Understanding SSD Performance Using the SNIA SSS Performance Test Specification

How to Use the PTS Results
to Evaluate & Compare SSD Performance

An SSSI White Paper - January 2012
www.snia.org/forums/sssi/knowledge/education

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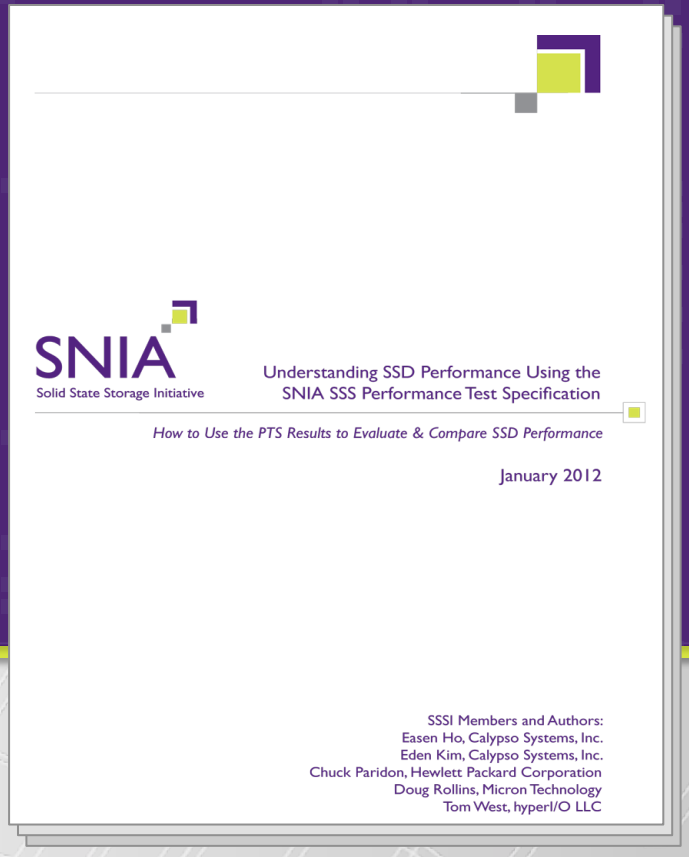
Solid State Storage Initiative



About the Presenters

Eden Kim is Chair of the SNIA Solid State Storage Technical Working Group and a member of the SNIA Solid State Storage Initiative Governing Board.

Mr. Kim was recognized in 2010 as the SNIA Outstanding Contributor for his work with the Solid State Storage Initiative and SSS Technical Working Group. Mr. Kim has been Chair of the SSS TWG since 2009 and has ushered the PTS through to publication.

Mr. Kim is CEO of Calypso Systems, Inc. which is the developer of the Calypso RTP / CTS SSD test platform. Calypso provides SSD Test and Measurement equipment and services to the solid state storage industry.

Mr. Kim previously founded hard disk drive test companies Media Measurements, Inc., Swan Instruments, Inc. and acquired Scotts Valley Instruments. Mr. Kim received his BA/JD from the University of CA.

Doug Rollins joined Micron in 2009 as an applications engineer with the Enterprise SSD Products group. Prior to joining Micron, Mr. Rollins spent 13 years working in server system, network appliance, and storage platform/ data protection design and manufacture.

Mr. Rollins is the named inventor in 13 U.S. patents and has been recognized by both the Storage Networking Industry Association (SNIA) and Intel Corporation for outstanding technical achievement. Mr. Rollins is an active member of several technical groups within SNIA including: The Solid State Storage Initiative and its Technical Working Group; Data Protection and Capacity Optimization; Marketing and Technical Development; Total Cost of Ownership; and the IO and Trace Tools Analysis. As co-chair of SNIA's Solid State Storage Initiative's Technical Working Group, Mr. Rollins was instrumental in the early development and validation of SNIA's SSD Performance Test Specification.

Mr. Rollins earned his BA degree in mathematics from Humboldt State University.

Download this deck at www.snia.org/forums/sssi/pts

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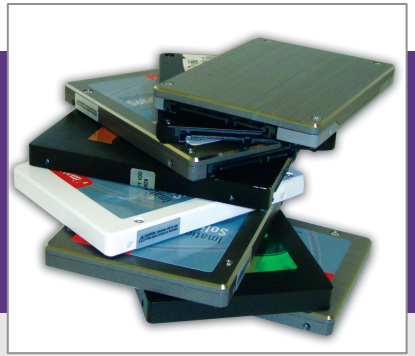
7. SSD Test Best Practices
8. Conclusion

Which SSD has the best Performance?

…… it Depends…..



Was the test done at the ***File System*** or ***Device Level***?

Was the Drive ***Preconditioned***? If so, ***how***?

Were the results taken at ***Steady State***?

How ***much*** data was written?

Where was the data was written?

What ***data pattern*** was tested?

What ***Test Platform*** was used to test the drives?

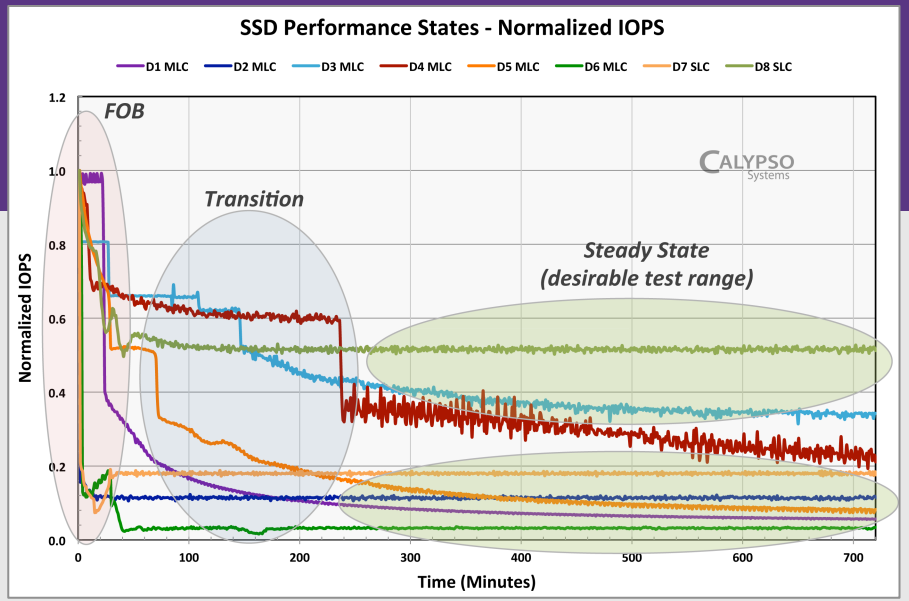
What ***Hardware/Software*** package was used?

Was the ***HBA bandwidth*** sufficient?

What type of ***NAND Flash*** is it?

What is the ***target workload***? High Writes? High Reads?

Are there ***warranty*** life design issues?



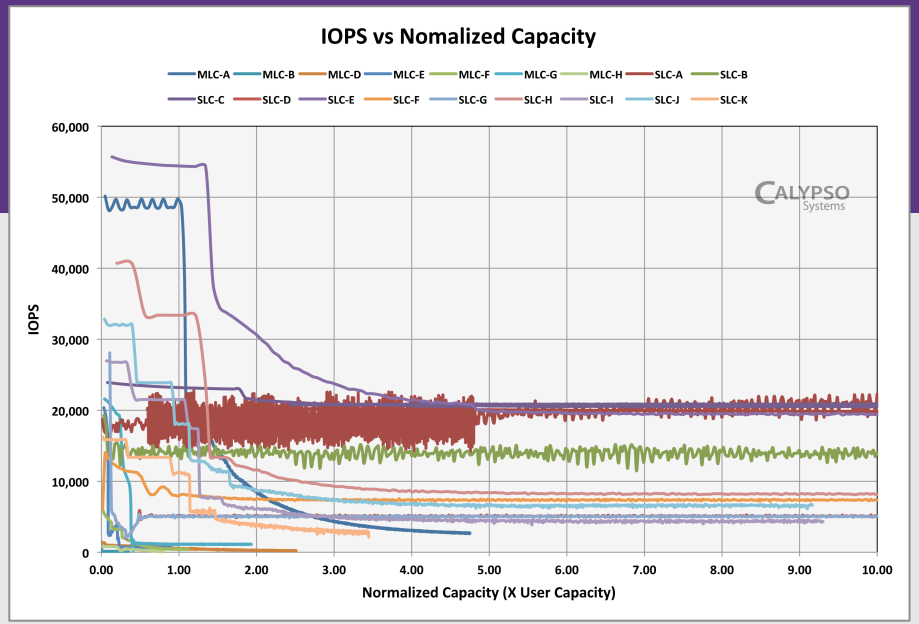
All NAND Flash SSDs Exhibit at least 3 Distinct Performance States:

"Fresh-Out-of-Box" (FOB)

"Transition"

"Steady State"

Steady State is the desirable test range.



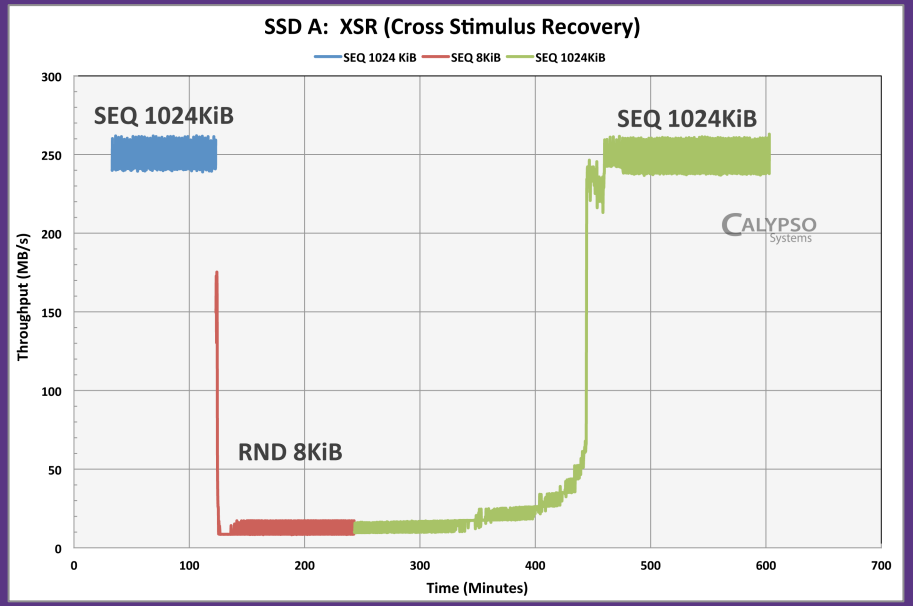
SSD Performance is *HIGHLY* Dependent on 3 Main Factors:

"Write History"

"Measured Workload"

"Hardware/Software Test Environment"

The ***exact same SSD*** can produce dramatically different results depending on these factors.



Write History

Previously written data may have more impact on performance than the measured IO command

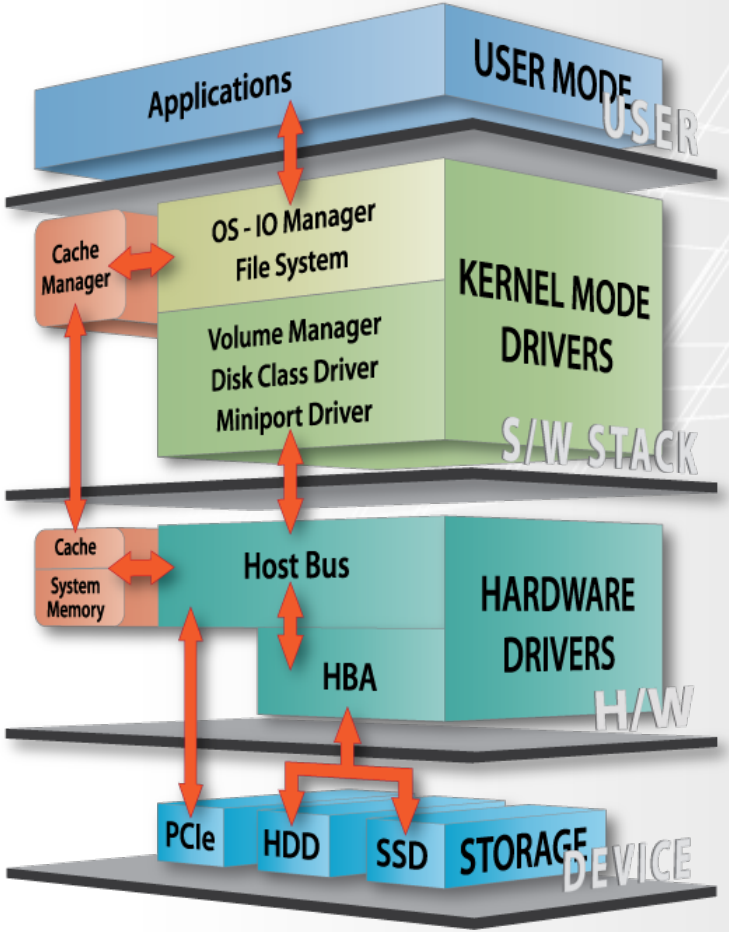
Measured Workload

The IO Access Pattern (Block Size / Read/Write Mix) can profoundly affect SSD performance - e.g. Large Block SEQ v Small Block RND

Hardware/Software

H/W S/W should minimally affect measurements - is there sufficient bandwidth and host processing resources to generate the necessary IO loads? How much software overhead is there?

PTS Numbering Convention - IO Transfer Sizes and Alignment Reported in base 2 (eg RND 4KiB)
Transfer Rates & Amounts Reported in base 10 (eg MB/s or TGBW)



File System Test

- Specific File IO operations issued in the File System
- IOs targeted at the Device traverse the SW/HW Stack
- IOs are subject to cache, OS task switching & timing, driver fragmentation & coalescing
- Original IO can be different at the Device level
- Can lose 1:1 correspondence original IO & Physical Device IO

Synthetic Device Level Test

- Applies a known and repeatable test stimulus
- Targets Block IO Devices (not File System devices)
- Uses Specified Test Workloads (Access Patterns, Data Pattern)
- Specifies LBAs allowed to be used (ActiveRange, AR Amount)
- Prescribes the Test Methodology

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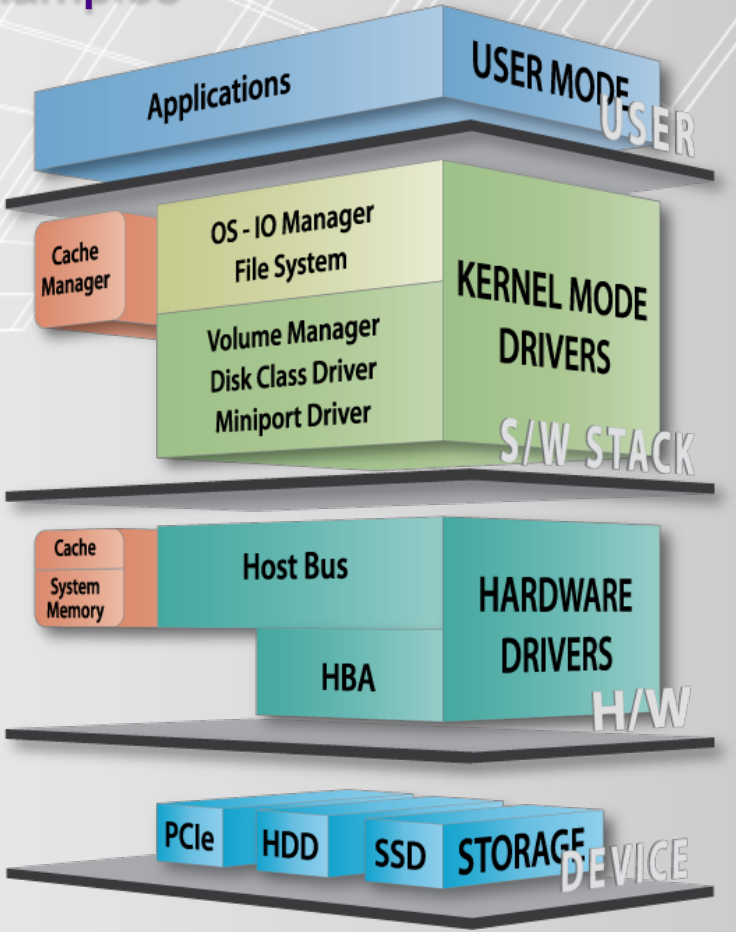
IOs Traversing the SW/HW Stack - 7 Examples

NOTE: There will be a detailed webcast on

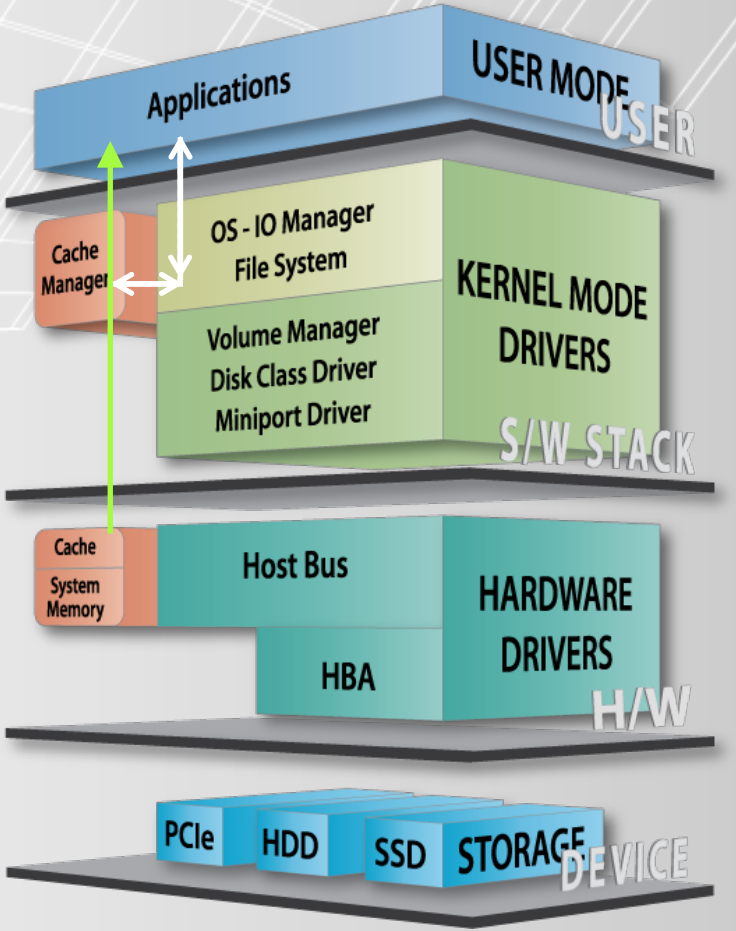
How IOs Traverse the SW/HW Stack

At a later date



1. Cached File READ (or WRITE) I/O

NOTE: There is no R/W to SSD in this scenario



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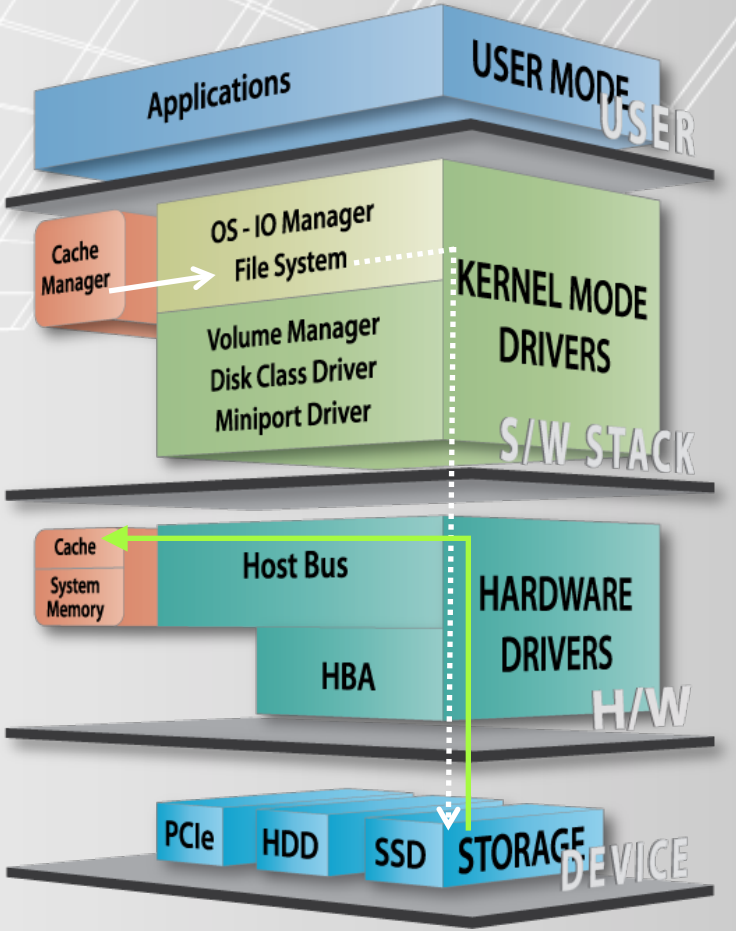
2. “Read-Ahead” Caching I/O

