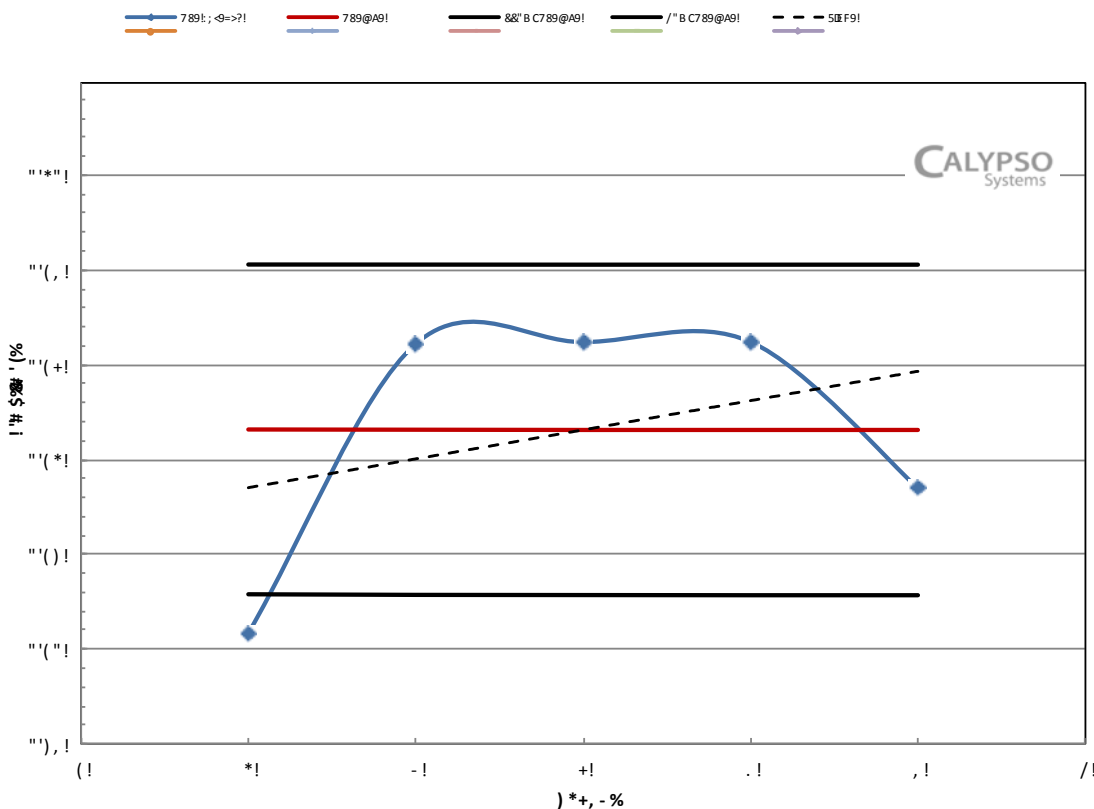


Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM
<b>Client Latency (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 2 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR: CALYPSO Systems
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	Convergence YES
Capacity	Pre-Conditioning		Rounds 4-8
NAND Type	Workload Independent	2X SEQ/128KiB RND LAT Loop	PC AR 100%
Device I/F			Outstanding IO OIO/Thread (OD) 1
Test Platform	Workload Dep.	Full Latency Loop	Thread Count (TC) 1
			AR Segments 2048
<b>Client Steady State Convergence Plot – MAX Latency - 100% Writes</b>			






Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM
<b>Client Latency (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 3 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR <b>CALYPSO Systems</b>
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	REQUIRED: Convergence YES
Capacity	Pre-Conditioning		Rounds 4-8
NAND Type	Workload Independent	2X SEQ/128KiB RND LAT Loop	PC AR 100%
Device I/F	Workload Dep.	Full Latency Loop	AR AMOUNT 16 GiB
Test Platform	RTP 2.0 CTS 6.5		AR Segments 2048
<b>Client - Steady State Measurement Window – RND/4KiB</b>			



