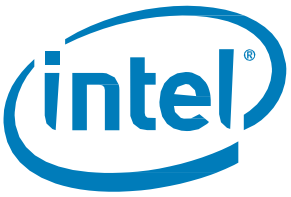

Intel® Solid-State Drive 750 Series

Evaluation Guide

March 2015

Order Number: 332075-001US

Ordering Information

Contact your local Intel sales representative for ordering information.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase. Results have been estimated based on internal Intel analysis and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

All documented performance test results are obtained in compliance with JESD218 Standards; refer to individual sub-sections within this document for specific methodologies. See www.jedec.org for detailed definitions of JESD218 Standards.

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Contents

Revision History

Revision	Description	Date
001	Initial release	March 2015

Terms and Acronyms

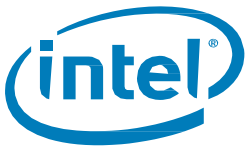
Term	Definition
AHCI	Advanced Host Controller Interface
API	Application Programming Interface
ATA	Advanced Technology Attachment
DIPM	Device Initiated Power Management
GB	Gigabyte
HDD	Hard Disk Drive
KB	Kilobytes
I/O	Input/Output
IOPS	Input/Output Operations Per Second
MB	Megabytes
NCQ	Native Command Queuing
RAID	Redundant Array of Independent Disks
SATA	Serial Advanced Technology Attachment
SSD	Solid-State Drive

Related Documentation

Title	Order Number
Intel® Solid-State Drive 750 Series Product Specification	332059

Related Tools

Product	Download Link
Intel® SSD Data Center Tool	http://www.intel.com/support/ssd
Intel® SSD Toolbox	http://www.intel.com/go/ssdtoolbox
IOMeter*	http://www.iometer.org/



1 Overview

This guide is intended for publications, OEMs, technical analysts, and individuals who plan to test or evaluate the Intel Solid-State Drive 750 Series performance benefits and features. This guide gives specific and detailed instruction on how evaluate the 750 Series using IOMeter.

This guide is significant due to the technology transition from AHCI (SATA) based SSDs to NVMe* /PCIe* based SSDs. Performance benchmarks originally designed for SATA SSDs are not optimized for NVMe SSDs. Hence, the results reflected in these benchmarks may never read maximum performance values stated in the product specification. NVMe allows multiple CPU queues with deep queue depths (up to 64K outstanding IOs). To date, benchmarks such as Crystal Disk Mark*, AS SSD*, ATTO*, Anvil*, and many others do not run with multiple queues and high queue depths to highlight the maximum bandwidth of NVMe technology. The only known benchmark with this capability is IOMeter.

For the latest on NVMe technology, go to http://www.nvmexpress.org/.

	AHCI (Old Technology)	NVMe (New Technology)
Maximum queue depth	1 command queue; 32 commands per queue	65536 queues; 65536 commands per queue
Uncacheable register accesses (2000 cycles each)	6 per non-queued command; 9 per queued command	2 per command
MSI-X and interrupt steering	Single interrupt; no steering	2048 MSI-X interrupts
Parallelism and multiple threads	Requires synchronization lock to issue a command	No locking
Efficiency for 4 KB commands	1 command queue; 32 commands per queue	65536 queues; 65536 commands per queue

With PCIe Gen3 support and NVMe interface, the family of products deliver excellent sequential read performance up to 2.4 GB/s and sequential write speeds up to 1.2 GB/s. It delivers very high random read IOPS of up to 440K and random write IOPS of up to 290K for 4KB operations. Taking advantage of the direct path from the storage to the CPU by means of NVMe, the SSD 750 Series exhibits low latency of less than 20 µs for sequential accesses. See the Intel Solid-State Drive 750 Series Product Specification for more information.

The 2.5-inch form factor of the SSD 750 Series takes advantage of the 8639 connector and provides hot-pluggable removal and insertion, providing in-service replacement options.

This document provides guidance on how to achieve the performance numbers as stated in the SSD 750 Series Product Specification using IOMeter.

2 System Requirements

To replicate the performance numbers stated in the benchmark, your system will need to meet the following hardware and software requirements.

2.1 Hardware Requirements

The following hardware is necessary to replicate the performance numbers stated in the SSD 750 Series Product Specification:

- ASUS X-99 Deluxe Motherboard
- Intel Core i7-5960X CPU
- 32 GB of DDR4 DRAM
- A GTX 980/970 Graphics Card
- A 730 Series SATA SSD
- An Intel 750 Series SSD

Any deviation from this setup may yield less then optimal results.

2.2 Software Requirements

The following software is necessary to replicate the performance numbers stated in the SSD 750 Series Product Specification:

- Latest ASUS* Motherboard Drivers
- Graphics Card Driver
- Microsoft* Windows* 8.1 64 bit
- Latest Intel NVMe Driver

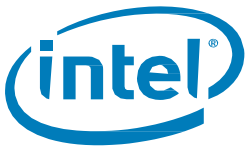
  You can download the latest at: https://downloadcenter.intel.com/download/23929/Intel-Solid-State-Drive-Data-Center-Family-for-PCIe-Drivers
- IOMeter Version 1.1.0 for Windows x64

  You can download the latest version at: http://www.iometer.org/doc/downloads.html
- Latest Intel SSD Toolbox

  Link: https://downloadcenter.intel.com/download/18455/Intel-Solid-State-Drive-Toolbox
- Latest Intel Data Center Toolbox

  Link: https://downloadcenter.intel.com/download/23931/Intel-Solid-State-Drive-Data-Center-Tool

Any deviation from this setup may yield less then optimal results.