***Note**: “Read-Ahead” caching I/O activity can occur:*

***separately from** or*

***concurrently with** application I/O operations.*



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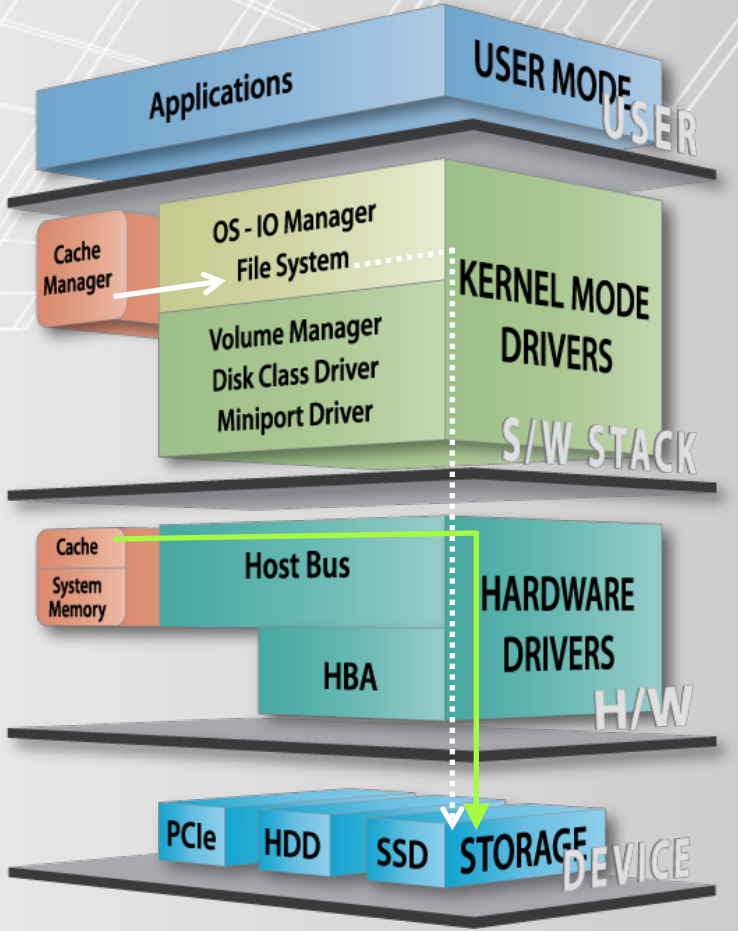
3. “Write-Behind” Caching I/O

Note *“Write-Behind” caching I/O activity is occurs:*

separately from *and/or*
concurrent with *the application I/Os*

Note *Cached data is subject to loss in the event of a power loss.*



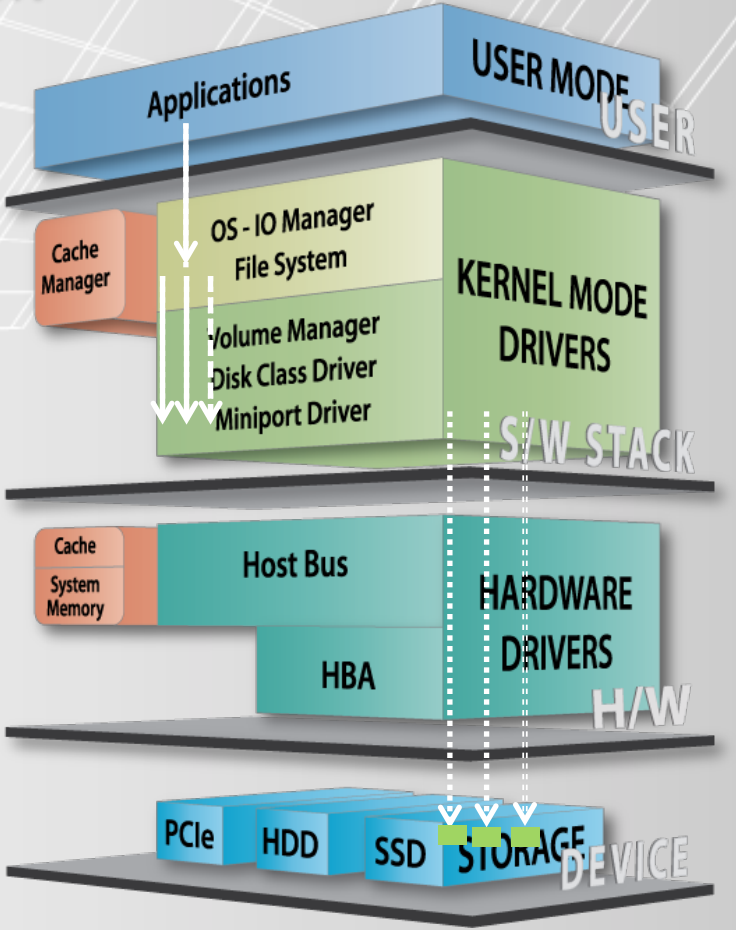
4. “Fragmented File” I/O Operation

“Fragmented File” I/Os can occur for both

***READ** and*
***WRITE** I/O operations*

The number of

***application I/Os** may not correspond to*
***device I/O** operations to storage.*



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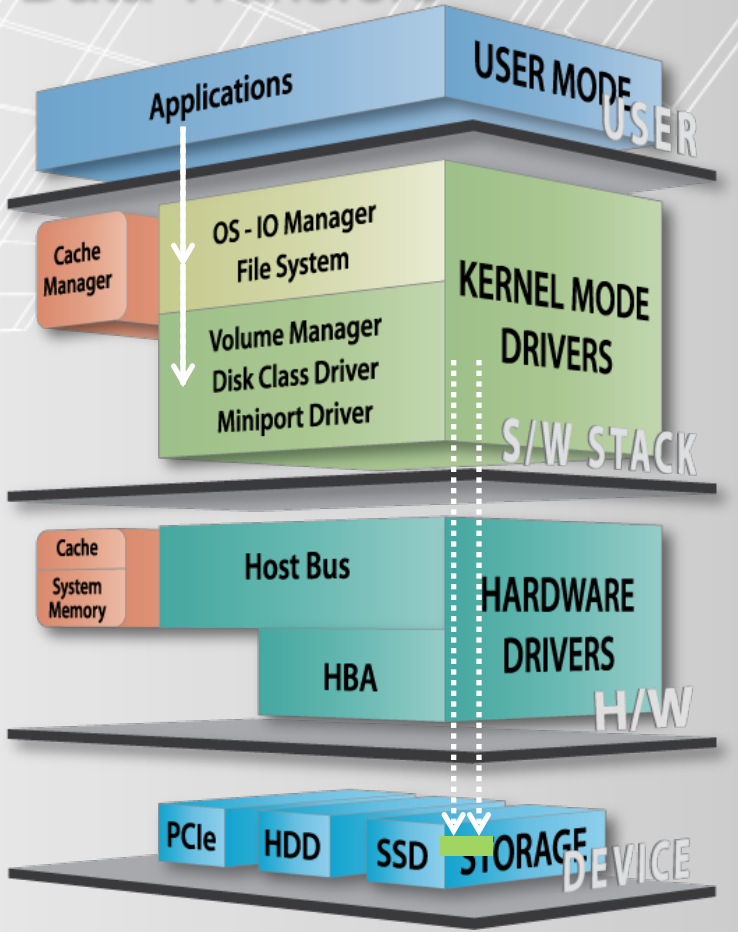
5. Split I/O Commands for Large Data Transfers

"Split I/O Commands" due to large data transfer sizes can occur for both

***READ** and*
***WRITE** I/O operations.*

The number of

***application I/Os** may not correspond to*
***device I/O** operations to storage.*



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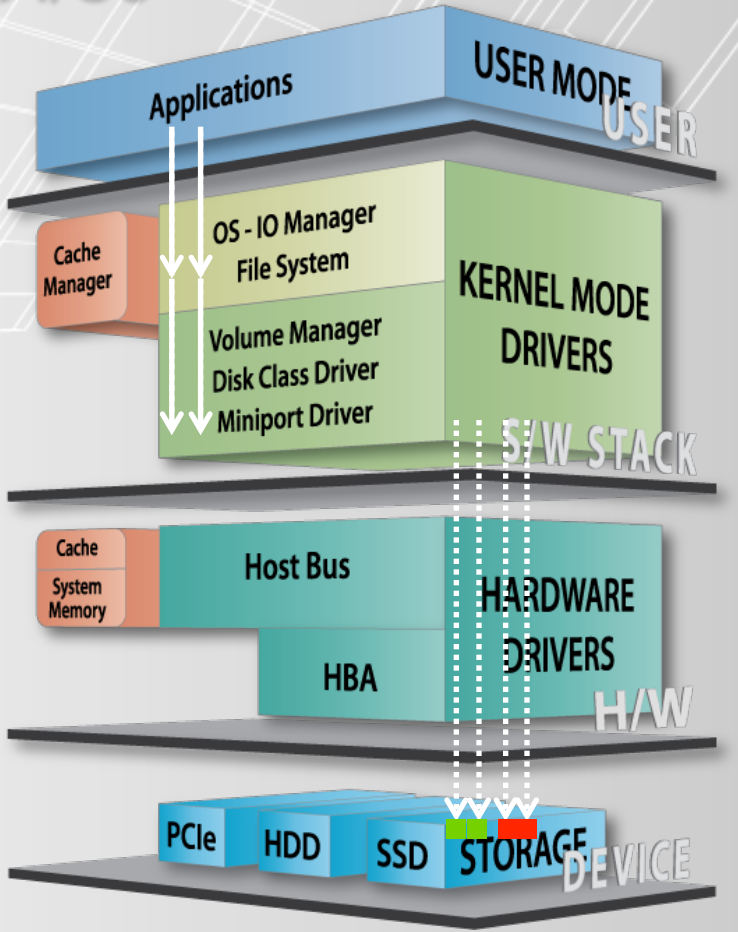
6. Concurrent Sequential Access I/Os

*RANDOM and SEQUENTIAL accesses are **relative** to*

***where** the respective I/O operations are performed/observed **within the I/O stack**.*

ACTUAL ACCESS PATTERNS impacted by

Concurrent I/O operations
"fragmented file" I/O operations
Timing considerations and other factors



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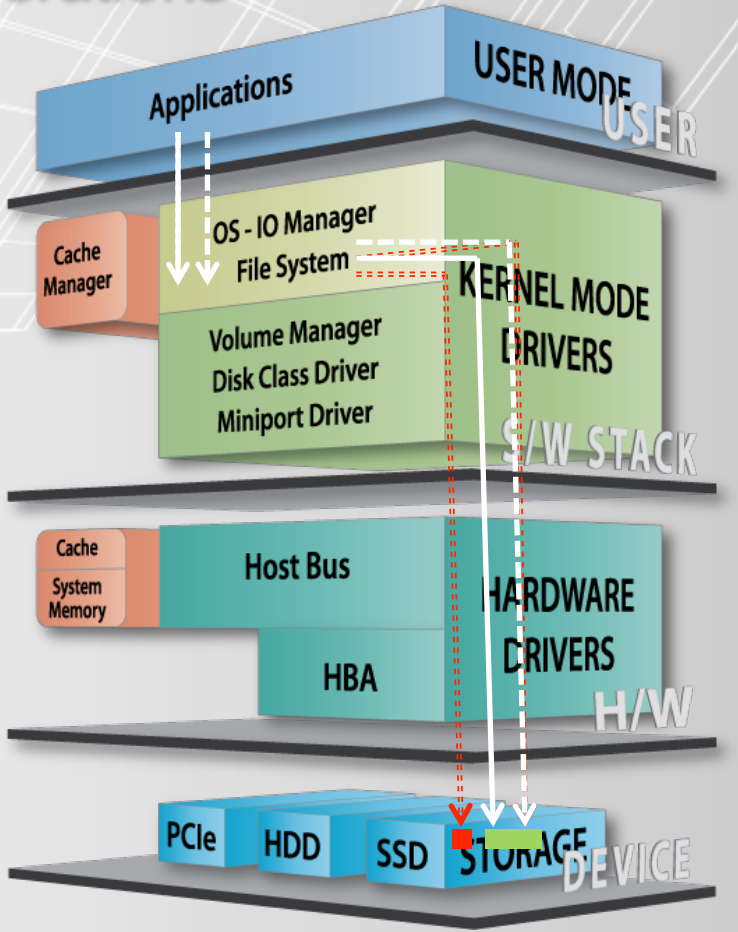
7. File System “MetaFile” I/O Operations

Metafile I/O operations

can introduce **random access** patterns to the device when interspersed with the **concurrent I/O** activity



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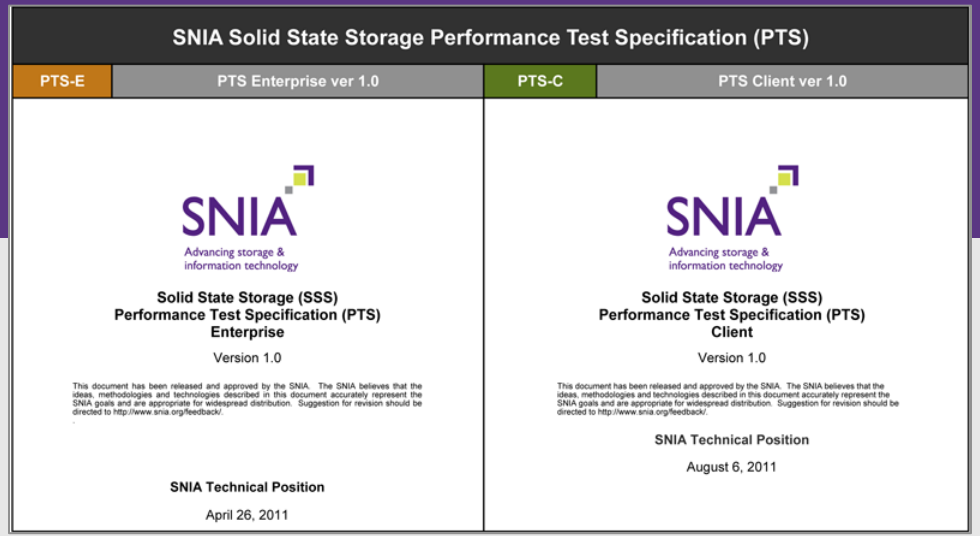
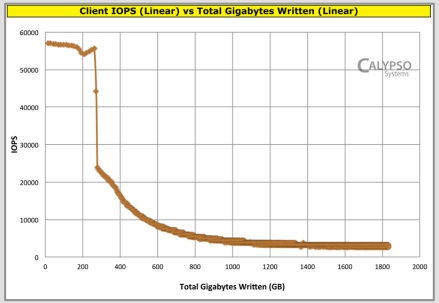


Creating a Standard:
SNIA PTS-C & PTS-E Specifications

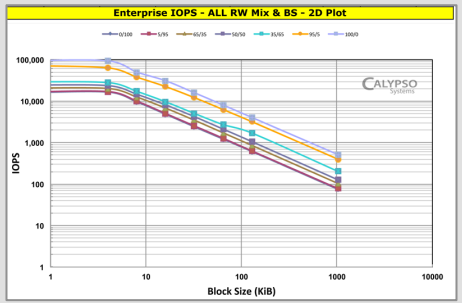
- Based on Synthetic Device Level Test
- Standardized Preconditioning Methodology
- Specified Test Workloads - Enterprise & Client
- Test Hardware Specific
- Test Software Agnostic - Tool Req's Listed
- Standardized PTS Report Format

PTS rev 1.0 Performance Tests

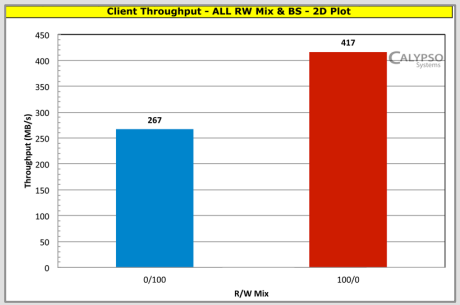
Test	Test Description	Purpose	Metric
WSAT	Continuous RND 4KiB W from FOB, No PC	FOB Performance Evolution over Time	IOPS
IOPS	Large & Small Block RND IOs at Steady State	Steady State IO Transfer Rate per second	IOPS
Throughput	Large Block SEQ R/W Data Transfer at Steady State	Steady State Bandwidth Speed	MB/Sec
Latency	AVE & MAX Response Times measured at a single OIO	Steady State IO Response Time Latency	mSec