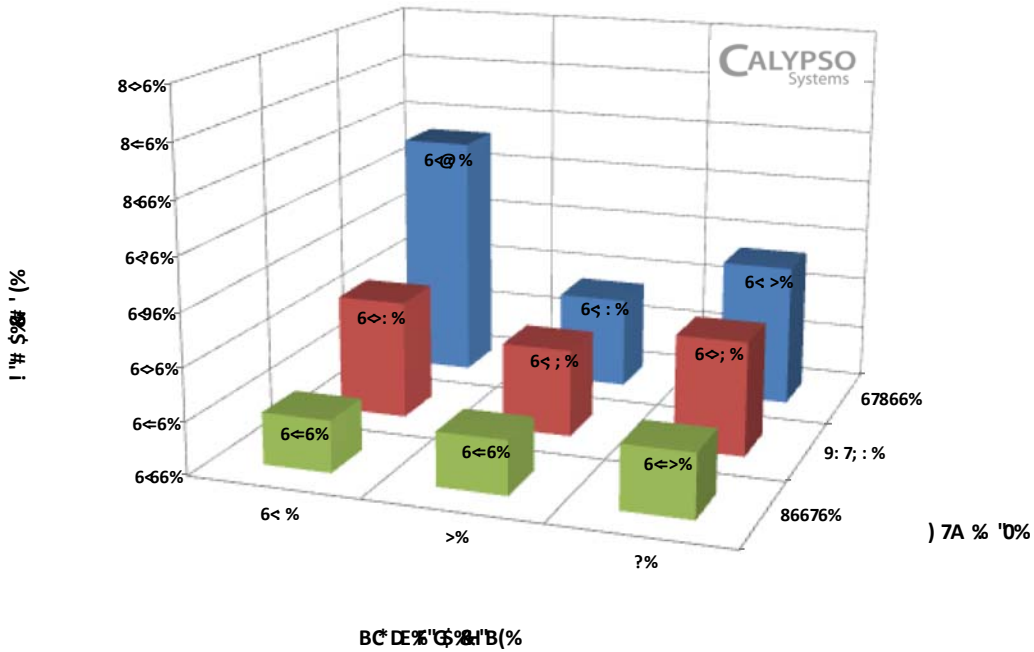
Average Latency (ms):	0.349	
Allowed Maximum Data Excursion:	0.070	Measured Maximum Data Excursion: 0.062
Allowed Maximum Slope Excursion:	0.035	Measured Maximum Slope Excursion: 0.025
Least Squares Linear Fit Formula:	0.006 * R + 0.312	

<b>Test Run Date:</b>		11/11/2011 09:53 AM		<b>Report Run Date:</b>		11/15/2011 03:34 PM	
<b>Client Latency (REQUIRED) - Report Page</b>							
<b>SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)</b>						Rev.	<b>PTS-C 1.0</b>
						Page	<b>4 of 6</b>
<b>Device Under Test (DUT)</b>		<b>VENDOR:</b>	<b>SSD MODEL NO:</b>		<b>TEST SPONSOR</b>		
		ABC CO.	MLC-A 256 GB				
<b>Serial No.</b>	#####	<b>DUT Preparation</b>		<b>Test Loop Parameters</b>		<b>Steady State</b>	
<b>Firmware Rev</b>	%&	<b>Purge</b>	Security Erase		<b>REQUIRED:</b>	<b>Convergence</b>	YES
<b>Capacity</b>	256 GB	<b>Pre-Conditioning</b>		<b>Data Pattern</b>	RND	<b>Rounds</b>	4-8
<b>NAND Type</b>	MLC	<b>Workload Independent</b>	2X SEQ/128KIB	<b>Outstanding IO</b>		<b>PC AR</b>	100%
<b>Device I/F</b>	6 Gb/s SATA		RND LAT Loop	<b>OIO/Thread (QD)</b>		<b>AR AMOUNT</b>	16 GiB
<b>Test Platform</b>	RTP 2.0 CTS 6.5	<b>Workload Dep.</b>	Full Latency Loop	<b>Thread Count (TC)</b>		<b>AR Segments</b>	2048
<b>Client - AVE and MAX Response Time - ALL RW Mix &amp; BS – Tabular Data</b>							