3 System Setup and Configuration

System configuration and SSD states can affect run-to-run performance. To overcome this, use a consistent system configuration for repeatable benchmark results.

3.1 System Setup and Driver Installation

Once you have installed your CPU, DRAM, Graphics card and all other hardware, install Windows 8.1 (64 bit) onto the SATA SSD. Windows 8.1 64 bit MUST be installed in UEFI mode. Be sure to set your UEFI BIOS into UEFI mode only. You will test the Intel 750 Series SSD as a secondary drive. For optimal performance, you MUST install the SSD 750 Series in a PCIe Gen 3 slot. Be sure to consult your motherboard manual to identify the correct Gen 3 PCIe slots.

- Update your motherboard to the latest UEFI BIOS.
- Be sure to install all chipset drivers for the motherboard as well as all peripheral drivers.
- Install the Intel NVMe Driver.
- Be sure that the Intel 750 Series has the latest firmware (confirm installation using the Device Manager).
- Do not format the 750 Series SSD.

Once you have installed all drivers, install these programs:

- Intel SSD ToolBox
- Intel Data Center Tool
- IOMeter

3.2 System Configuration

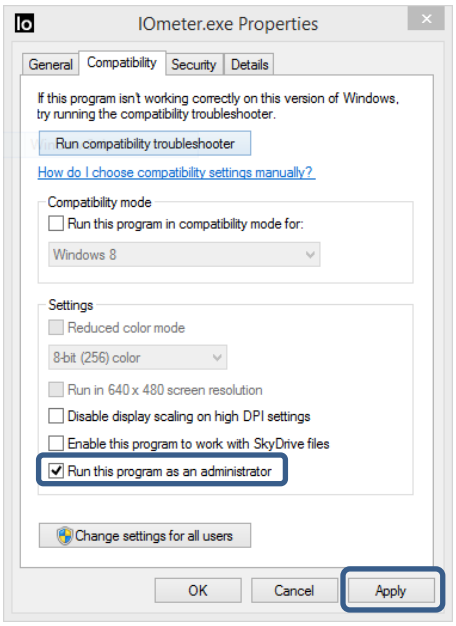
Many items can impact storage subsystem performance. Virus scanners and other various Windows based services can induce run to run variation.

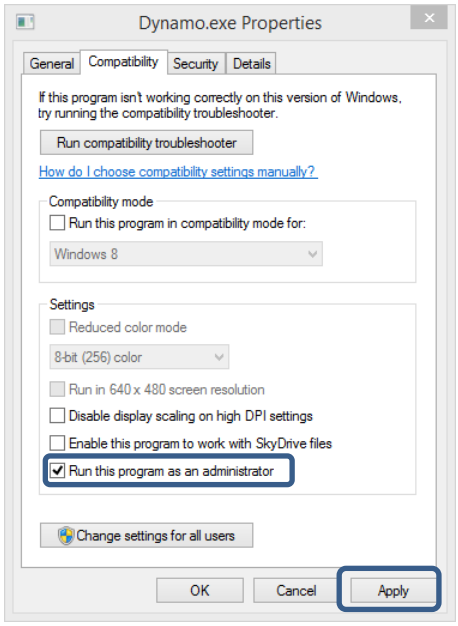
Make sure no other programs, such as a video card control panel, virus scanning software, etc., are running in the background at the same time as the workload. To ensure consistency, be sure to disable the following:

- Screen Saver – Disabled
- Power Management – High Performance
    - Turn off the Display - Never
    - Put the Computer to Sleep – Never
    - Hibernate after - Never
- Windows Defender/System Protection – Disabled
- Automatic Windows Updates – Disabled
- Disk Defragmentation – Disabled
- Any other Virus Protection – Disabled

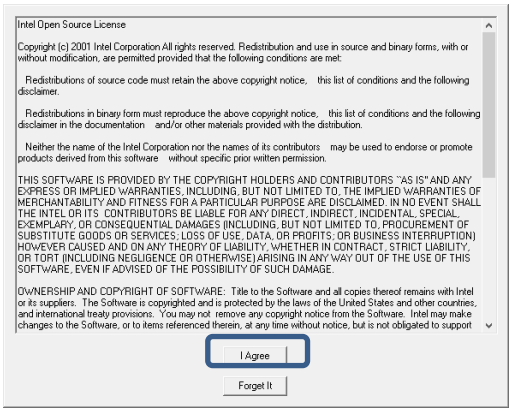
The objective is to disable any automatic services which may interrupt or disrupt the performance test. Once complete, the next step it to set up permissions for IOMeter:

1. Open the directory to IOMeter, right click on the IOMeter.exe icon and click **Properties**.
2. Click on the Compatibility tab and check *Run this program as an administrator*.
3. Click **Apply**.
4. Repeat for Dynamo.exe.

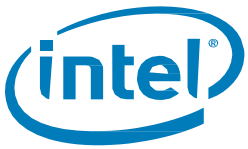




5. Once complete, double click on **IOMeter** and accept the terms and conditions.



You are now ready to use IOMeter.