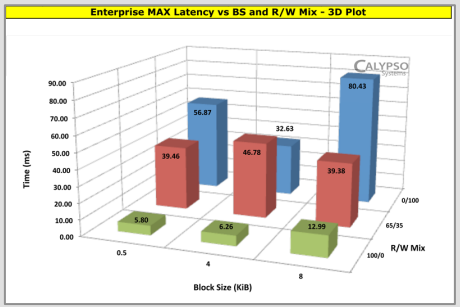
WSAT



IOPS

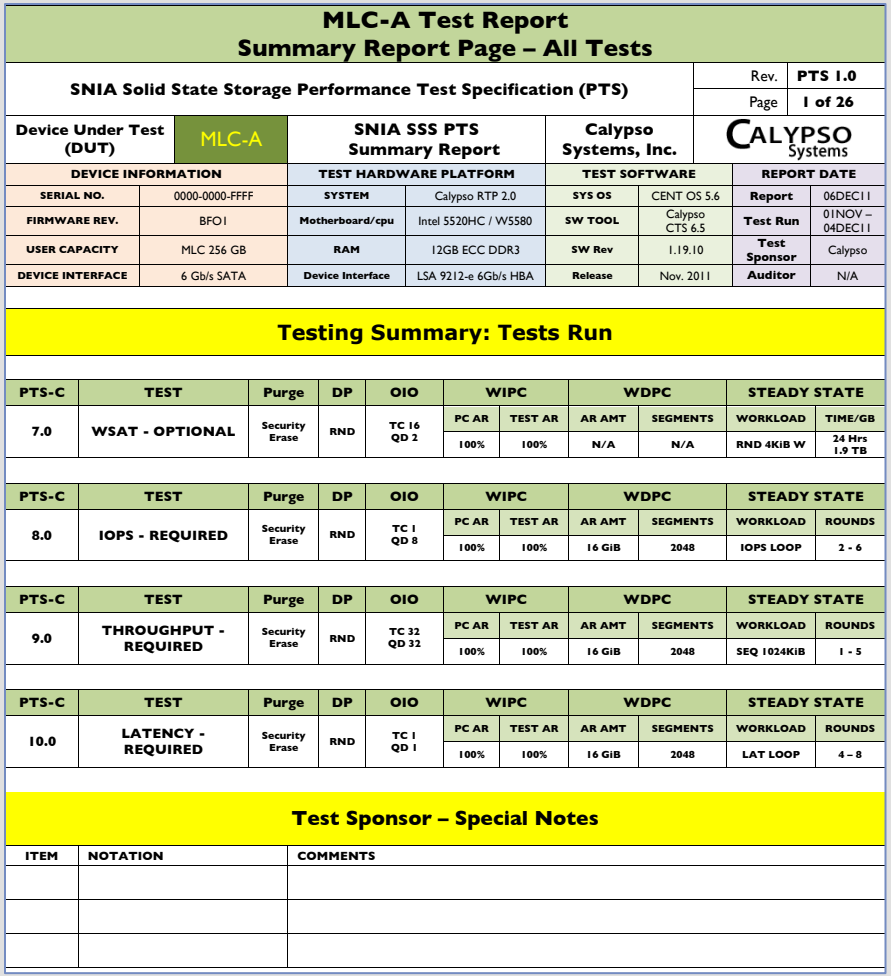


TP



LAT

Calypso Reference Test Platform (RTP 2.0)			
Hardware		**Software**	
Processor	Single Intel Xeon 5580W 3.2 Ghz 4 core	**Operating System - Back End**	CentOS 5.6
Motherboard	Intel 5520 HC	**Test Software - Back End**	CTS 6.5
RAM	12 GB ECC DDR3	**Front End - GUI**	Chrome Browser
HBA	6 Gb/s LSI 9212-4e-4i	**Front End: OS, Database**	Windows 7 / MySQL



MLC-A Test Report
Summary Report Page – All Tests

SNIA Solid State Storage Performance Test Specification (PTS)	Rev.	PTS 1.0
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Device Under Test (DUT)	MLC-A	SNIA SSS PTS Summary Report	Calypso Systems, Inc.	CALYPSO Systems

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.	BFO1	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 SATA	Device Interface	LSA 9212-e 6Gb/s HBA	Release	Nov. 2011	Auditor	N/A

Testing Summary: Tests Run

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 16 QD 2	100%	100%	N/A	N/A	RND 4KiB W	24 Hrs 1.9 TB

PTS-C	TEST	Purge	DP	OIO	WIPC		WDPC		STEADY STATE	
					PC AR	TEST AR	AR AMT	SEGMENTS	WORKLOAD	ROUNDS
8.0	IOPS - REQUIRED	Security Erase	RND	TC 1 QD 8	100%	100%	16 GiB	2048	IOPS LOOP	2 - 6

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

PTS-C	TEST	Purge	DP	OIO	WIPC		WDPC		STEADY STATE	
					PC AR	TEST AR	AR AMT	SEGMENTS	WORKLOAD	ROUNDS
10.0	LATENCY - REQUIRED	Security Erase	RND	TC 1 QD 1	100%	100%	16 GiB	2048	LAT LOOP	4 – 8

Test Sponsor – Special Notes

ITEM	NOTATION	COMMENTS

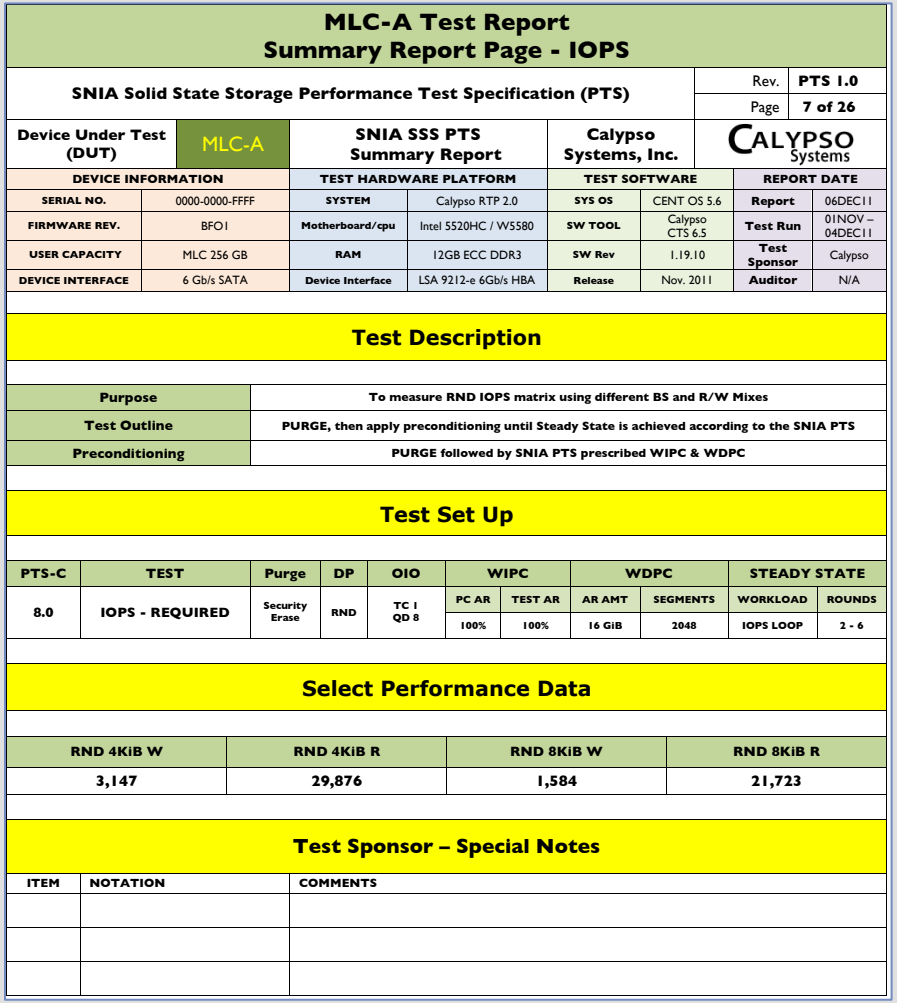
PTS 1.0 Report Format Summary Report Pages

- **Summary Report - All Tests**

Lists All Tests run on the Sample SSD

Includes Key Set-up Information

Generic Header Information applicable to All Tests



MLC-A Test Report
Summary Report Page - IOPS

SNIA Solid State Storage Performance Test Specification (PTS)				Rev.	PTS 1.0
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Device Under Test (DUT)	MLC-A	SNIA SSS PTS Summary Report	Calypso Systems, Inc.	CALYPSO Systems

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	01DEC11
FIRMWARE REV.	BFO1	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 SATA	Device Interface	LSA 9212-e 6Gb/s HBA	Release	Nov. 2011	Auditor	N/A

Test Description

Purpose	To measure RND IOPS matrix using different BS and R/W Mixes
Test Outline	PURGE, then apply preconditioning until Steady State is achieved according to the SNIA PTS
Preconditioning	PURGE followed by SNIA PTS prescribed WIPC & WDPC

Test Set Up

PTS-C	TEST	Purge	DP	OIO	WIPC		WDPC		STEADY STATE	
					PC AR	TEST AR	AR AMT	SEGMENTS	WORKLOAD	ROUNDS
8.0	IOPS - REQUIRED	Security Erase	RND	TC 1 QD 8	100%	100%	16 GiB	2048	IOPS LOOP	2 - 6

Select Performance Data

RND 4KiB W	RND 4KiB R	RND 8KiB W	RND 8KiB R
3,147	29,876	1,584	21,723

Test Sponsor – Special Notes

ITEM	NOTATION	COMMENTS

PTS 1.0 Report Format Summary Report Pages

- **Summary Report - IOPS Tests**

Summary of Individual Test

Includes Summary Test Description

Includes Key Set-up Information

Select Performance Data Extracted

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

Client IOPS (REQUIRED) - Report Page

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: 0123 ABCD MLC256	TEST SPONSOR	CALYPSO Systems

Serial No.	0000-0000-FFFF
Firmware Rev	BF01
Capacity	256 GB
NAND Type	MLC
Device I/F	6 Gb/s SATA
Test Platform	RTP 2.0 CTS 6.5

DUT Preparation	
Purge	Security Erase
Pre-Conditioning	
Workload Independent	2X SEQ/128KiB
Workload Dep.	Full IOPS Loop

Test Loop Parameters	
REQUIRED:	
Data Pattern	RND
Tester's Choice:	
OIO/Thread (QD)	8
Thread Count (TC)	1

Steady State	
Convergence	YES
Rounds	1-5
PC AR	100%
AR AMOUNT	16 GiB
AR Segments	2048

PTS 1.0 Report Format

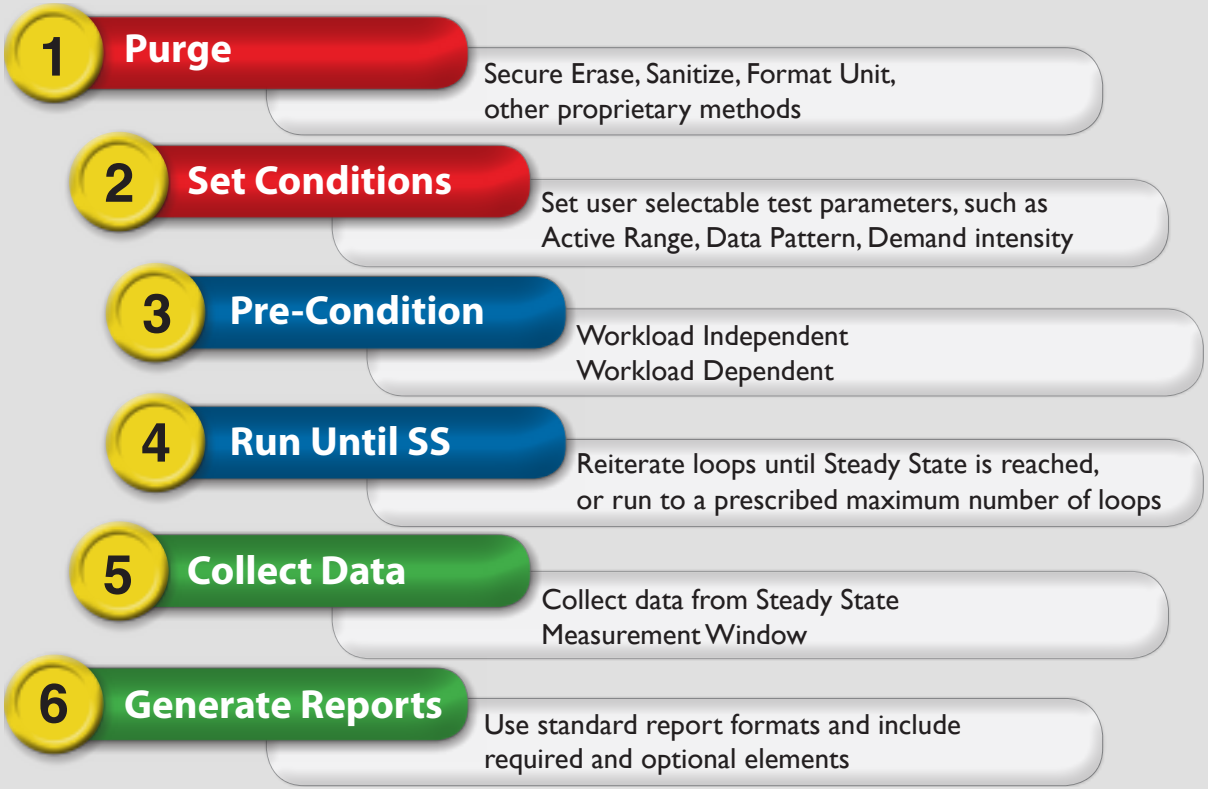
Individual Report Page Headers

- Required on Each Individual Test Report Page
- Lists the Settings pertaining to the reported Test

Key Header Information

- Device & Test System
- DUT Preparation: PURGE & Preconditioning
- Test Loop Parameters: Data Pattern, OIO in QD & TC
- Steady State: Convergence, Rounds, PC AR, AR Amount

PTS: Tests Steps



PTS-E IOPS: Steady State "Rounds"

Purge

WIPC:

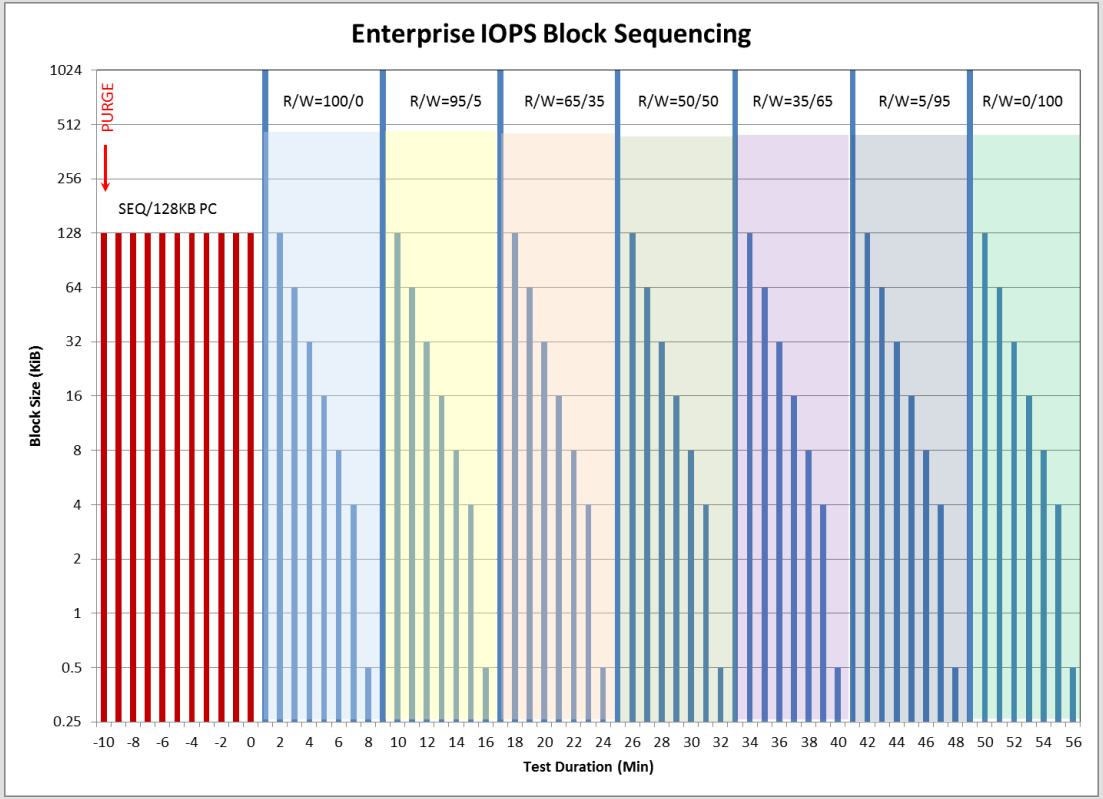
2X SEQ 128KiB W

WDPC:

IOPS "Loop"
(7) R/W Mixes x
(8) Block Sizes

= 56 (1) Minute Tests

1 Round = 56 Minutes



Test Run Date:	10/26/2011 01:14 PM	Report Run Date:	10/27/2011 09:37 AM

Client IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	PTS-C 1.0
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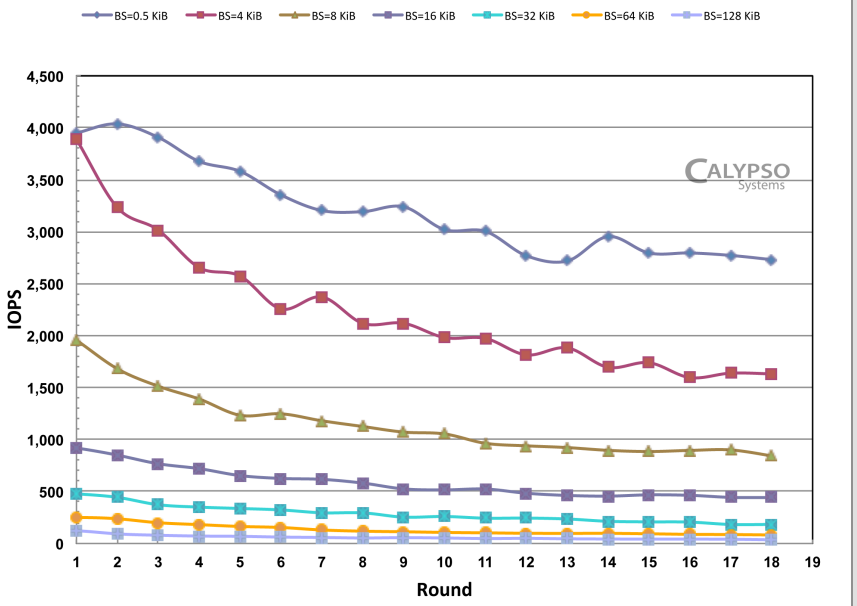
Device Under Test (DUT)		SLC-K	IOPS Test - REQUIRED	Calypso Systems Inc	CALYPSO Systems
MLC-K 240 GB		DUT Preparation		Test Loop Parameters	Steady State
S/N: 0000-0011-FFFF		Purge	Security Erase	REQUIRED:	Convergence: YES
DUT I/F	SATA 6Gb/s	Pre-Conditioning		Data Pattern: RND	Rounds: 14-18
SYS I/F	LSI 9212-4e4i ext. SAS	Workload Independent	2X SEQ/128KB	Tester's Choice:	Active Range
Test HW	Calypso RTP			OIO/Thread: 16	PC AR: 100%
Test SW	CTSv6.5	Workload Dep.	Full IOPS Loop	Thread Count: 2	AR Amount: 16 GB