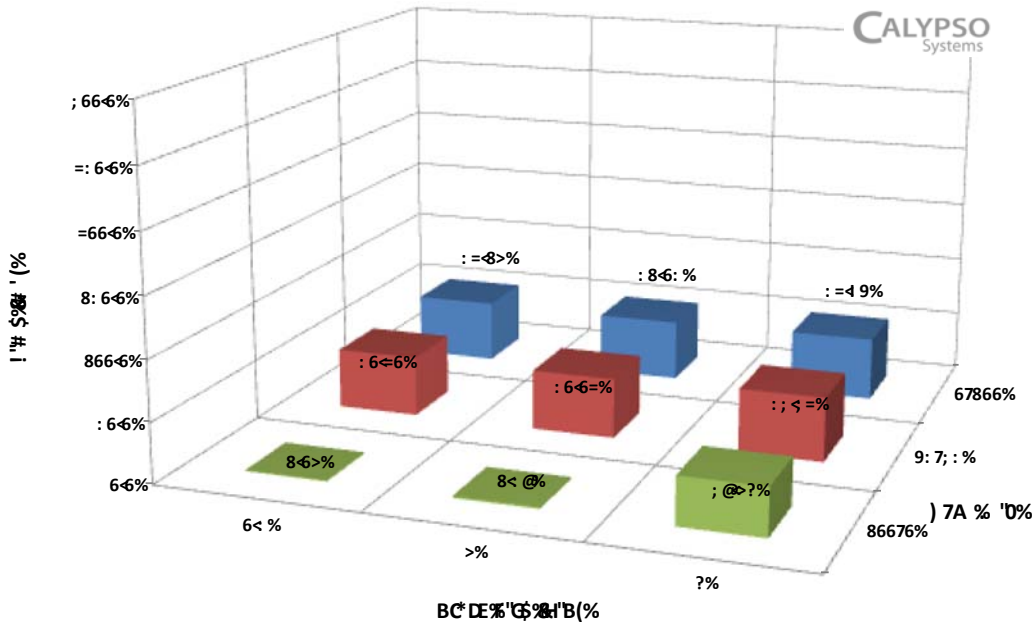
23\$4/5\$%\$'1*, '\$%!'# \$%# '(			
Read / Write Mix %			
Block Size (KiB)	0/100	65/35	100/0
0.5	0.932	0.449	0.196
4	0.349	0.332	0.203
8	0.537	0.432	0.240

. /0# +# %\$'1*, '\$%!'# \$%# '(			
Read / Write Mix %			
Block Size (KiB)	0/100	65/35	100/0
0.5	52.1	50.2	1.0
4	51.0	50.0	1.6
8	52.8	53.3	39.5

Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM
<b>Client Latency (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 5 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR <b>CALYPSO Systems</b>
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	Convergence YES
Capacity	Pre-Conditioning		Rounds 4-8
NAND Type	Workload Independent	2X SEQ/128KIB RND LAT Loop	PC AR 100%
Device I/F	Workload Dep.	Full Latency Loop	AR AMOUNT 16 GiB
Test Platform	RTP 2.0 CTS 6.5		AR Segments 2048
<b>Client - AVE Latency vs BS and R/W Mix - 3D Plot</b>			



Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM
<b>Client Latency (REQUIRED) - Report Page</b>			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)			Rev. PTS-C 1.0
			Page 6 of 6
Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR <b>CALYPSO Systems</b>
Serial No.	DUT Preparation		Steady State
Firmware Rev	Purge	Security Erase	Convergence YES
Capacity	Pre-Conditioning		Rounds 4-8
NAND Type	Workload Independent	2X SEQ/128KIB RND LAT Loop	PC AR 100%
Device I/F	Workload Dep.	Full Latency Loop	AR AMOUNT 16 GiB
Test Platform	RTP 2.0 CTS 6.5		AR Segments 2048
<b>Client - MAX Latency vs BS and R/W Mix - 3D Plot</b>			



## 12 Informative Annex B – Performance Test Platform Example

This annex describes the hardware/software Reference Test Platform (RTP) that was used by the SSS TWG to do the bulk of the research and validation of the SSS PTS.

The RTP is not required to run the SSS PTS tests; it is an example of a platform that was used to run the PTS.

In addition to the RTP, several other hardware/software platforms and software tools were used in the development and refinement of the PTS, such as IOmeter, Vdbench and several in-house stimulus generators running on several versions of the Windows and Linux O/S.

### 12.1 RTP Configurations

The RTP was designed to enable the testing of most SSS devices. It can also be extended in order for the testing of higher performance SSS products.

The table below shows the two currently defined configurations of the RTP; the validation of the PTS was performed using the Standard configuration.

Component	Type / Part Number	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, 7200K RPM	1	1
6Gb/s SAS/SATA HBA	LSI 9212-4i4e	1	1
Operating System	Linux	CentOS 5.6	CentOS 5.6
Test Software	Calypso CTS	CTS v 6.5	CTS v 6.5

### 12.2 RTP Components

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

The chassis used 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 S5520HC. 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 fully populated with 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 is advisable to install the memory in multiples of three DIMMs, to optimize performance.

The HDD used in the RTP was 160 GB, 7200K RPM, with a SATA interface. It is not clear what impact the HDD has on performance testing, so the highest performance SATA drive that is widely available was selected.

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 DUT bays separate from the main power supply.

RTP utilized CTS test software made by Calypso Systems, Inc. <http://www.calypsotesters.com>

- CTSv6.5 is the Standard version.

The Calypso software requires the CentOS 5.6 Linux OS.