3.3 SSD Pre-Conditioning

The performance of an SSD is at its best when the SSD is new (out-of-the-box). As the SSD fills with data, performance will degrade. Performance degradation varies based on the workload applied to the drive. Because performance measurements vary depending on the state of the drive, performing benchmark testing on an SSD that is in an out-of-box state is recommended. This can be done by erasing the drive.

3.3.1 Erasing the SSD

To regain out-of-the-box performance of a 750 Series, perform an erase on the drive. An erase deletes all data and returns the SSD to a common starting point for benchmarking consistency.

NOTE: To run Secure Erase, the Intel SSD must be installed as a secondary SSD in your system

For the SSD 750 Series, an erase can be performed with either the Intel SSD Toolbox or the Intel SSD Data Center Tool:

3.3.1.1 Intel® SSD Toolbox

1. Select the Intel SSD on the home screen and view the Drive Summary information to verify the Intel SSD is the drive you want to erase.
2. Click the **Secure Erase** button on the left side of the tool.
3. Click **Erase**.

Note: For issues running Secure Erase, see the tool's help documentation.

3.3.1.2 Intel® SSD Data Center Tool

In **Windows**, run the command:

```
isdct.exe -erase -drive [<drivenum> | all]
```

Where `<drivenum>` is the drive number, or use `all` to erase all drives. For a list of all the drives:

In **Windows**, run the command:

```
isdct.exe -list
```

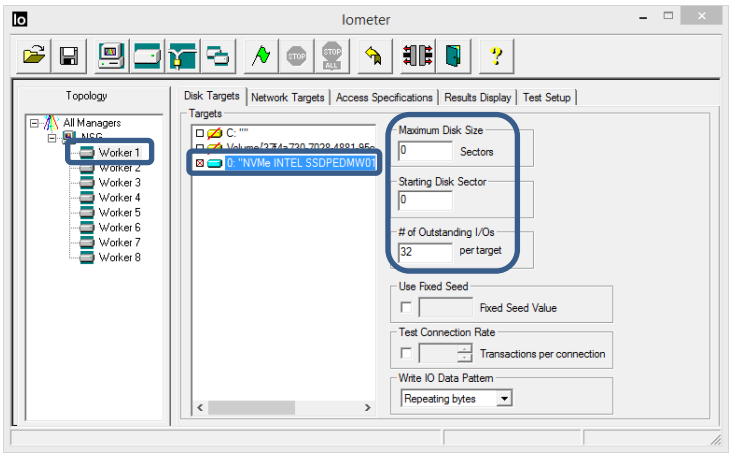
See the Intel® Data Center Tool Users Guide for more details.

3.3.2 Prefilling the drive

As standard in the industry, the drive must be sequentially filled prior to running a workload. This can be done with IOMeter by running a sequential write operation.

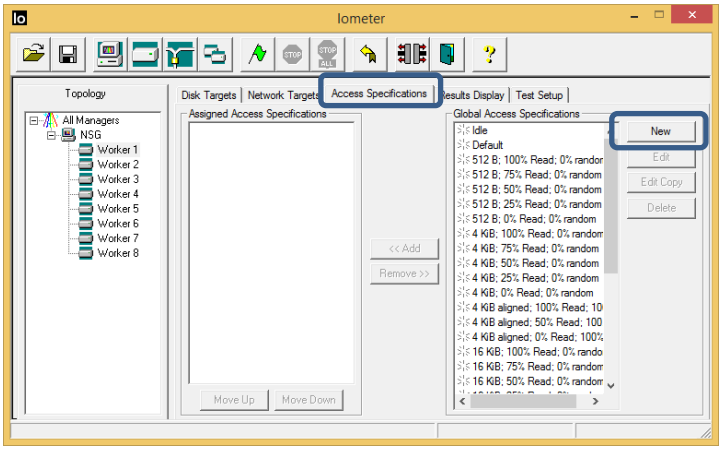
3.3.2.1 Setting up the Disk Target

1. Click on the **Disk Target** tab.
2. Click on **Worker 1**.
3. Click on the target drive (in this case, the NVMe Intel drive).
4. Leave Maximum Disk Size at 0.
5. Leave Starting Disk Sector at 0.
6. Set # of Outstanding I/Os to 32 per target.