Client Steady State Convergence Plot – All Block Sizes



Steady State Convergence Plot – IOPS

- Tracks Block Size IOPS by Rounds until Steady State
- (8) IOPS Block Sizes: 0.5, 4, 8, 16, 32, 64, 128 & 1024 KiB

Note Header Preconditioning & Test Loop Data

- WIPC: 2X SEQ 128KiB
- WDPC: Full IOPS Loop
- Data Pattern: RND
- OIO: 32 (TC 16 x QD 2)

Reader can observe:

- The Effects of RND IOs after SEQ Preconditioning
- If all Block Sizes are evolving to Steady State
- If the tracking Block Size variable is trending or fluctuating
- The IOPS value of any Block Size at any Round

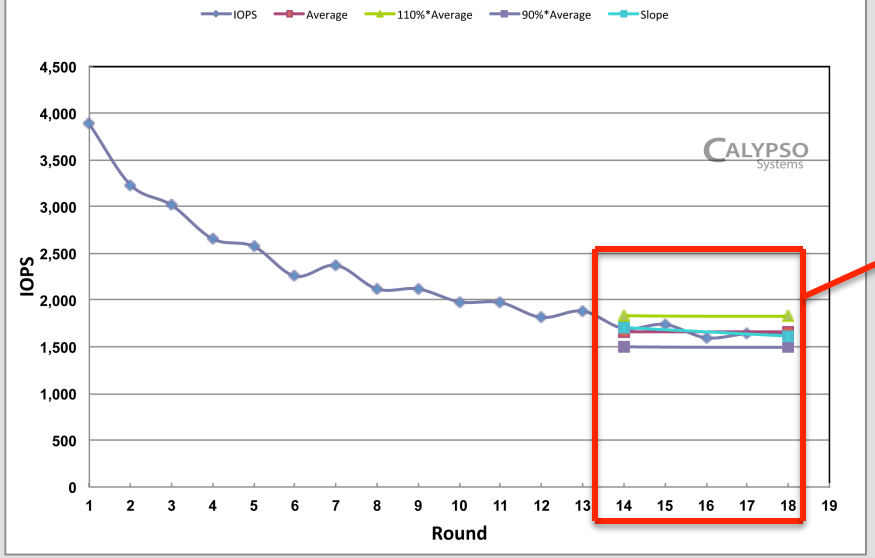
Test Run Date:	10/26/2011 01:14 PM	Report Run Date:	10/27/2011 09:37 AM

Client IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)				Rev.	PTS-C 1.0
				Page	2 of 6
Device Under Test (DUT)	SLC-K	IOPS Test - REQUIRED	Calypso Systems Inc	CALYPSO Systems	

MLC-K 240 GB	DUT Preparation		Test Loop Parameters		Steady State	
S/N: 0000-0011-FFFF	Purge	Security Erase	REQUIRED:		Convergence	YES
DUT I/F	SATA 6Gb/s	Pre-Conditioning	Data Pattern	RND	Rounds	14-18
SYS I/F	LSI 9212-4e4i ext. SAS	Workload Independent	Tester's Choice:		Active Range	
Test HW	Calypso RTP	2X SEQ/128KB	OIO/Thread	16	PC AR	100%
Test SW	CTSv6.5	Workload Dep.	Thread Count	2	AR Amount	16 GB
		Full IOPS Loop				

Client Steady State Measurement Window



Steady State Measurement Window – IOPS

- Tracking Variable by Rounds until Steady State
- IOPS Tracking Variable - RND 4KiB

Note Header Steady State Information:

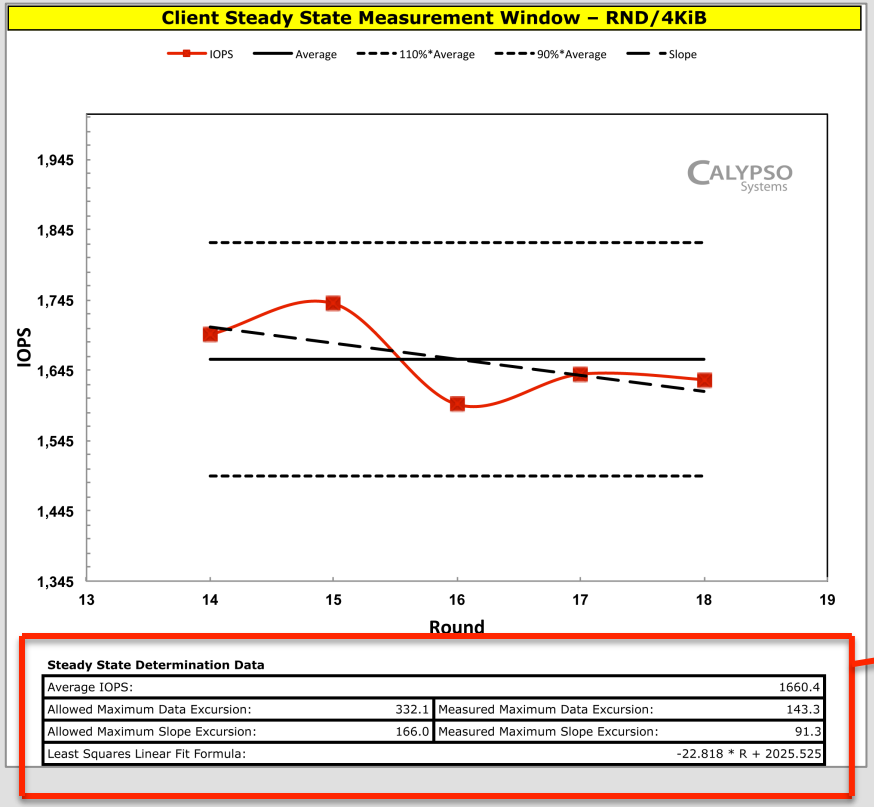
- Steady State Convergence: Yes
- Steady State Rounds: 14-18
- PC AR: 100%
- AR Amount: 16GiB

Reader can observe the:

- Behavior of Tracking Variable over Convergence Rounds
- Rounds constituting Steady State Measurement Window

Note: Throughput and Latency Tracking Variables

- PTS-C TP: SEQ 1024KiB in MB/s
- PTS-E TP: SEQ 128KiB /1024KiB in MB/s
- PTS-C & PTS-E LAT: RND 4KiB in mSec



SS Measurement Window Calculation - IOPS

Expands the 5 Round Steady State Measurement Window

Note Steady State Determination Data:

- 20% Max Data Excursion Bounds (2 dotted black lines)
- Average IOPS of 5 Rounds (solid black line)
- Least Mean Squares Linear Curve Fit (red line)
- 10% Max Slope Excursion of Curved Fit (dashed black line)

Reader can observe the:

- "Quality" of Steady State Window
- Scale of IOPS for Window Round Variation
- Steady State Determination Calculations at bottom of page

MLC-A PTS Test Report IOPS: Test Set-Up Pages 1-3

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

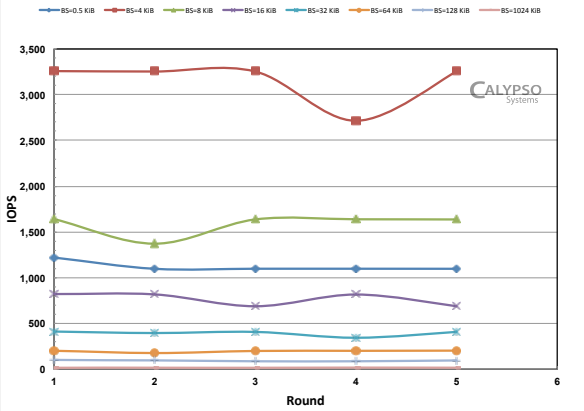
Client IOPS (REQUIRED) - Report Page

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.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State
Firmware Rev	BF01	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	Tester's Choice:		PC AR / 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	8	AR AMOUNT / 16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	1	AR Segments / 2048

Steady State Convergence Plot – All Block Sizes



Steady State Convergence

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

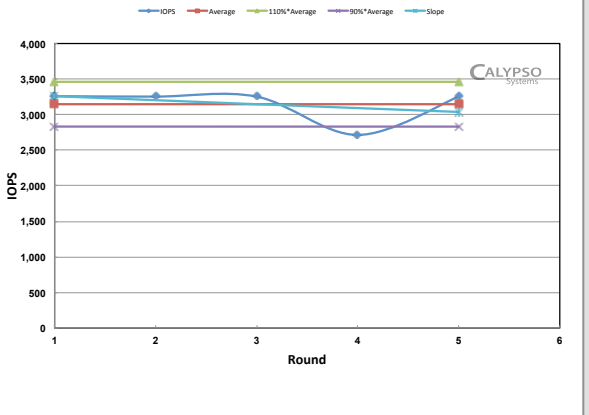
Client IOPS (REQUIRED) - Report Page

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.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State
Firmware Rev	BF01	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	Tester's Choice:		PC AR / 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	8	AR AMOUNT / 16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	1	AR Segments / 2048

Steady State Measurement Window



Steady State Window

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

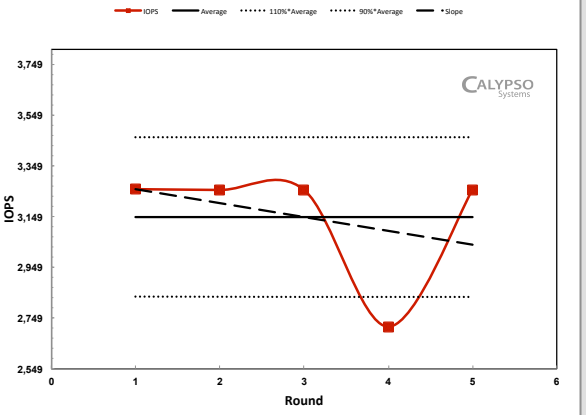
Client IOPS (REQUIRED) - Report Page

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.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State
Firmware Rev	BF01	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	Tester's Choice:		PC AR / 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	8	AR AMOUNT / 16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	1	AR Segments / 2048

Steady State Measurement Window – RND/4KiB



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

Steady State Measurement Calculations

MLC-A PTS Test Report IOPS: Results Pages 4-6

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

Client IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-C 1.0 — Page 4 of 6

Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR

Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	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	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	8	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	1	AR Segments	2048

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

Tabular Data

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

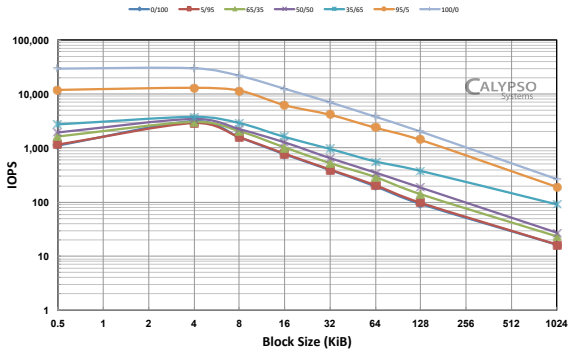
Client IOPS (REQUIRED) - Report Page

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

Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	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	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	8	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	1	AR Segments	2048

Client IOPS - ALL RW Mix & BS - 2D Plot



2D Plot

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

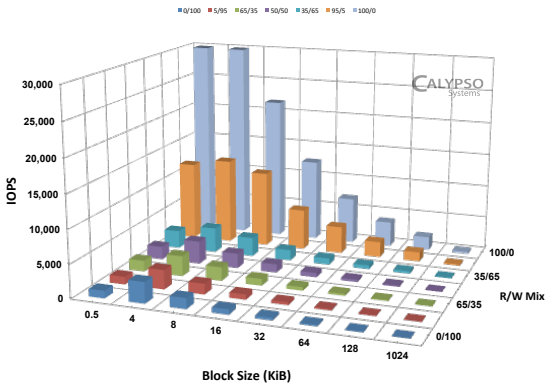
Client IOPS (REQUIRED) - Report Page

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

Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	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	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	8	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	1	AR Segments	2048

Client IOPS - ALL RW Mix & BS – 3D Columns



3D Bar Plot

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8. Conclusion

SNIA PTS SSD Performance Test Comparison				
Products Tested	MLC-A 256 GB	MLC-B 160 GB	SLC-A 100 GB	SLC-B 100 GB
Test Platform Hardware / Software	Calypso RTP 2.0 Intel 5520HC, Intel Xeon 5580 12GB ECC DDR3 RAM, LSI 6GB/s HBA		Calypso CTS 6.5 Cent OS 5.6	
Tests Run	WSAT (FOB)	IOPS (Steady State)	TP (Steady State)	LAT (Steady State)

Summary Performance - Selected					
Test	Workload	MLC-A 256 GB	MLC-B 160 GB	SLC-A 100 GB	SLC-B 100 GB
WSAT	FOB RND 4KiB W	56,896	20,364	39,092	55,677
	Steady State RND 4KiB W	2,714	658	16,305	19,415
IOPS	RND 4KiB R	29,876	38,087	93,707	46,365
	RND 4KiB W	3,147	152	16,563	19,561
Throughput MB/s	SEQ 1024KiB R	417	264	514	437
	SEQ 1024KiB W	267	99	157	205
Latency mSec (smaller value is better)	RND 4KiB R Ave	0.20	0.19	0.16	0.18
	RND 4KiB W Ave	0.35	1.00	0.09	0.08
	RND 4KiB R Max	1.60	1.43	6.26	0.39
	RND 4KiB W Max	51.00	288.29	32.63	443.94
LINKS		MLC-A	MLC-B	SLC-A	SLC-B

SNIA PTS SSD Performance Test Comparison				
Products Tested	MLC-A 256 GB	MLC-B 160 GB	SLC-A 100 GB	SLC-B 100 GB
Test Platform Hardware / Software	Calypso RTP 2.0 Intel 5520HC, Intel Xeon 5580 12GB ECC DDR3 RAM, LSI 6GB/s HBA		Calypso CTS 6.5 Cent OS 5.6	
Tests Run	WSAT (FOB)	IOPS (Steady State)	TP (Steady State)	LAT (Steady State)

Summary Performance - Selected					
Test	Workload	MLC-A 256 GB	MLC-B 160 GB	SLC-A 100 GB	SLC-B 100 GB
WSAT	FOB RND 4KiB W	56,896	20,364	39,092	55,677
	Steady State RND 4KiB W	2,714	658	16,305	19,415
IOPS	RND 4KiB R	29,876	38,087	93,707	46,365
	RND 4KiB W	3,147	152	16,563	19,561
Throughput MB/s	SEQ 1024KiB R	417	264	514	437
	SEQ 1024KiB W	267	99	157	205
Latency mSec (smaller value is better)	RND 4KiB R Ave	0.20	0.19	0.16	0.18
	RND 4KiB W Ave	0.35	1.00	0.09	0.08
	RND 4KiB R Max	1.60	1.43	6.26	0.39
	RND 4KiB W Max	51.00	288.29	32.63	443.94
LINKS		MLC-A	MLC-B	SLC-A	SLC-B

Individual PTS Tests

SNIA PTS SSD Performance Test Comparison				
Products Tested	MLC-A 256 GB	MLC-B 160 GB	SLC-A 100 GB	SLC-B 100 GB
Test Platform Hardware / Software	Calypso RTP 2.0 Intel 5520HC, Intel Xeon 5580 12GB ECC DDR3 RAM, LSI 6GB/s HBA		Calypso CTS 6.5 Cent OS 5.6	
Tests Run	WSAT (FOB)	IOPS (Steady State)	TP (Steady State)	LAT (Steady State)

Summary Performance - Selected					
Test	Workload	MLC-A 256 GB	MLC-B 160 GB	SLC-A 100 GB	SLC-B 100 GB
WSAT	FOB RND 4KiB W	56,896	20,364	39,092	55,677
	Steady State RND 4KiB W	2,714	658	16,305	19,415
IOPS	RND 4KiB R	29,876	38,087	93,707	46,365
	RND 4KiB W	3,147	152	16,563	19,561
Throughput MB/s	SEQ 1024KiB R	417	264	514	437
	SEQ 1024KiB W	267	99	157	205
Latency mSec (smaller value is better)	RND 4KiB R Ave	0.20	0.19	0.16	0.18
	RND 4KiB W Ave	0.35	1.00	0.09	0.08
	RND 4KiB R Max	1.60	1.43	6.26	0.39
	RND 4KiB W Max	51.00	288.29	32.63	443.94
LINKS		MLC-A	MLC-B	SLC-A	SLC-B

Link to Summary Report

Link to Full SNIA Report

PTS-C — MLC-A Summary Performance - Selected

WSAT (Optional)

BS / RW	FOB / Steady State	IOPS
RND 4KiB 100% W	FOB	56,896
	Steady State	2,714

Parameter	Setting	Parameter	Setting
PC AR	100%	QD / TC	2 / 16
Test AR	100%	Duration (T or SB)	20 Hr/18 TB
WIPC	NA - FOB	Device I/F	6Gb/s SATAII
WDPC	NA - FOB	Test System	RTP 2.0 / CTS 6.5

FOB: No PC

IOPS TEST

Block Size	R/W Mix	IOPS
RND 4KiB	100% R	29,876
	100% W	3,147
RND 8KiB	100% R	21,723
	100% W	1,585

Parameter	Setting	Parameter	Setting
PC AR / Test AR	100% / 100%	QD / TC	8 / 1
AR Amt/Segments	16 GiB/2048	SS Rounds	1 - 5
WIPC	2X SEQ 128KiB W + IOPS Loop	Device I/F	6Gb/s SATAII
WDPC	IOPS Loop	Test System	RTP 2.0 / CTS 6.5

WIPC: SEQ128KiB + IOPS Loop
WDPC: IOPS Loop

THROUGHPUT MB/Sec

Block Size	R/W Mix	MB/Sec
SEQ 1024KiB	100% R	417
	100% W	267

Parameter	Setting	Parameter	Setting
PC AR / Test AR	100% / 100%	QD / TC	32 / 32
AR Amt/Segments	16 GiB/2048	SS Rounds	1 - 5
WIPC	2X SEQ 128KiB W + SEQ 1024KiB	Device I/F	6Gb/s SATAII
WDPC	SEQ 1024KiB	Test System	RTP 2.0 / CTS 6.5

WIPC: SEQ128KiB + SEQ 1024KiB
WDPC: SEQ 1024KiB

LATENCY mSec (smaller value is better)

Block Size	R/W Mix	mSec
RND 4KiB AVE	100% R	0.20
	100% W	0.35
RND 4KiB MAX	100% R	1.60
	100% W	51.00

Parameter	Setting	Parameter	Setting
PC AR / Test AR	100% / 100%	QD / TC	1 / 1
AR Amt/Segments	16 GiB/2048	SS Rounds	4 - 8
WIPC	2X SEQ 128KiB W + LAT Loop	Device I/F	6Gb/s SATAII
WDPC	LAT Loop	Test System	RTP 2.0 / CTS 6.5

OIO = 1

PTS-C — MLC-B Summary Performance - Selected

	BS / RW	FOB / Steady State	IOPS
WSAT (Optional)	RND 4KiB 100% W	FOB	20,364
		Steady State	658

Parameter	Setting	Parameter	Setting
PC AR	100%	QD / TC	2/ 16
Test AR	100%	Duration (T or GB)	12 Hr/250 GB
WIPC	NA - FOB	Device I/F	6Gb/s SATAII
WDPC	NA - FOB	Test System	RTP 2.0 / CTS 6.5

	Block Size	R/W Mix	IOPS
IOPS TEST	RND 4KiB	100% R	38,088
		100% W	152
	RND 8KiB	100% R	22,979
		100% W	151

Parameter	Setting	Parameter	Setting
PC AR / Test AR	100% / 100%	QD / TC	32 / 1
AR Amt/Segments	16 GiB/2048	SS Rounds	9 - 13
WIPC	2X SEQ 128KiB W + IOPS Loop	Device I/F	6Gb/s SATAII
WDPC	IOPS Loop	Test System	RTP 2.0 / CTS 6.5

PC AR:
16GiB
2048 Segments

	Block Size	R/W Mix	MB/Sec
THROUGHPUT MB/Sec	SEQ 1024KiB	100% R	264
		100% W	99

Parameter	Setting	Parameter	Setting
PC AR / Test AR	100% / 100%	QD / TC	2 / 1
AR Amt/Segments	16 GiB/2048	SS Rounds	1 - 5
WIPC	2X SEQ 128KiB W + SEQ 1024KiB	Device I/F	6Gb/s SATAII
WDPC	SEQ 1024KiB	Test System	RTP 2.0 / CTS 6.5

	Block Size	R/W Mix	mSec
LATENCY mSec (smaller value is better)	RND 4KiB AVE	100% R	0.19
		100% W	1.00
	RND 4KiB MAX	100% R	1.43
		100% W	288.29

Parameter	Setting	Parameter	Setting
PC AR / Test AR	100% / 100%	QD / TC	1 / 1
AR Amt/Segments	16 GiB/2048	SS Rounds	12 - 16
WIPC	2X SEQ 128KiB W + LAT Loop	Device I/F	6Gb/s SATAII
WDPC	LAT Loop	Test System	RTP 2.0 / CTS 6.5

PTS-E	SLC-A Summary Performance - Selected							
WSAT	BS / RW	FOB / Steady State	IOPS		Parameter	Setting	Parameter	Setting
	RND 4KiB 100% W	FOB	39,092		PC AR	100%	QD / TC	16 / 2
		Steady State	16,305		Test AR	100%	Duration (T or GB)	12 Hr / 2.9 TB
					WIPC	NA - FOB	Device I/F	6Gb/s SAS
					WDPC	NA - FOB	Test System	RTP 2.0 / CTS 6.5
IOPS TEST	Block Size	R/W Mix	IOPS		Parameter	Setting	Parameter	Setting
	RND 4KiB	100% R	93,707		PC AR	100%	QD / TC	16 / 2
		100% W	16,563		Test AR	100%	SS Rounds	1 - 5
	RND 8KiB	100% R	50,301		WIPC	2X SEQ 128KiB W	Device I/F	6Gb/s SAS
		100% W	9,560		WDPC	IOPS Loop	Test System	RTP 2.0 / CTS 6.5
THROUGHPUT MB/Sec	Block Size	R/W Mix	MB/Sec		Parameter	Setting	Parameter	Setting
	SEQ 128KiB	100% R	409		PC AR	100%	QD / TC	16 /2
		100% W	145		Test AR	100%	SS Rounds	5 - 9
	SEQ 1024KiB	100% R	514		WIPC	2X SEQ 128KiB W	Device I/F	6Gb/s SAS
		100% W	157		WDPC	SEQ 128./1024KiB	Test System	RTP 2.0 / CTS 6.5
LATENCY mSec (smaller value is better)	Block Size	R/W Mix	mSec		Parameter	Setting	Parameter	Setting
	RND 4KiB AVE	100% R	0.16		PC AR	100%	QD / TC	1 / 1
		100% W	0.09		Test AR	100%	SS Rounds	3 - 7
	RND 4KiB MAX	100% R	6.26		WIPC	2X SEQ 128KiB W	Device I/F	6Gb/s SAS
		100% W	32.63		WDPC	LAT Loop	Test System	RTP 2.0 / CTS 6.5

PTS-E TP
2 Block Sizes

PC AR:
100% LBA

PTS-E	SLC-B Summary Performance - Selected							
WSAT	BS / RW	FOB / Steady State	IOPS		Parameter	Setting	Parameter	Setting
	RND 4KiB 100% W	FOB	55,677		PC AR	100%	QD / TC	16 / 2
					Test AR	100%	Duration (T or GB)	6 Hr / 1.9 TB
		Steady State	19,415		WIPC	NA - FOB	Device I/F	6Gb/s SAS
					WDPC	NA - FOB	Test System	RTP 2.0 / CTS 6.5
IOPS TEST	Block Size	R/W Mix	IOPS		Parameter	Setting	Parameter	Setting
	RND 4KiB	100% R	46,365		PC AR	100%	QD / TC	16 / 2
		100% W	19,561		Test AR	100%	SS Rounds	2 - 6
	RND 8KiB	100% R	32,259		WIPC	2X SEQ 128KiB W	Device I/F	6Gb/s SAS
		100% W	10,630		WDPC	IOPS Loop	Test System	RTP 2.0 / CTS 6.5
THROUGHPUT MB/Sec	Block Size	R/W Mix	MB/Sec		Parameter	Setting	Parameter	Setting
	SEQ 128KiB	100% R	419		PC AR	100%	QD / TC	16 / 2
		100% W	248		Test AR	100%	SS Rounds	4 - 8
	SEQ 1024KiB	100% R	437		WIPC	2X SEQ 128KiB W	Device I/F	6Gb/s SAS
		100% W	205		WDPC	SEQ 128/1024KiB	Test System	RTP 2.0 / CTS 6.5
LATENCY mSec (smaller value is better)	Block Size	R/W Mix	mSec		Parameter	Setting	Parameter	Setting
	RND 4KiB AVE	100% R	0.18		PC AR	100%	QD / TC	1 / 1
		100% W	0.08		Test AR	100%	SS Rounds	2 - 6
	RND 4KiB MAX	100% R	0.39		WIPC	2X SEQ 128KiB W	Device I/F	6Gb/s SAS
		100% W	443.94		WDPC	LAT Loop	Test System	RTP 2.0 / CTS 6.5

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WSAT Client WSAT MLC-A

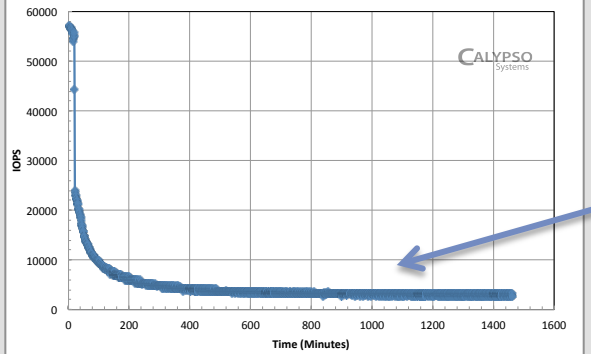
Test Run Date:	11/17/2011 09:30 AM	Report Run Date:	11/22/2011 12:44 PM

Client WSAT (OPTIONAL) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-C 1.0 — Page 1 of 4

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:	Convergence N/A
Capacity	256 GB	Pre-Conditioning		Data Pattern RND	Rounds N/A
NAND Type	MLC	Workload Independent	N/A	Tester's Choice:	PC AR 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD) 2	AR AMOUNT 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC) 16	AR Segments N/A

Client IOPS (Linear) vs Time (Linear)



IOPS v Time

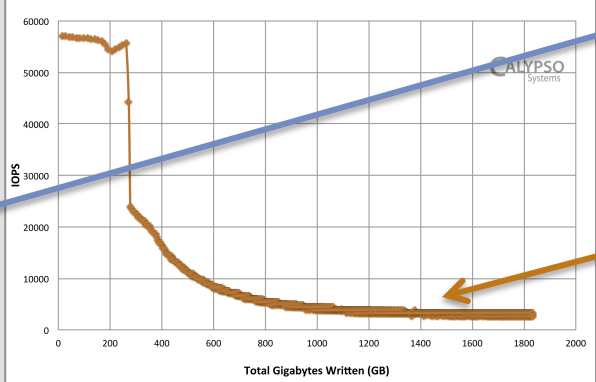
Test Run Date:	11/17/2011 09:30 AM	Report Run Date:	11/22/2011 12:44 PM

Client WSAT (OPTIONAL) - Report Page

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	CALYPSO Systems
Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:	Convergence N/A
Capacity	256 GB	Pre-Conditioning		Data Pattern RND	Rounds N/A
NAND Type	MLC	Workload Independent	N/A	Tester's Choice:	PC AR 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD) 2	AR AMOUNT 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC) 16	AR Segments N/A

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



IOPS v TGBW

RND 4KiB W from FOB

IOPS v TIME:

- FOB Peak Drop: **60 Minutes**
- FOB to Steady State: **1000 Minutes**
- Peak IOPS: **56,896**
- Steady State IOPS: **2,714**

IOPS v TGBW:

- FOB Peak Drop: **250 TGBW**
- FOB to Steady State: **1400 TGBW**
- SSD Capacity 256GB
- Peak Drop in (1) Drive Fill
- Steady State after (5) Drive Fills

Note Header Information:

- WIPC: None
- WDPC: RND 4KiB
- OIO: 32 (QD=2 / TC=16)

Client IOPS MLC-A

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

Client IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	PTS-C 1.0
	Page	4 of 6

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BF01	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	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 8	AR AMOUNT: 16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC): 1	AR Segments: 2048

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

RND 4KiB IOPS 100% W:

- IOPS = 3,147 IOPS
- WSAT = 2,714 IOPS

Header Information:

- WIPC: 2X SEQ 128KiB
- WDPC: IOPS Loop
- OIO: 8 (QD=8 / TC=1)
- SS Rounds: 1-5
- AR Amount = 16GiB
- AR Segments = 2048

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

Client IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	PTS-C 1.0
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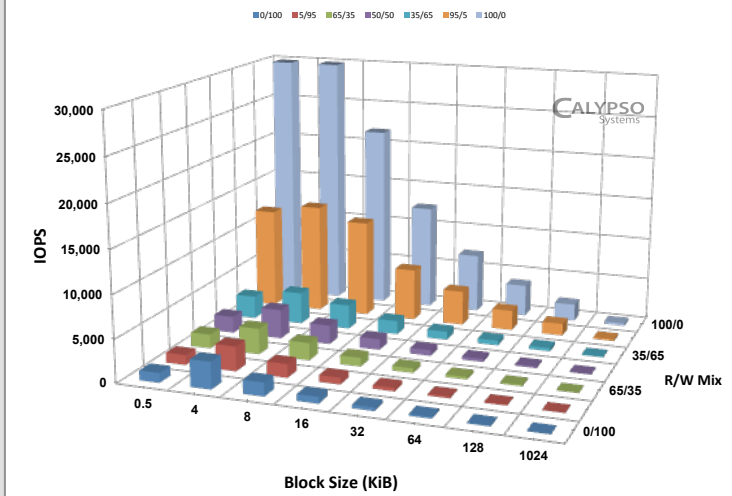
Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:	Convergence: YES
Capacity	256 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 1-5
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 8	AR AMOUNT: 16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC): 1	AR Segments: 2048

Client IOPS - ALL RW Mix & BS – 3D Columns

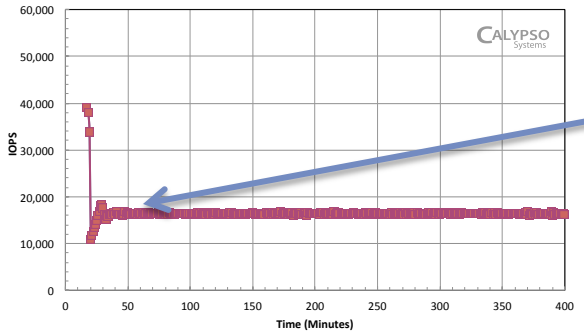


WSAT Enterprise WSAT SLC-A

Test Run Date:	11/07/11 08:40 AM	Report Run Date:	11/14/2011 08:45 AM
Enterprise WSAT (REQUIRED) - Report Page			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)		Rev.	PTS-E 1.0
		Page	1 of 4

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Convergence N/A
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:	Rounds N/A
Capacity	100 GB	Pre-Conditioning		Data Pattern RND	PC AR 100%
NAND Type	SLC	Workload Independent	None	Tester's Choice:	AR AMOUNT 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD) 16	AR Segments N/A
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC) 2	OPT: N/A

Enterprise IOPS (Linear) vs Time (Linear)

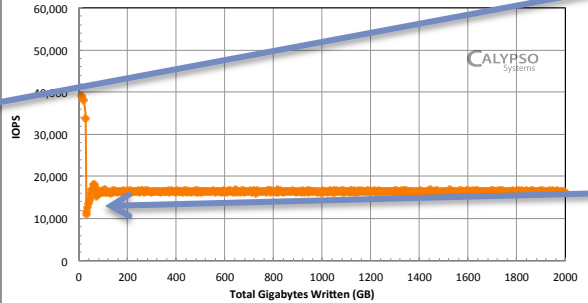


IOPS v Time

Test Run Date:	11/07/11 08:40 AM	Report Run Date:	11/14/2011 08:45 AM
Enterprise WSAT (REQUIRED) - Report Page			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)		Rev.	PTS-E 1.0
		Page	3 of 4

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Convergence N/A
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:	Rounds N/A
Capacity	100 GB	Pre-Conditioning		Data Pattern RND	PC AR 100%
NAND Type	SLC	Workload Independent	None	Tester's Choice:	AR AMOUNT 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD) 16	AR Segments N/A
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC) 2	OPT: N/A

Enterprise IOPS (Linear) vs TGBW (Linear)



IOPS v TGBW

RND 4KiB W from FOB

IOPS v TIME:

- FOB Peak Drop: **30 Minutes**
- FOB to Steady State: **50 Minutes**
- Peak IOPS: **39,092**
- Steady State IOPS: **16,305**

IOPS v TGBW:

- FOB Peak Drop: **70 GB**
- FOB to Steady State: **150 GB**
- SSD Capacity 100GB
- Peak Drop in (0.7) Drive Fills
- Steady State after (1.5) Drive Fills

Note Header Information:

- WIPC: None
- WDPC: RND 4KiB
- OIO: 32 (QD=16 / TC=2)

Enterprise IOPS SLC-A

Test Run Date:	11/02/2011 02:56 PM	Report Run Date:	11/14/2011 08:43 AM

Enterprise IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	PTS-E 1.0
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Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 1-5
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD): 16	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC): 2	AR Segments: N/A

Enterprise IOPS - ALL RW Mix & BS – Tabular Data

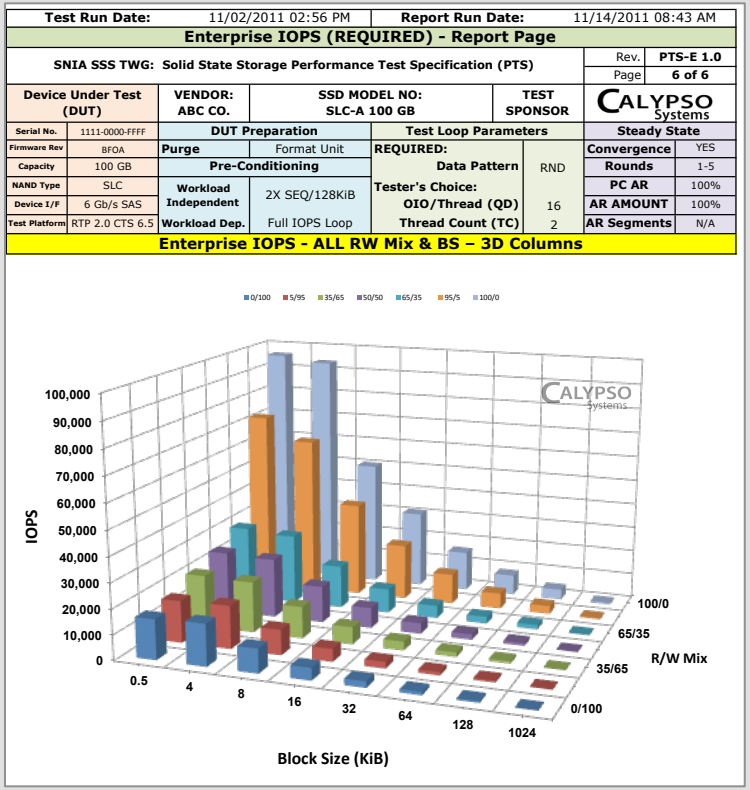
Block Size (KiB)	Read / Write Mix %						
	0/100	5/95	35/65	50/50	65/35	95/5	100/0
0.5	15,887.4	16,634.7	20,678.6	24,402.8	29,386.2	72,428.4	95,924.3
4	16,563.0	17,032.2	20,234.2	23,705.2	28,018.6	63,447.7	93,707.0
8	9,559.8	9,998.4	12,547.1	14,636.6	17,199.1	37,872.9	50,301.2
16	4,842.2	5,032.3	6,802.5	8,132.1	9,655.8	22,462.2	31,072.8
32	2,413.3	2,535.4	3,478.4	4,241.3	5,061.7	12,174.7	15,994.2
64	1,219.2	1,275.7	1,728.4	2,126.1	2,726.3	6,284.6	8,094.9
128	612.7	632.5	859.1	1,061.4	1,709.4	3,205.7	4,060.8
1024	74.8	78.0	103.6	126.7	202.7	398.8	514.6

RND 4KiB IOPS 100% W:

- IOPS = 16,563 IOPS
- WSAT = 16,305 IOPS

Header Information:

- WIPC: 2X SEQ 128KiB
- WDPC: IOPS Loop
- OIO: 32 (QD=16 / TC=2)
- SS Rounds: 1-5
- PC AR = 100%



TP Client Throughput MLC-A

Test Run Date:	11/13/2011 10:24 AM	Report Run Date:	11/21/2011 04:03 PM

Client Throughput Test (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-C 1.0 — Page 4 of 5

Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR	CALYPSO Systems

Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	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	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	32	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	SEQ 1024KiB	Thread Count (TC)	32	AR Segments	2048