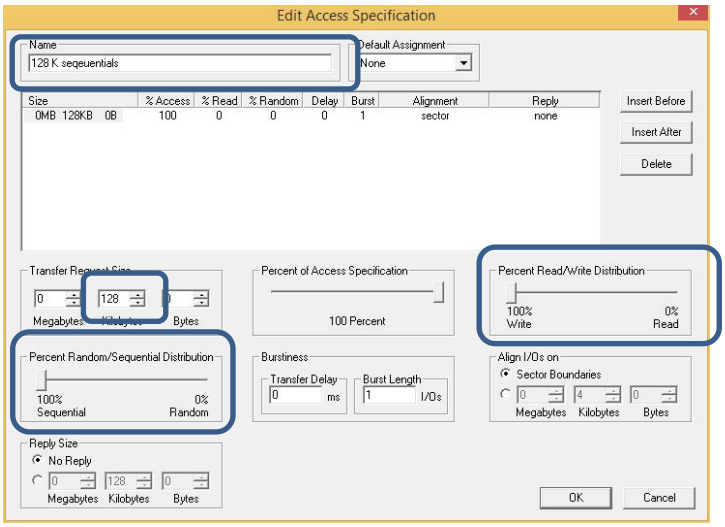


3.3.2.2 Setting up Access Specifications

1. Click on the **Access Specification** tab.
2. Click **New** to open a new workload.

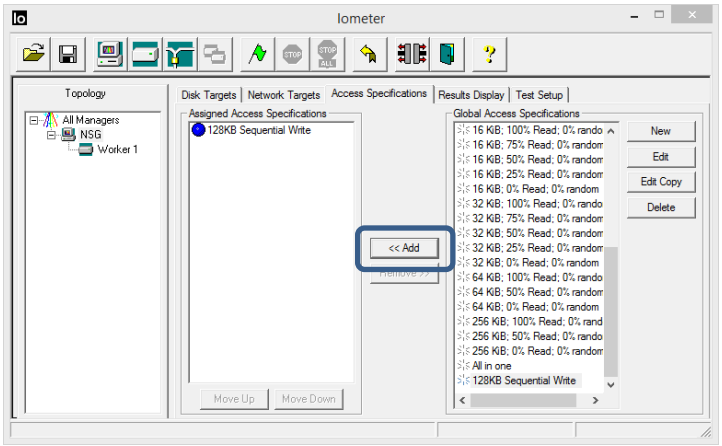


3. Create a name for your workload.
4. Copy the settings below to setup a 128KB, aligned, sequential write workload.



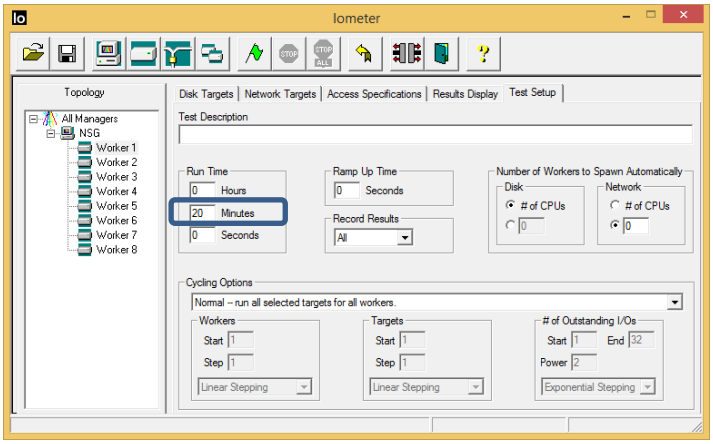
5. After completion, click **OK**.

   You now have created a new workload.
6. Click **Add** to assign it to Worker 1, NVMe Intel Disk.



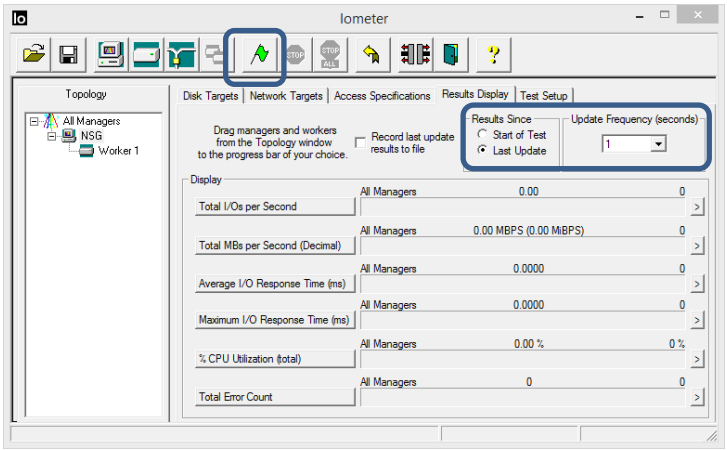
3.3.2.3 Setting Up Test Duration

1. Click on the **Test Setup** tab.
2. Set the number of minutes to 20.



3.3.2.4 Running the Test

1. Click on the **Results Display** tab.
2. Under the Results Since setting, click the **Last Update** radio button.
3. Set Update Frequency to 1 second.
4. Click the green flag to begin testing.



5. Name the results file that IOMeter will create and click **Save**.

After the workload completes, the drive will be full. It is now ready for testing. Be sure not to assign any workloads to other workers (Worker 2 to Worker 8). If you want, you can delete these workers.

4 Evaluating the Intel® SSD 750 Series

This section provides the steps for evaluating the Intel SSD 750 Series with IOMeter. After the IOMeter workload is configured, you can save the configuration file as an .icf file for later testing. The workload order is:

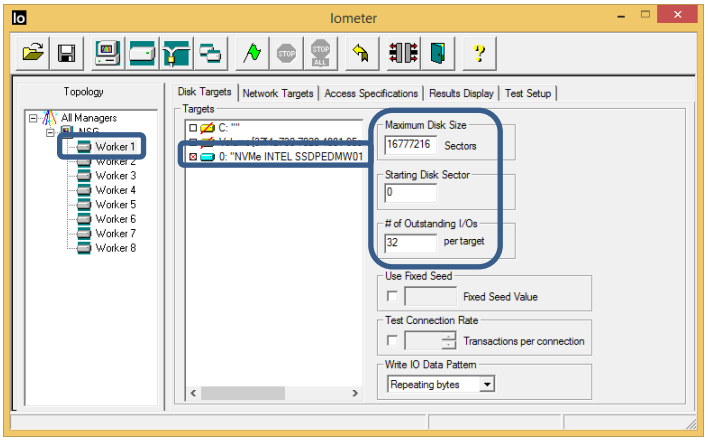
- 128KB Sequential Writes
- 128KB Sequential Reads
- 4KB Random Writes
- 4KB Random Reads

4.1 128KB Sequential Writes

This workload is very similar to the prefill workload, but instead of writing the entire drive, it writes over an 8GB span. This is done by defining the Maximum Disk Size.