Client Throughput - ALL RW Mix & BS – Tabular Data

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

TP Tables

Test Run Date:	11/13/2011 10:24 AM	Report Run Date:	11/21/2011 04:03 PM

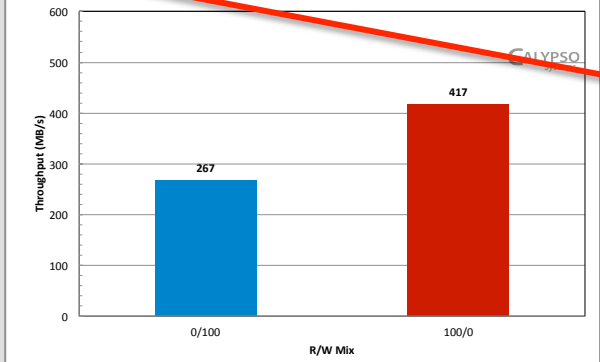
Client Throughput Test (REQUIRED) - Report Page

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	CALYPSO Systems

Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	256 GB	Pre-Conditioning		Data Pattern	RND	Rounds	1-5
Device I/F	6 Gb/s SATA	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
		Workload Dep.	SEQ 1024KiB	OIO/Thread (QD)	32	AR AMOUNT	16 GiB
				Thread Count (TC)	32	AR Segments	2048

Client Throughput - ALL RW Mix & BS - 2D Plot



TP Pots

SEQ 1024KiB R/W

100% R: 417 MB/Sec

100% W: 267 MB/Sec

Note Header Information:

- Device I/F: 6Gb/s SATA
- OIO: 1024 (QD=32 / TC=32)
- WIPC: SEQ 128KiB
- WDPC: SEQ 1024KiB
- SS Rounds: 1-5
- AR Amount: 16GiB
- AR Segments: 2048

TP Enterprise Throughput SLC-A 1024KiB

Test Run Date:	12/04/2011 08:21 AM	Report Run Date:	12/04/2011 10:03 AM

Enterprise Throughput Test (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 4 of 5

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 4-8
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD): 16	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	SEQ 1024KiB	Thread Count (TC): 2	AR Segments: N/A

Enterprise 1024KiB Throughput - ALL RW Mix & BS – Tabular Data

Block Size (KiB)	Read / Write Mix % 0/100	100/0
1024	157.5	514.3

TP Tables

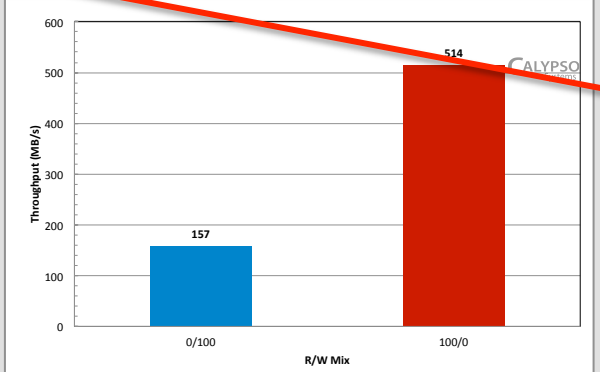
Test Run Date:	12/04/2011 08:21 AM	Report Run Date:	12/04/2011 10:03 AM

Enterprise Throughput Test (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 5 of 5

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 4-8
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD): 16	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	SEQ 1024KiB	Thread Count (TC): 2	AR Segments: N/A

Enterprise 1024KiB Throughput - ALL RW Mix & BS - 2D Plot



TP Pots

SEQ 1024KiB R/W

100% R: 514 MB/Sec

100% W: 157 MB/Sec

Note Header Information:

- Device I/F: 6Gb/s SAS
- OIO: 32 (QD=16 / TC=2)
- WIPC: SEQ 128KiB
- WDPC: SEQ 1024KIB
- SS Rounds: 4-8
- AR Amount: 100%
- AR Segments: N/A

TP Enterprise Throughput SLC-A 128KiB

Test Run Date:	12/03/2011 04:32 PM	Report Run Date:	12/04/2011 10:04 AM

Enterprise Throughput Test (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 4 of 5

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 4-8
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD): 16	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	SEQ 128KiB	Thread Count (TC): 2	AR Segments: N/A

Enterprise 128KiB Throughput - ALL RW Mix & BS – Tabular Data

Block Size (KiB)	Read / Write Mix % 0/100	100/0
128	144.5	409.3

TP Tables

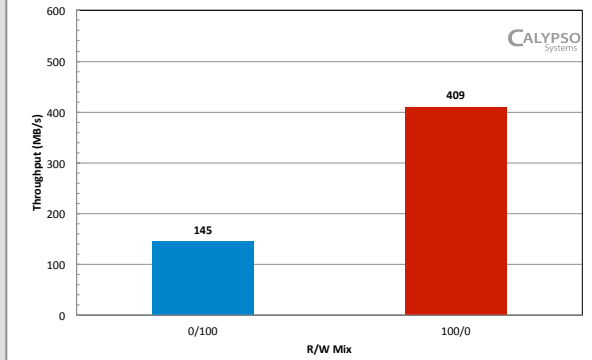
Test Run Date:	12/03/2011 04:32 PM	Report Run Date:	12/04/2011 10:04 AM

Enterprise Throughput Test (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 5 of 5

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 4-8
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD): 16	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	SEQ 128KiB	Thread Count (TC): 2	AR Segments: N/A

Enterprise 128KiB Throughput - ALL RW Mix & BS - 2D Plot



TP Pots

SEQ 128KiB R/W

100% R: 409 MB/Sec

100% W: 145 MB/Sec

Note Header Information:

- Device I/F: 6Gb/s SAS
- OIO: 32 (QD=16 / TC=2)
- WIPC: SEQ 128KiB
- WDPC: SEQ 128KiB
- SS Rounds: 4-8
- AR Amount: 100%
- AR Segments: N/A

LAT Client Latency MLC-A

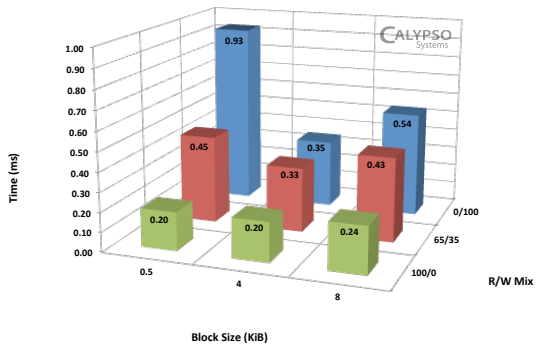
Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM

Client Latency (REQUIRED) - Report Page

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.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:	Convergence: YES
Capacity	256 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 4-8
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 1	AR AMOUNT: 16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full Latency Loop	Thread Count (TC): 1	AR Segments: 2048

Client - AVE Latency vs BS and R/W Mix - 3D Plot



AVE Latency

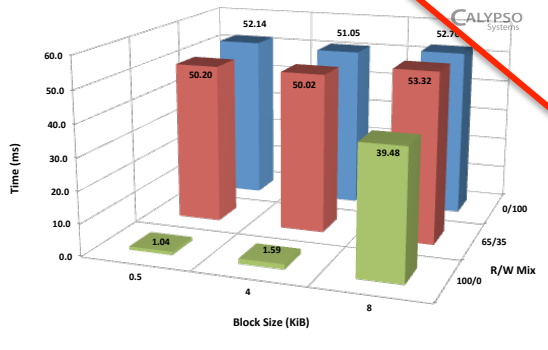
Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM

Client Latency (REQUIRED) - Report Page

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.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:	Convergence: YES
Capacity	256 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 4-8
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 1	AR AMOUNT: 16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full Latency Loop	Thread Count (TC): 1	AR Segments: 2048

Client - MAX Latency vs BS and R/W Mix - 3D Plot



MAX Latency

RND 0.5, 4, 8 KiB

AVE Latency:

- 4KiB 100/0 R/W: **0.20 mSec**
- 4KiB 65/35 R/W: **0.30 mSec**
- 4KiB 0/100 R/W: **0.35 mSec**

MAX Latency:

- 4KiB 100/0 R/W: **1.30 mSec**
- 4KiB 65/35 R/W: **50.02 mSec**
- 4KiB 0/100 R/W: **51.05 mSec**

Note Header Information:

- OIO: 1 (QD=1 / TC=1)
- WIPC: 2X SEQ 128KiB
- WDPC: LAT Loop
- SS Rounds: 4-8

LAT Enterprise Latency SLC-A

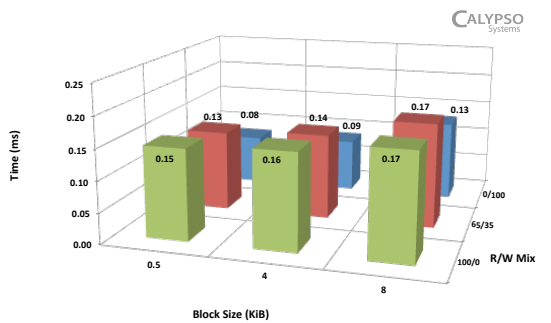
Test Run Date:	11/10/2011 05:07 AM	Report Run Date:	11/14/2011 08:47 AM

Enterprise Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 5 of 6

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	8F0A	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 3-7
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice: OIO/Thread (QD): 1	PC AR: 100%
Device I/F	6 Gb/s SAS				AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full LAT Loop	Thread Count (TC): 1	AR Segments: N/A

Enterprise AVE Latency vs BS and R/W Mix - 3D Plot



AVE Latency

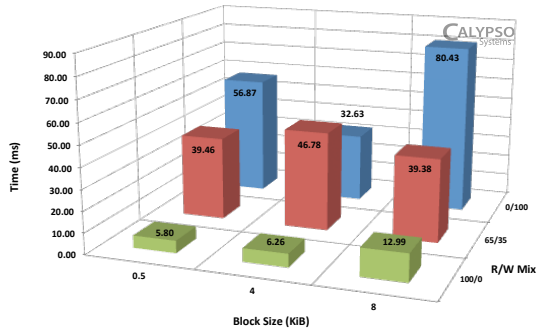
Test Run Date:	11/10/2011 05:07 AM	Report Run Date:	11/14/2011 08:47 AM

Enterprise Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 6 of 6

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	8F0A	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 3-7
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice: OIO/Thread (QD): 1	PC AR: 100%
Device I/F	6 Gb/s SAS				AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full LAT Loop	Thread Count (TC): 1	AR Segments: N/A

Enterprise MAX Latency vs BS and R/W Mix - 3D Plot



MAX Latency

RND 0.5, 4, 8 KiB

AVE Latency:

- 4KiB 100/0 R/W: **0.16 mSec**
- 4KiB 65/35 R/W: **0.14 mSec**
- 4KiB 0/100 R/W: **0.09 mSec**

MAX Latency:

- 4KiB 100/0 R/W: **6.26 mSec**
- 4KiB 65/35 R/W: **46.78 mSec**
- 4KiB 0/100 R/W: **32.63 mSec**

Note Header Information:

- OIO: 1 (QD=1 / TC=1)
- WIPC: 2X SEQ 128KiB
- WDPC: LAT Loop
- SS Rounds: 3-7

Download this deck at www.snia.org/forums/sssi/pts

1. Principles of NAND Flash SSD Performance
2. How IOs Traverse the S/W H/W Stack
3. PTS Client & Enterprise Test Specifications
4. Summary SSD Comparisons – **www.snia.org/forums/sssi/pts**
5. Using PTS Reports to Understand SSD Behavior
6. **Using PTS Reports to Compare SSD Behavior**
7. SSD Test Best Practices
8. Conclusion

WSAT Comparing Client WSAT - IOPS v TIME

Test Run Date:	11/17/2011 09:30 AM	Report Run Date:	11/22/2011 12:44 PM

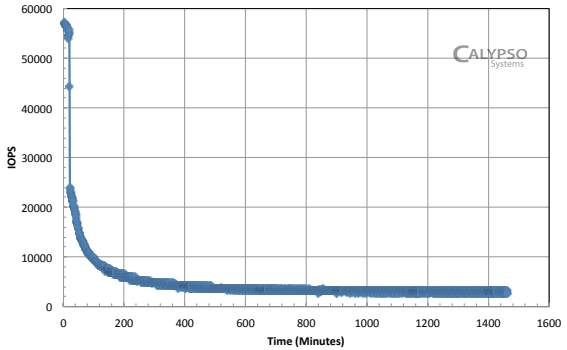
Client WSAT (OPTIONAL) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-C 1.0 — Page 1 of 4

Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR	CALYPSO Systems

Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:		Convergence	N/A
Capacity	256 GB	Pre-Conditioning		Data Pattern	RND	Rounds	N/A
NAND Type	MLC	Workload Independent	N/A	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	2	AR AMOUNT	100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC)	16	AR Segments	N/A

Client IOPS (Linear) vs Time (Linear)



MLC-A 256 GB

Test Run Date:	11/21/2011 06:35 AM	Report Run Date:	11/24/2011 04:44 PM

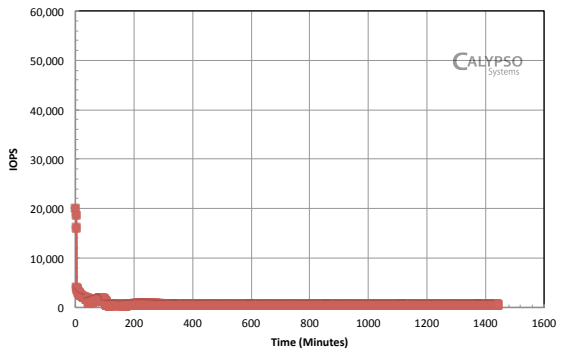
Client WSAT (OPTIONAL) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-C 1.0 — Page 1 of 4

Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-B 160 GB	TEST SPONSOR	CALYPSO Systems

Serial No.	0000-1111-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	02HD	Purge	Security Erase	REQUIRED:		Convergence	N/A
Capacity	160 GB	Pre-Conditioning		Data Pattern	RND	Rounds	N/A
NAND Type	MLC	Workload Independent	N/A	Tester's Choice:		PC AR	100%
Device I/F	3 Gb/s SATA			OIO/Thread (QD)	2	AR AMOUNT	100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC)	16	AR Segments	N/A

Client IOPS (Linear) vs Time (Linear)



MLC-B 160 GB

WSAT	IOPS v TIME	
	MLC-A	MLC-B
FOB 4KiB	55,896	20,364
SS 4KiB	2,714	658
Peak Drop	60 Min	46 Min
Steady State	1,000 Min	275 Min

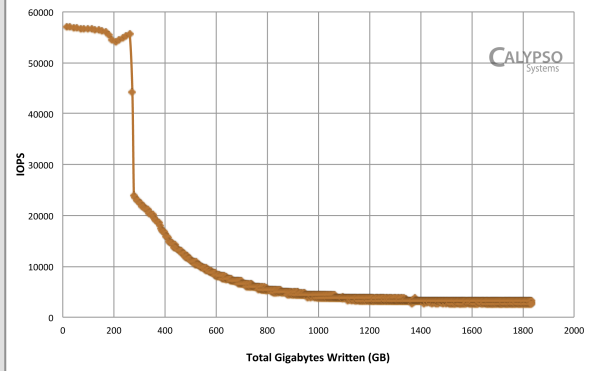
NOTE:
MLC-B x & y axis are scaled to match MLC-A for comparison

WSAT Comparing Client WSAT - IOPS v TGBW

Test Run Date:	11/17/2011 09:30 AM	Report Run Date:	11/22/2011 12:44 PM
Client WSAT (OPTIONAL) - Report Page			
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	CALYPSO Systems
Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:	Convergence N/A
Capacity	256 GB	Pre-Conditioning		Data Pattern RND	Rounds N/A
NAND Type	MLC	Workload Independent	N/A	Tester's Choice:	PC AR 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD) 2	AR AMOUNT 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC) 16	AR Segments N/A

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



MLC-A
256 GB

Test Run Date:	11/21/2011 06:35 AM	Report Run Date:	11/24/2011 04:44 PM
Client WSAT (OPTIONAL) - Report Page			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)		Rev.	PTS-C 1.0
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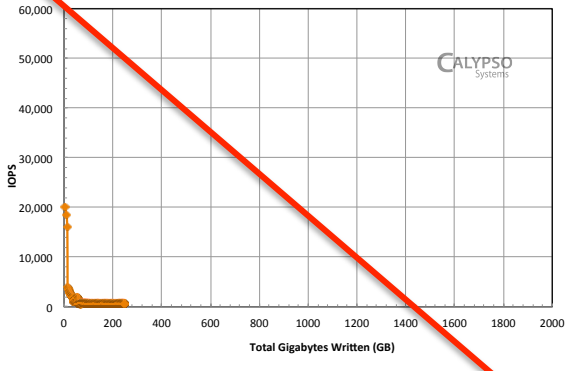
Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: MLC-B 160 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	0000-1111-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	02HD	Purge	Security Erase	REQUIRED:	Convergence N/A
Capacity	160 GB	Pre-Conditioning		Data Pattern RND	Rounds N/A
NAND Type	MLC	Workload Independent	N/A	Tester's Choice:	PC AR 100%
Device I/F	3 Gb/s SATA			OIO/Thread (QD) 2	AR AMOUNT 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC) 16	AR Segments N/A

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



MLC-B
160 GB

WSAT	IOPS v TGBW	
	MLC-A	MLC-B
FOB 4KiB	55,896	20,364
SS 4KiB	2,714	658
Peak Drop	250 TGBW	38 TBBW
Steady State	1,400 TGBW	80 TGBW
Peak Drop User Capacity	1 Drive Fill	.38 Drive Fills
Steady State User Capacity	5 Drive Fills	.8 Drive Fills

NOTE:
MLC-B x & y axis are scaled
to match MLC-A for comparison

NOTE:
MLC-B TGBW is limited by slower
RND 4KiB W speed (1440 minute test)

MLC-A interface is 6Gb/s
MLC-B interface is 3Gb/s

WSAT Comparing Enterprise WSAT - IOPS v TIME

Test Run Date:	11/07/11 08:40 AM	Report Run Date:	11/14/2011 08:45 AM

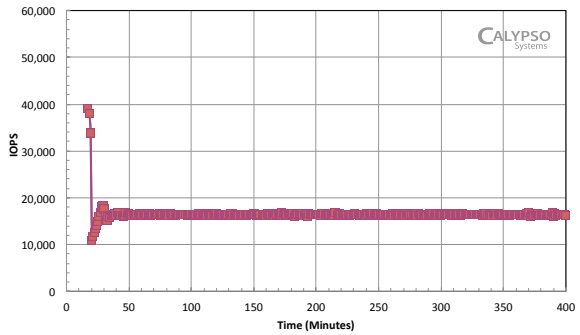
Enterprise WSAT (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 1 of 4

Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems

Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters		Convergence	N/A
Firmware Rev	8F0A	Purge	Format Unit	REQUIRED:		Rounds	N/A
Capacity	100 GB	Pre-Conditioning		Data Pattern	RND	PC AR	100%
NAND Type	SLC	Workload Independent	None	Tester's Choice:		AR AMOUNT	100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD)	16	AR Segments	N/A
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC)	2	OPT:	N/A

Enterprise IOPS (Linear) vs Time (Linear)



SLC-A 100 GB

Test Run Date:	11/02/2011 11:54 AM	Report Run Date:	11/14/2011 01:15 AM

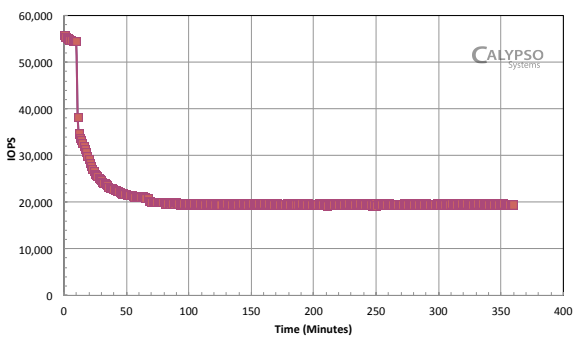
Enterprise WSAT (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 1 of 4

Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: SLC-B 100 GB	TEST SPONSOR	CALYPSO Systems

Serial No.	1111-1111-FFFF	DUT Preparation		Test Loop Parameters		Convergence	N/A
Firmware Rev	8901	Purge	Security Erase	REQUIRED:		Rounds	N/A
Capacity	100 GB	Pre-Conditioning		Data Pattern	RND	PC AR	100%
NAND Type	SLC	Workload Independent	None	Tester's Choice:		AR AMOUNT	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	16	AR Segments	N/A
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC)	2	OPT:	N/A

Enterprise IOPS (Linear) vs Time (Linear)



SLC-B 100 GB

WSAT	IOPS v TIME	
	SLC-A	SLC-B
FOB 4KiB	39,092	55,677
SS 4KiB	16,305	19,415
Peak Drop	30 Min	30 Min
Steady State	50 Min	100 Min

NOTE:
SLC-A x & y axis are scaled to match SLC-B for comparison

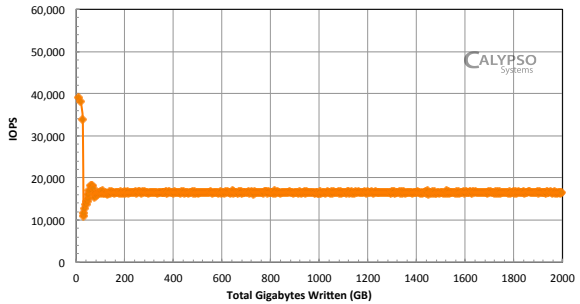
NOTE:
SLC-B TIME is less due to faster RND 4KiB W speed (to X User Capacity)

WSAT Comparing Enterprise WSAT - IOPS v TGBW

Test Run Date:	11/07/11 08:40 AM	Report Run Date:	11/14/2011 08:45 AM
Enterprise WSAT (REQUIRED) - Report Page			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)		Rev.	PTS-E 1.0
		Page	3 of 4

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Convergence N/A
Firmware Rev	8F0A	Purge	Format Unit	REQUIRED:	Rounds N/A
Capacity	100 GB	Pre-Conditioning		Data Pattern RND	PC AR 100%
NAND Type	SLC	Workload Independent	None	Tester's Choice:	AR AMOUNT 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD) 16	AR Segments N/A
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC) 2	OPT: N/A

Enterprise IOPS (Linear) vs TGBW (Linear)

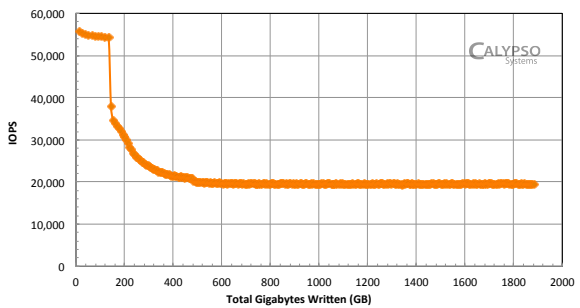


SLC-A 100 GB

Test Run Date:	11/02/2011 11:54 AM	Report Run Date:	11/14/2011 01:15 AM
Enterprise WSAT (REQUIRED) - Report Page			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)		Rev.	PTS-E 1.0
		Page	3 of 4

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-B 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-1111-FFFF	DUT Preparation		Test Loop Parameters	Convergence N/A
Firmware Rev	8901	Purge	Security Erase	REQUIRED:	Rounds N/A
Capacity	100 GB	Pre-Conditioning		Data Pattern RND	PC AR 100%
NAND Type	SLC	Workload Independent	None	Tester's Choice:	AR AMOUNT 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD) 16	AR Segments N/A
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	RND 4KiB	Thread Count (TC) 2	OPT: N/A

Enterprise IOPS (Linear) vs Total Gigabytes Written (Linear)



SLC-B 100 GB

WSAT	IOPS v TGBW	
	SLC-A	SLC-B
FOB 4KiB	39,092	55,677
SS 4KiB	16,305	19,415
Peak Drop	70 TGBW	200 TBBW
Steady State	150 TGBW	600 TGBW
Peak Drop User Capacity	.7 Drive Fill	2 Drive Fills
Steady State User Capacity	1.5 Drive Fills	6 Drive Fills

NOTE:
SLC-A x & y axis are scaled to match SLC-B for comparison

Comparing Client IOPS

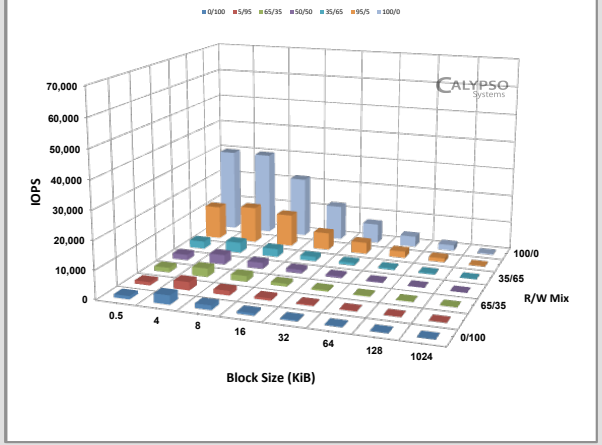
Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

Client IOPS (REQUIRED) - Report Page

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.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	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	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	8	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	1	AR Segments	2048

Client IOPS - ALL RW Mix & BS – 3D Columns



MLC-A
256 GB

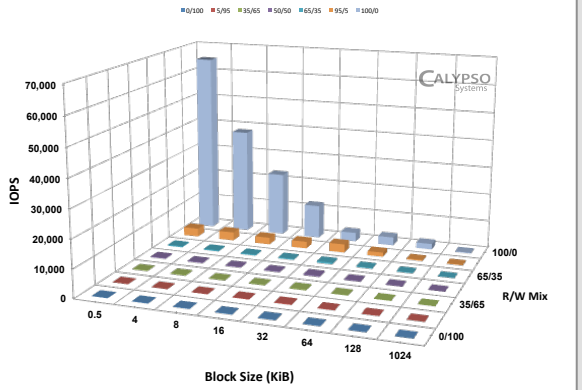
Test Run Date:	11/17/2011 10:54 AM	Report Run Date:	11/21/2011 04:47 PM

CLIENT IOPS (REQUIRED) - Report Page

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-B 160 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	0000-1111-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	02HD	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	160 GB	Pre-Conditioning		Data Pattern	RND	Rounds	9-13
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
Device I/F	3 Gb/s SATA			OIO/Thread (QD)	1	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	32	AR Segments	2048

IOPS - ALL RW Mix & BS – 3D Columns



MLC-B
160 GB

RND IOPS	Steady State	
	MLC-A	MLC-B
0.5KiB 100% R	29,861	64,918
4KiB 100% R	29,876	38,087
4KiB 65:35 R/W	3,779	423
4KiB 100% W	3,147	152
128KiB 65:35	378	167

NOTE:
MLC-A y-axis is scaled to match MLC-B for comparison

Key Points:

- MLC-B:
  - Higher small block Reads
  - Lower small block Writes.
- MLC-A
  - More balanced Block Size optimization
  - Generally higher W performance

- Writes have a disproportionately strong influence in any R/W mix performance (note 65/35 R/W comparisons)

IOPS Comparing Client IOPS

Test Run Date:	11/14/2011 12:39 AM	Report Run Date:	11/21/2011 04:12 PM

Client IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	PTS-C 1.0
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Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-A 256 GB	TEST SPONSOR	CALYPSO Systems

Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	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	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	8	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	1	AR Segments	2048

Client IOPS - ALL RW Mix & BS – Tabular Data

Block Size (KiB)	Read / Write Mix %						
	0/100	5/95	65/35	50/50	35/65	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	97.5	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

MLC-A 256 GB

Test Run Date:	11/17/2011 10:54 AM	Report Run Date:	11/21/2011 04:47 PM

CLIENT IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	PTS-C 1.0
	Page	4 of 6

Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: MLC-B 160 GB	TEST SPONSOR	CALYPSO Systems

Serial No.	0000-1111-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	02HD	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	160 GB	Pre-Conditioning		Data Pattern	RND	Rounds	9-13
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
Device I/F	3 Gb/s SATA			OIO/Thread (QD)	1	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	32	AR Segments	2048

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	160.9	182.5	234.4	307.6	436.3	3,046.3	64,918.3
4	151.9	178.6	230.6	293.4	425.5	3,081.5	38,087.5
8	151.3	179.5	220.1	284.3	402.6	2,510.8	22,978.6
16	146.8	194.9	218.1	281.4	400.3	2,483.1	12,195.5
32	225.7	249.4	329.3	435.5	606.1	3,032.2	3,258.2
64	119.9	126.3	182.7	228.5	318.6	1,526.2	2,993.1
128	61.1	64.1	92.8	119.3	167.4	370.3	2,037.7
1024	8.4	8.7	13.1	17.7	24.6	164.9	252.3

MLC-B 160 GB

Comparing Enterprise IOPS

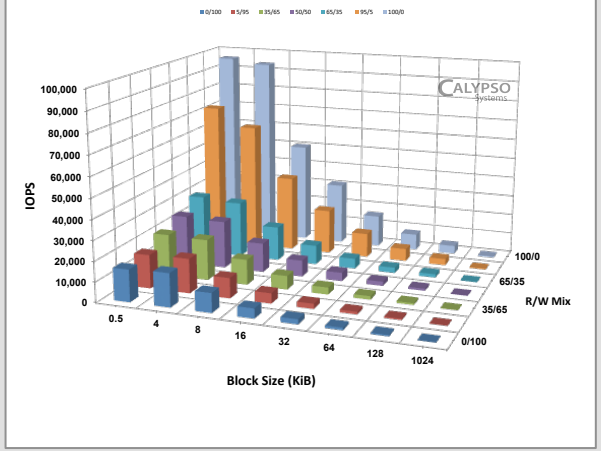
Test Run Date:	11/02/2011 02:56 PM	Report Run Date:	11/14/2011 08:43 AM

Enterprise IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 6 of 6

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	8F0A	Purge	Format Unit	REQUIRED: Data Pattern: RND	Convergence: YES
Capacity	100 GB	Pre-Conditioning			Rounds: 1-5
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice: OIO/Thread (QD): 16	PC AR: 100%
Device I/F	6 Gb/s SAS				AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC): 2	AR Segments: N/A

Enterprise IOPS - ALL RW Mix & BS – 3D Columns



SLC-A 100 GB

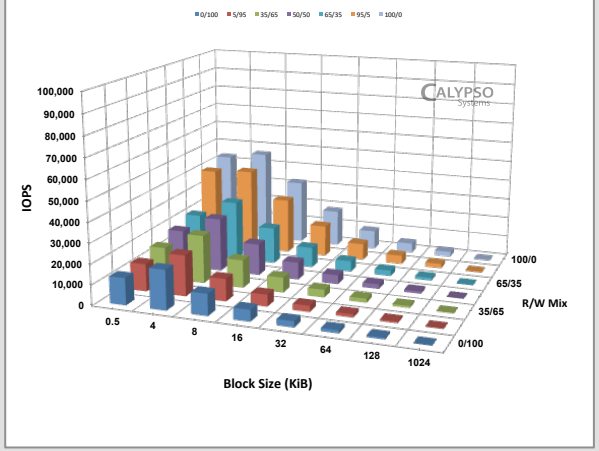
Test Run Date:	11/09/2011 11:35 AM	Report Run Date:	11/14/2011 04:17 PM

Enterprise IOPS (REQUIRED)

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 6 of 6

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-B 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-1111-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	8901	Purge	Security Erase	REQUIRED: Data Pattern: RND	Convergence: YES
Capacity	100 GB	Pre-Conditioning			Rounds: 2-6
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice: OIO/Thread (QD): 16	PC AR: 100%
Device I/F	6 Gb/s SATA				AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC): 2	AR Segments: N/A

Enterprise IOPS - ALL RW Mix & BS – 3D Columns



SLC-B 100 GB

RND IOPS	Steady State	
	SLC-A	SLC-B
0.5KiB 100% R	95,924	43,368
4KiB 100% R	93,707	46,365
4KiB 65:35 R/W	28,019	41,460
4KiB 100% W	16,563	19,561
128KiB 65:35	1,709	1,389

NOTE:
SLC-B y-axis is scaled to match SLC-A for comparison

Key Points:

- SLC-A:
  - Higher small block Reads
  - Lower small block Writes.
- SLC-B
  - More balanced Block Size optimization
  - Generally higher W performance
- Writes have a disproportionately strong influence in any R/W mix performance (note 65/35 R/W comparisons)

Comparing Enterprise IOPS

Test Run Date:	11/02/2011 02:56 PM	Report Run Date:	11/14/2011 08:43 AM

Enterprise IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	PTS-E 1.0
	Page	4 of 6

Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR

Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:		Convergence	YES
Capacity	100 GB	Pre-Conditioning		Data Pattern	RND	Rounds	1-5
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD)	16	AR AMOUNT	100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	2	AR Segments	N/A

Enterprise 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	15,887.4	16,634.7	20,678.6	24,402.8	29,386.2	72,428.4	95,924.3
4	16,563.0	17,032.2	20,234.2	23,705.2	28,018.6	63,447.7	93,707.0
8	9,559.8	9,998.4	12,547.1	14,636.6	17,199.1	37,872.9	50,301.2
16	4,842.2	5,032.3	6,802.5	8,132.1	9,655.8	22,462.2	31,072.8
32	2,413.3	2,535.4	3,478.4	4,241.3	5,061.7	12,174.7	15,994.2
64	1,219.2	1,275.7	1,728.4	2,126.1	2,726.3	6,284.6	8,094.9
128	617.7	632.5	859.1	1,061.4	1,709.4	3,205.7	4,060.8
1024	74.0	78.0	103.6	126.7	202.7	398.8	514.6

SLC-A
100 GB

Test Run Date:	11/09/2011 11:35 AM	Report Run Date:	11/14/2011 04:17 PM

Enterprise IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	PTS-E 1.0
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Device Under Test (DUT)	VENDOR: ABC CO.	SSD MODEL NO: SLC-B 100 GB	TEST SPONSOR

Serial No.	1111-1111-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	B901	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	100 GB	Pre-Conditioning		Data Pattern	RND	Rounds	2-6
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	16	AR AMOUNT	100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full IOPS Loop	Thread Count (TC)	2	AR Segments	N/A

Enterprise 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	13,255.7	13,581.2	15,581.3	18,393.7	21,115.5	40,004.8	43,368.3
4	19,560.6	20,238.4	23,886.3	26,641.2	29,827.0	41,460.1	46,365.3
8	10,630.3	11,033.1	13,806.4	15,780.9	18,244.6	27,803.9	32,259.3
16	5,620.5	5,824.9	7,451.9	8,651.6	10,174.7	15,772.3	18,309.1
32	2,872.2	3,002.7	3,862.5	4,513.2	5,377.6	8,337.0	9,472.3
64	1,461.8	1,515.4	1,962.1	2,293.9	2,751.4	4,304.9	4,829.3
128	735.7	763.7	987.4	1,148.8	1,389.0	2,187.9	2,439.4
1024	92.5	95.9	124.1	144.6	173.1	277.2	307.6

SLC-B
100 GB

TP Comparing Client Throughput

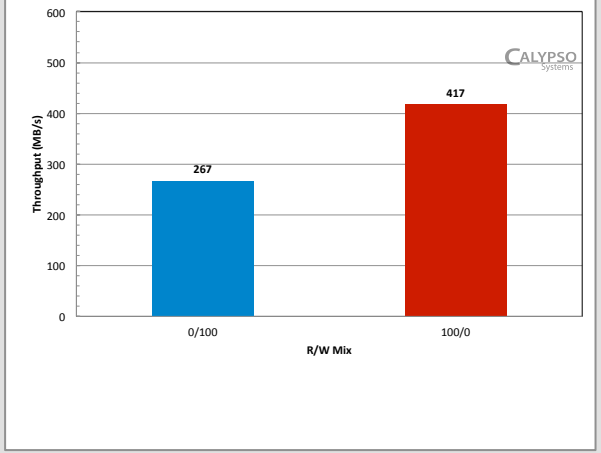
Test Run Date: 11/13/2011 10:24 AM | Report Run Date: 11/21/2011 04:03 PM

Client Throughput Test (REQUIRED) - Report Page

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
Serial No. 0000-0000-FFFF	DUT Preparation	Test Loop Parameters	Steady State
Firmware Rev BF01	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	Tester's Choice:	PC AR: 100%
Device I/F 6 Gb/s SATA	Workload Dep.: SEQ 1024KiB	OIO/Thread (QD): 32	AR AMOUNT: 16 GiB
Test Platform RTP 2.0 CTS 6.5		Thread Count (TC): 32	AR Segments: 2048

Client Throughput - ALL RW Mix & BS - 2D Plot



MLC-A 256 GB

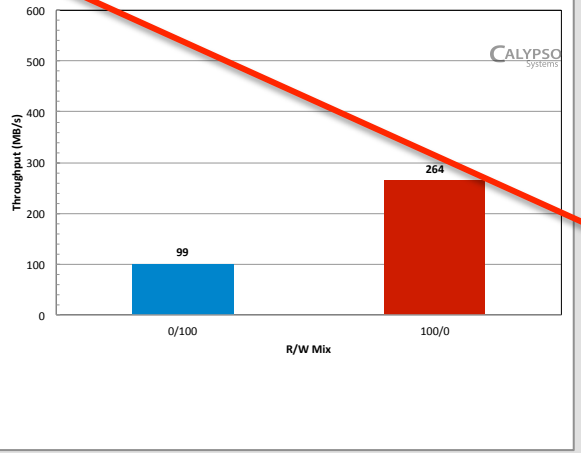
Test Run Date: 11/15/2011 12:46 AM | Report Run Date: 11/21/2011 04:50 PM