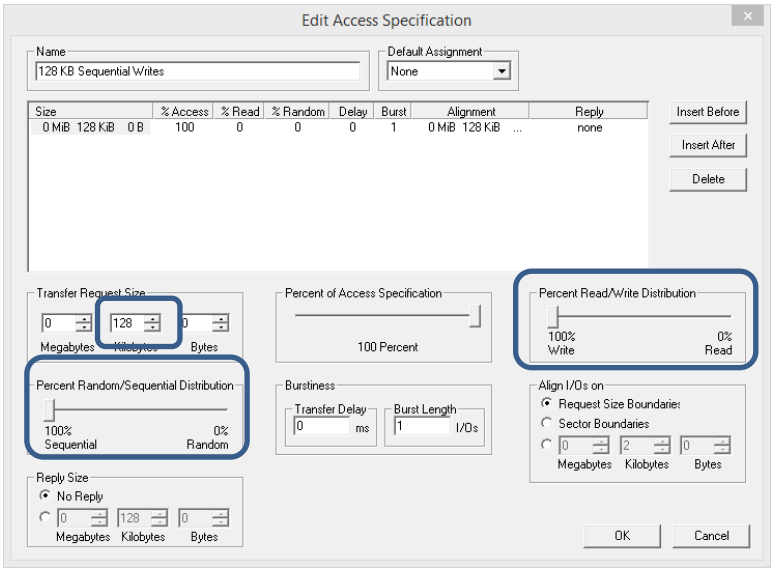
4.1.1 Setting the Disk Target

1. Click on the **Disk Target** tab.
2. Click on **Worker 1**.
3. Click on the target drive (in this case, the NVMe Intel drive).
4. Set Maximum Disk Size to 16777216 sectors.
5. Leave Starting Disk Sector at 0.
6. Set # of Outstanding I/Os to 32 per target.



4.1.2 Setting Access Specifications

1. Reuse/Recreate the same workload as the Prefill workload.
2. After the workload is created, click **Add** to assign it to Worker 1.

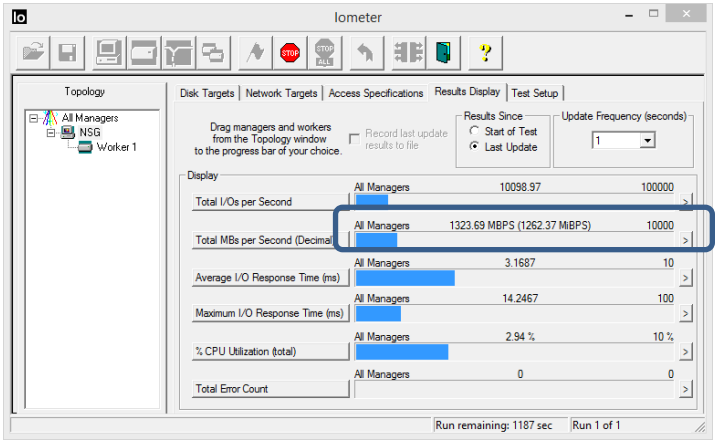


4.1.3 Setting Up Test Duration

1. Click the **Test Setup** tab.
2. Set for 20 minutes.

4.1.4 Running the Test

1. Click the **Results Display** tab.
2. Set Last Update and Update Frequency to 1 second.
3. Click the green flag to run the workload.
4. Name and save the output file.
5. Check to see the Sequential Writes Surpasses specifications:
    - 900MB/s for 400GB 750 Series SSD
    - 1200MB/s for 1.2TB 750 Series SSD



Once the test is complete, you can refer to your output file which will provide various statistics of the workload.

4.2 128KB Sequential Reads

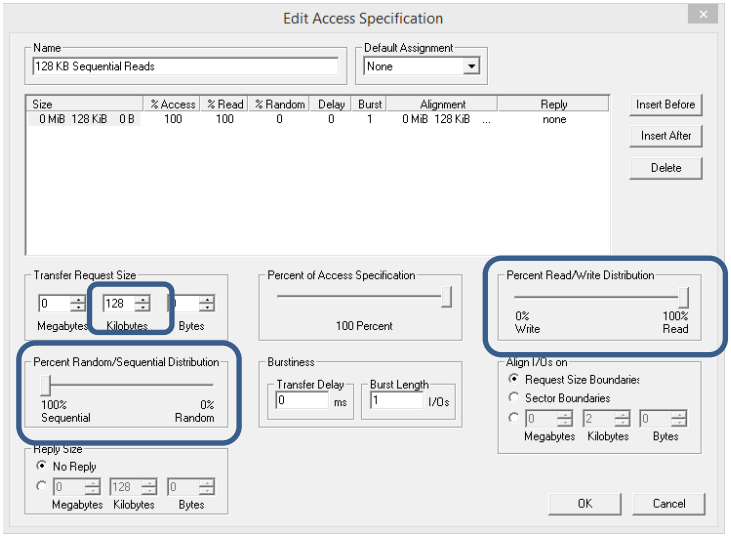
The second workload is the sequential read workload. Just like the sequential writes workload, it only uses 1 worker at 32 outstanding I/Os per target, spans over 8GB, and is run for 20 minutes.