Client Throughput Test (REQUIRED) - Report Page

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-B 160 GB	TEST SPONSOR
Serial No. 0000-1111-FFFF	DUT Preparation	Test Loop Parameters	Steady State
Firmware Rev 02H0	Purge: Security Erase	REQUIRED:	Convergence: YES
Capacity 160 GB	Pre-Conditioning	Data Pattern: RND	Rounds: 1-5
Device I/F 3 Gb/s SATA	Workload Independent: 2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
	Workload Dep.: SEQ 1024KiB	OIO/Thread (QD): 2	AR AMOUNT: 16 GiB
		Thread Count (TC): 1	AR Segments: 2048

Client Throughput - ALL RW Mix & BS - 2D Plot



MLC-B 160 GB

SEQ 1024KIB TP	Steady State	
	MLC-A	MLC-B
100% R	417 MB/s	264 MB/s
100% W	267 MB/s	99 MB/s

Key Points:

- MLC-A:
  - DUT Interface 6Gb/s SATA
  - Higher large block SEQ Reads & Writes
- MLC-B
  - DUT Interface 3 Gb/s SATA
  - Slower large block SEQ Reads & Writes

TP Comparing Enterprise Throughput

Test Run Date:	12/04/2011 08:21 AM	Report Run Date:	12/04/2011 10:03 AM
Enterprise Throughput Test (REQUIRED) - Report Page			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)		Rev.	PTS-E 1.0
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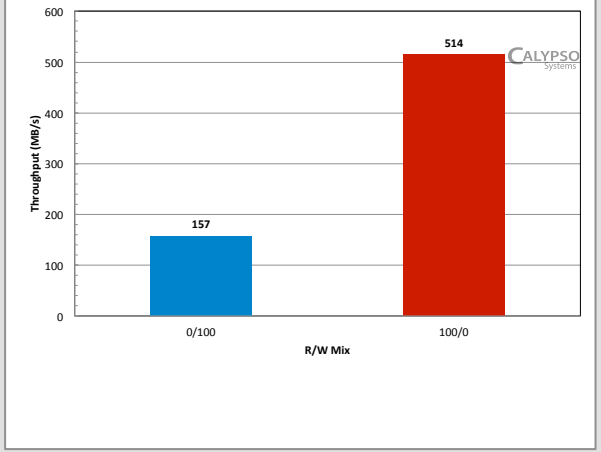
Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	BFOA	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 4-8
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SAS			OIO/Thread (QD): 16	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	SEQ 1024KiB	Thread Count (TC): 2	AR Segments: N/A

Enterprise 1024KiB Throughput - ALL RW Mix & BS - 2D Plot

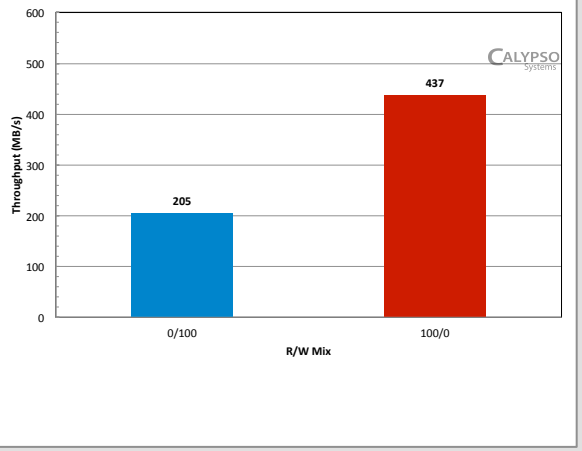


SLC-A
100 GB

Test Run Date:	12/04/2011 10:43 AM	Report Run Date:	12/04/2011 11:48 AM
Enterprise Throughput Test (REQUIRED) - Report Page			
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)		Rev.	PTS-E 1.0
		Page	5 of 5

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-B 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-1111-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	B901	Purge	Security Erase	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 4-8
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 16	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	SEQ 1024KiB	Thread Count (TC): 2	AR Segments: N/A

Enterprise 1024KiB Throughput - ALL RW Mix & BS - 2D Plot



SLC-B
100 GB

SEQ 1024 KIB TP	Steady State	
	SLC-A	SLC-B
100% R	514 MB/s	437 MB/s
100% W	157 MB/s	205 MB/s

Key Points:

- SLC-A:
  - Higher large block SEQ Reads & Writes
  - DUT Interface 6 Gb/s SAS
- SLC-B
  - Slower large block SEQ Reads & Writes
  - DUT Interface 6 Gb/s SATA

LAT Comparing Client Latency AVE

Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM

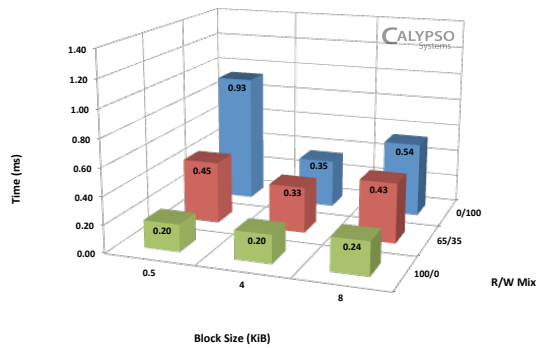
Client Latency (REQUIRED) - Report Page

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

Serial No.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	256 GB	Pre-Conditioning		Data Pattern	RND	Rounds	4-8
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	1	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full Latency Loop	Thread Count (TC)	1	AR Segments	2048

Client - AVE Latency vs BS and R/W Mix - 3D Plot



MLC-A
256 GB

Test Run Date:	11/16/2011 01:01 AM	Report Run Date:	11/22/2011 10:40 AM

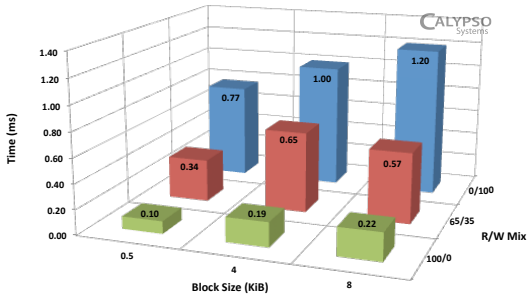
Client Latency (REQUIRED) - Report Page

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-B 160 GB	TEST SPONSOR

Serial No.	0000-1111-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	02HD	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	160 GB	Pre-Conditioning		Data Pattern	RND	Rounds	12-16
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	1	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full LAT Loop	Thread Count (TC)	1	AR Segments	2048

Client - AVE Latency vs BS and R/W Mix - 3D Plot



MLC-B
160 GB

Latency RND 4KiB AVE	Steady State	
	MLC-A	MLC-B
100% R AVE	0.20 mSec	0.19 mSec
65/35 R/W AVE	0.33 mSec	0.65 mSec
100% W AVE	0.35 mSec	1.00 mSec

Key Points:

- MLC-A:
  - More stable & faster RND 4KiB AVE Latency
  - Higher RND 0.5KiB 100% W AVE Latency
- MLC-B
  - Slower overall RND 4KiB AVE Latency
  - Higher RND 8KiB 100% W AVE Latency

LAT Comparing Client Latency MAX

Test Run Date:	11/11/2011 09:53 AM	Report Run Date:	11/15/2011 03:34 PM

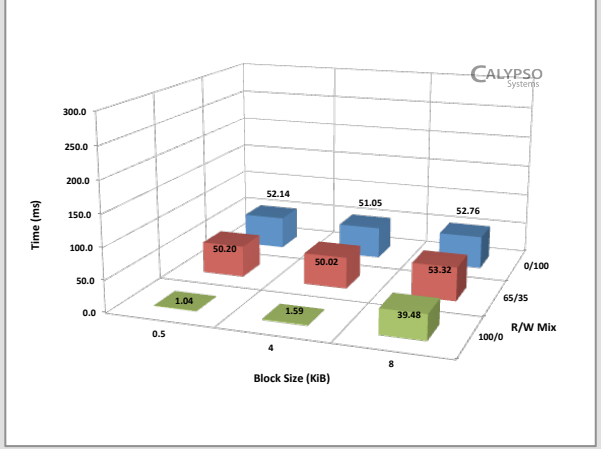
Client Latency (REQUIRED) - Report Page

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.	0000-0000-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	BF01	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	256 GB	Pre-Conditioning		Data Pattern	RND	Rounds	4-8
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	1	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full Latency Loop	Thread Count (TC)	1	AR Segments	2048

Client - MAX Latency vs BS and R/W Mix - 3D Plot



MLC-A 256 GB

Test Run Date:	11/16/2011 01:01 AM	Report Run Date:	11/22/2011 10:40 AM

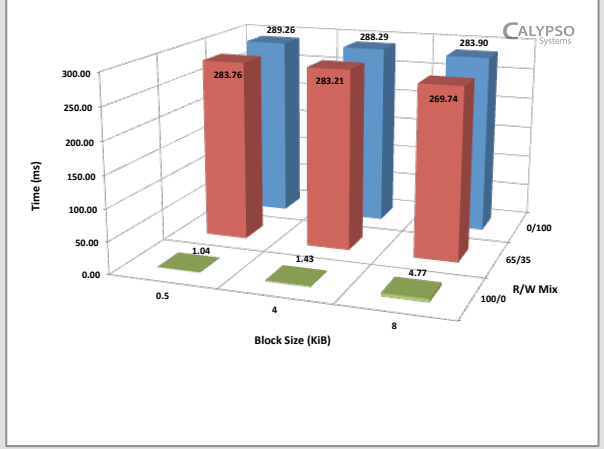
Client Latency (REQUIRED) - Report Page

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-B 160 GB	TEST SPONSOR: CALYPSO Systems

Serial No.	0000-1111-FFFF	DUT Preparation		Test Loop Parameters		Steady State	
Firmware Rev	02HD	Purge	Security Erase	REQUIRED:		Convergence	YES
Capacity	160 GB	Pre-Conditioning				Rounds	12-16
NAND Type	MLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:		PC AR	100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD)	1	AR AMOUNT	16 GiB
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full LAT Loop	Thread Count (TC)	1	AR Segments	2048

Client - MAX Latency vs BS and R/W Mix - 3D Plot



MLC-B 160 GB

Latency RND 4KiB MAX	Steady State	
	MLC-A	MLC-B
100% R MAX	1.59 mSec	1.43 mSec
65/35 R/W MAX	50.02 mSec	283.21 mSec
100% W MAX	51.05 mSec	288.29 mSec

Key Points:

- MLC-A:
  - More stable & faster RND 4KiB MAX Latency
  - Smaller RND 0.5KiB & 8KiB MAX Latency
- MLC-B
  - Slower overall RND 4KiB MAX Latency
  - Higher RND 0.5KiB & 8KiB MAX Latency

LAT Comparing Enterprise Latency AVE

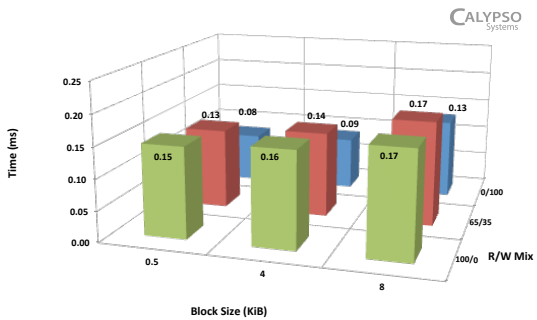
Test Run Date:	11/10/2011 05:07 AM	Report Run Date:	11/14/2011 08:47 AM

Enterprise Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0 — Page 5 of 6

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	8F0A	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 3-7
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 1	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full LAT Loop	Thread Count (TC): 1	AR Segments: N/A

Enterprise AVE Latency vs BS and R/W Mix - 3D Plot



SLC-A 100 GB

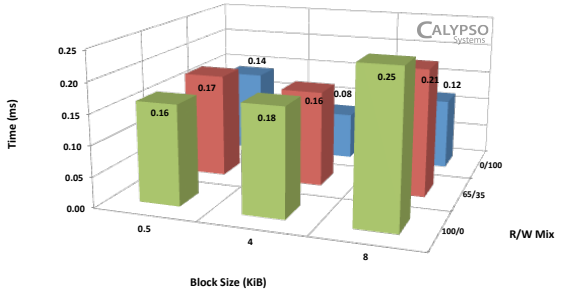
Test Run Date:	12/04/2011 12:14 PM	Report Run Date:	12/04/2011 03:22 PM

Enterprise Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E — Page 5 of 6

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-B 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-1111-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	8901	Purge	Security Erase	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 5-9
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 1	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full LAT Loop	Thread Count (TC): 1	AR Segments: N/A

Enterprise AVE Latency vs BS and R/W Mix - 3D Plot



SLC-B 100 GB

Latency RND 4KiB AVE	Steady State	
	SLC-A	SLC-B
100% R AVE	0.16 mSec	0.18 mSec
65/35 R/W AVE	0.14 mSec	0.16 mSec
100% W AVE	0.09 mSec	0.08 mSec

Key Points:

- SLC-A & SLC-B:
  - Comparable AVE Latency speeds

LAT Comparing Enterprise Latency MAX

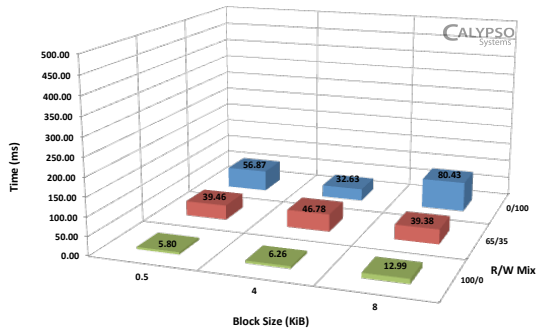
Test Run Date:	11/10/2011 05:07 AM	Report Run Date:	11/14/2011 08:47 AM

Enterprise Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. PTS-E 1.0, Page 6 of 6

Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-A 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-0000-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	8F0A	Purge	Format Unit	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 3-7
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 1	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full LAT Loop	Thread Count (TC): 1	AR Segments: N/A

Enterprise MAX Latency vs BS and R/W Mix - 3D Plot



SLC-A 100 GB

Test Run Date:	12/04/2011 12:14 PM	Report Run Date:	12/04/2011 03:22 PM

Enterprise Latency (REQUIRED) - Report Page

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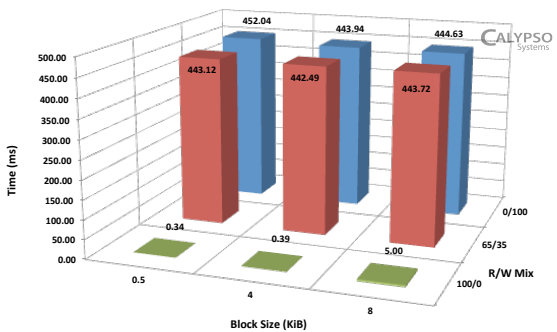
Device Under Test (DUT)		VENDOR: ABC CO.	SSD MODEL NO: SLC-B 100 GB	TEST SPONSOR	CALYPSO Systems
Serial No.	1111-1111-FFFF	DUT Preparation		Test Loop Parameters	Steady State
Firmware Rev	8901	Purge	Security Erase	REQUIRED:	Convergence: YES
Capacity	100 GB	Pre-Conditioning		Data Pattern: RND	Rounds: 5-9
NAND Type	SLC	Workload Independent	2X SEQ/128KiB	Tester's Choice:	PC AR: 100%
Device I/F	6 Gb/s SATA			OIO/Thread (QD): 1	AR AMOUNT: 100%
Test Platform	RTP 2.0 CTS 6.5	Workload Dep.	Full LAT Loop	Thread Count (TC): 1	AR Segments: N/A

Enterprise MAX Latency vs BS and R/W Mix - 3D Plot



SLC-B 100 GB

Latency RND 4KiB MAX	Steady State	
	SLC-A	SLC-B
100% R MAX	6.26 mSec	0.39 mSec
65/35 R/W MAX	46.78 mSec	442.49 mSec
100% W MAX	32.63 mSec	443.94 mSec

Key Points:

- SLC-A:
  - More stable & faster RND 4KiB MAX Latency
  - Smaller RND 0.5KiB & 8KiB MAX Latency
- SLC-B
  - Slower overall RND 4KiB MAX Latency
  - Much Higher RND 65/35 and 100% W MAX Latency

Download this deck at www.snia.org/forums/sssi/pts

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2. How IOs Traverse the S/W H/W Stack
3. PTS Client & Enterprise Test Specifications
4. Summary SSD Comparisons – **www.snia.org/forums/sssi/pts**
5. Using PTS Reports to Understand SSD Behavior
6. Using PTS Reports to Compare SSD Behavior
7. **SSD Test Best Practices**
8. Conclusion

Basic Test Procedures

Verified Test Environment. Do not bottleneck SSD performance.

- ***Hardware Bottlenecks*** - Anywhere within the data/control paths (HBA, data bus lanes, RAM CPU)
- ***Software Influences*** - OS background tasks, application software, APIs and device drivers
- ***Test Software Tools*** - Stimulus generators and Measurement tools can introduce performance overhead

Normalized Test Platform. Use the SAME platform to normalize the test environment across measurements.

Calibration. Periodically calibrate using the same test stimulus / workload on a known device.

Test Plan. A good test plan enumerates test objectives, test methodology and selection of tests.

This includes:

- establishing the relevance of the test to the test objectives
- defining the test baseline, and
- prescribing the test procedures, number samples, test runs and statistical analysis employed.

SSD Specific Testing

Purge

Any SSD test should begin with a device Purge.

Preconditioning

Precisely define the preconditioning regime.

Steady State

Precisely define the preconditioning workload and steady state determination criteria.

Demand Intensity

Map the target SSD on the test platform to determine the optimal OIO settings for the given test.

Block Size Sequencing

Avoid Block Size Sequence / Cross Stimulus effects on the SSD performance.

Test Stimulus Workload

Ensure the test workload is relevant to the characteristics of the targeted user workload.

SSD Test Best Practices

Use Standardized Methodologies

Benefit from industry, scientific and academic research in SSD tests and methodologies.

Reference Test Platform (RTP)

Normalize the test environment and ensure repeatable and reproducible test results.

Standardized Tests

Use of the RTP / PTS allows for easy comparison of performance between different SSD devices.

Standardized Reporting

Ensures test standards compliance and disclosure of required test set-up conditions.

SNIA SSS PTS

Uniform prescriptions for SSD testing allows valid comparison and understanding of SSD device performance.

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Conclusion

NAND storage technology increases performance by orders of magnitude.

SSD performance characteristics are considerably different from those of conventional spinning drives.

NAND based SSDs are very "write history" sensitive requiring precise preconditioning & steady state

SSD Test Environments can Adversely affect test results.

New SSD Testing is Required for accurate, objective comparison.

Use SNIA PTS & RTP for SSD Test & Measurement.

End Users' workloads are infinitely diverse.

Knowing the attributes of the particular IO profile, end users can select those test results which best represents their workloads and disregard those less relevant.

SSD Client & Enterprise PTS Comparison Data

Available at

www.snia.org/forums/sssi/pts

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