4.2.1 Setting the Disk Target

1. Click the **Disk Target** tab.
2. Click on **Worker 1**.
3. Click on the target drive (in this case, the NVMe Intel drive).
4. Set Maximum Disk Size to 16777216 sectors.
5. Leave Starting Disk Sector at 0.
6. Set # of Outstanding I/Os to 32 per target.

4.2.2 Setting Access Specifications

1. Click the **Access Specifications** tab.
2. Create the 128KB sequential read workload.
3. After the workload is created, click **Add** to assign it to Worker 1.



4.2.3 Setting Up the Test Duration

1. Click the **Test Setup** tab.
2. Set for 20 minutes.

4.2.4 Running the Test

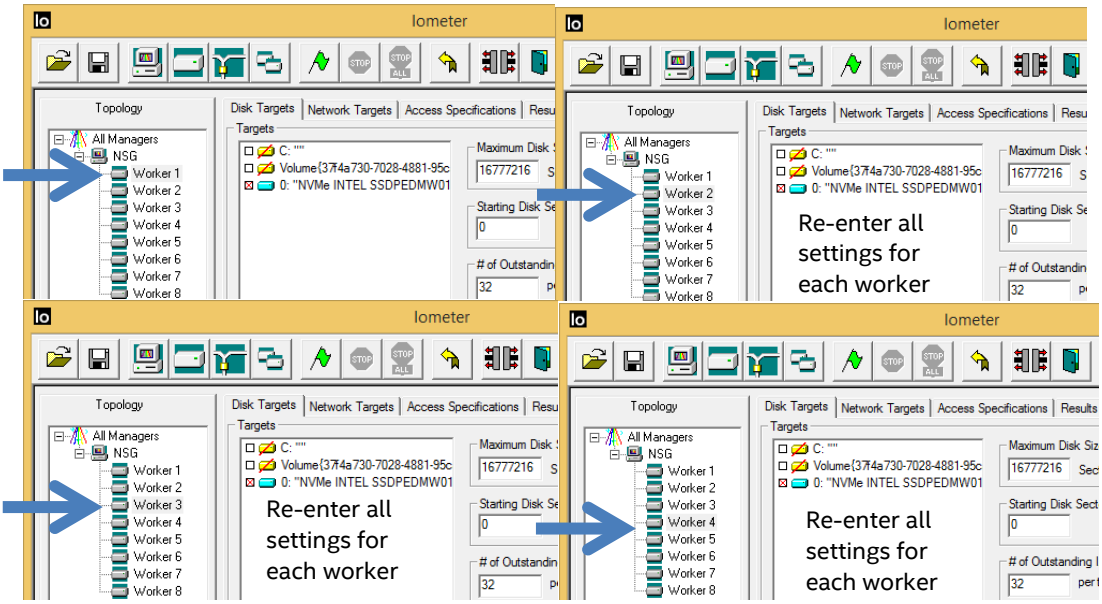
1. Click the **Results Display** Tab.
2. Set Last Update and Update Frequency to 1 second.
3. Click the green flag to run the workload.
4. Name and save the output file.
5. Check to see the Sequential Reads surpasses the specifications:
   - 2200MB/s for 400GB 750 Series SSD
   - 2400MB/s for 1.2TB 750 Series SSD

4.3 4KB Random Writes

The third workload is the 4KB, aligned, random writes. Although many parameters are similar (Maximum Disk Size to 16777216 sectors and # of Outstanding I/Os to 32 per target), there is one key difference. To take advantage of NVMe technology, you must use multiple CPU queues. This is done by using multiple workers in IOMeter.

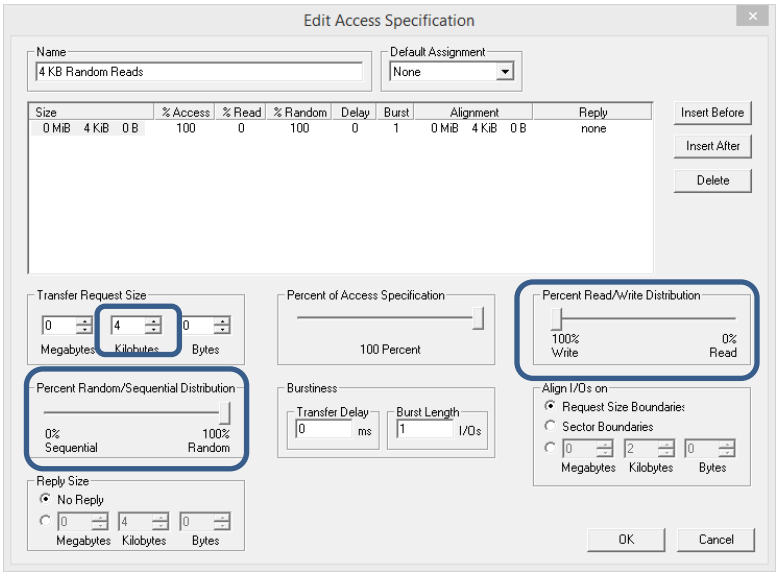
4.3.1 Setting the Disk Target

1. Click the **Disk Target** tab.
2. Click on **Worker 1**.
3. Click on the target drive (in this case, the NVMe Intel drive).
4. Set Maximum Disk Size to 16777216 sectors.
5. Leave Starting Disk Sector at 0.
6. Set # of Outstanding I/Os to 32 per target.
7. Click on **Worker 2**.
8. Copy all Worker 1 parameters to Worker 2.
9. Click on **Worker 3** and re-enter the parameters.
10. Repeat for Worker 4.

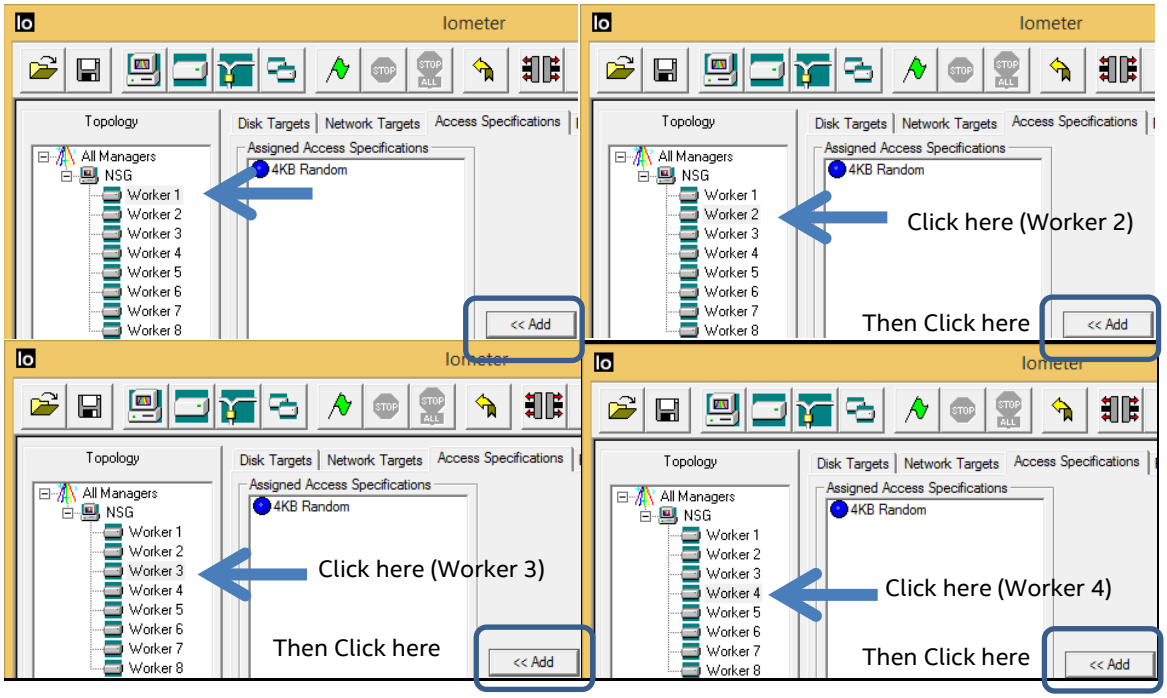


4.3.2 Setting Access Specifications

1. Click the **Access Specifications** tab.
2. Create the 4KB random writes workload.



3. After workload is created, click **Add** to assign it to Worker 1.
4. Click on Worker 2 and click **Add** to assign it to Worker 2.
5. Repeat for Workers 3 and 4.

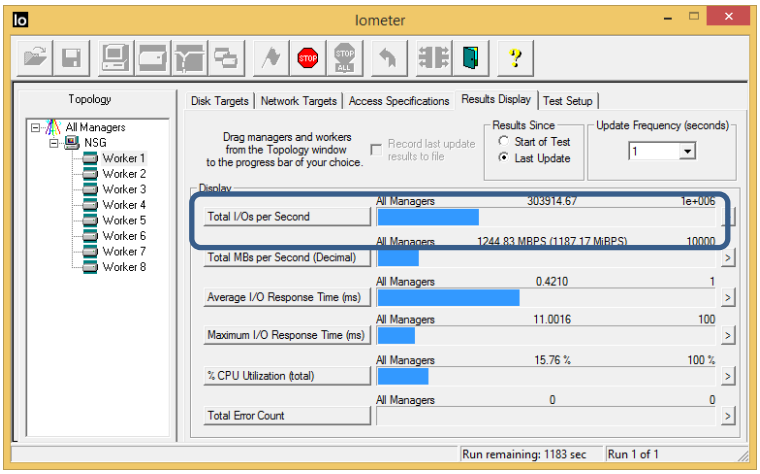


4.3.3 Setting Up the Test Duration

1. Click the **Test Setup** tab.
2. Set for 20 minutes.

4.3.4 Running the Test

1. Click the **Results Display** tab.
2. Set Last Update and Update Frequency to 1 second.
3. Click the green flag to run the workload.
4. Name and save the output file.
5. Check to see the Random Writes (Total I/Os per Second) surpasses the specifications:
    - 230,000 IOPs for 400GB 750 Series SSD
    - 290,000 IOPs for 1.2TB 750 Series SSD



4.4 4KB Random Reads

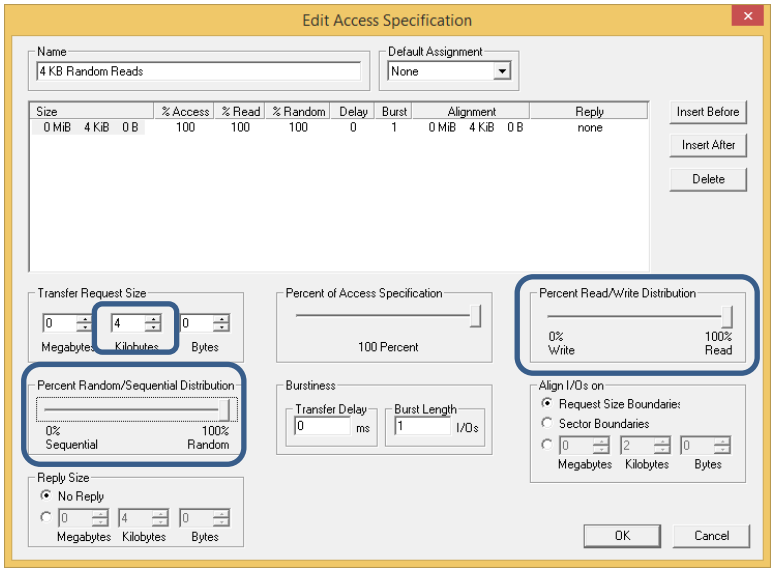
The final workload is 4KB random reads. The setup is essentially the same as the random writes workloads. The only thing that differs is the workload. If you still have the random writes setup, change the workload to 4K random reads and assign it to all four workers.

4.4.1 Setting the Disk Target

1. Click the **Disk Target** tab.
2. Click on **Worker 1**.
3. Click on the target drive (in this case, the NVMe Intel drive).
4. Set Maximum Disk Size to 16777216 sectors.
5. Leave Starting Disk Sector at 0.
6. Set # of Outstanding I/Os to 32 per target.
7. Click on **Worker 2**.
8. Copy all Worker 1 parameters to Worker 2.
9. Repeat for Workers 3 and 4.

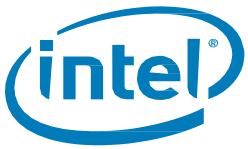
4.4.2 Setting Access Specifications

1. Click the **Access Specifications** tab.
2. Create the 4KB random read workload.



3. Once workload is created, click **Add** to assign it to Worker 1

   You will also need to assign the workload to Workers 2, 3, and 4.
4. Click on Worker 2, then click **Add** to assign it to Worker 2.
5. Repeat for Workers 3 and 4.



4.4.2.1 Setting Up the Test Duration

1. Click the **Test Setup** tab.
2. Set for 20 minutes.

4.4.2.2 Running the Test

1. Click the **Results Display** tab.
2. Set Last Update and Update Frequency to 1 second.
3. Click the green flag to run the workload.
4. Name and save the output file.
5. Check to see the Random IOPs surpasses specifications:
   - 430,000 IOPs for 400GB 750 Series SSD
   - 440,000 IOPs for 1.2TB 750 Series SSD

5 Evaluating the Results

After running the workload, IOMeter will produce .csv files you can view in excel to analyze additional data. The .csv files will contain average data and will not necessarily show maximum or peak values (up to numbers). However, the average values should still surpass SSD 750 Product Specifications.

- For Random workloads, check for IOPS, column G
- For Sequential workloads, check for MiBps: column J

Below are results from the 4KB Random Write Workload viewed in Excel:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	'Test Type	Test Description													
2	0														
3	'Version														
4	1.1.0														
5	'Time Stamp														
6	2015-03-18 22:36:51:327														
7	'Access specifications														
8	'Access sp	default assignment													
9	Untitled 1	0													
10	'size	% of size	% reads	% random	delay	burst	align	reply							
11	4096	100	0	100	0		4096	0							
12	'End access specifications														
13	'Results														
14	'Target Ty	Target Na	Access Sp	# Manage	# Workers	# Disks	IOps	Read IOps	Write IOp	MiBps (Bi	Read MiB	Write MiB	MBps (De	Read MBp	Write MB	Trar
15	ALL	All	Untitled 1	1	4		295741.8	0	295741.8	1155.241	0	1155.241	1211.358	0	1211.358	295
16	MANAGEF	NSG	Untitled 1		4		295741.8	0	295741.8	1155.241	0	1155.241	1211.358	0	1211.358	295
17	PROCESSC	CPU 0														
18	PROCESSC	CPU 1														
19	PROCESSC	CPU 2														

In this case, IOMeter reports 295741.8 IOPs for random writes. The data sheet specs the SSD 750 Series 1.2TB at 290,000 IOPs. These results align with the data sheet.

Next, we have the results from a sequential read. The results show MB/s of 2591.396. This aligns with the SSD 750 Series 1.2TB product specification statement of 2400 MB/s

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	'Test Type	Test Description														
2	0															
3	'Version															
4	1.1.0															
5	'Time Stamp															
6	2015-03-18 22:35:30:227															
7	'Access specifications															
8	'Access sp	default assignment														
9	Untitled 1	0														
10	'size	% of size	% reads	% random	delay	burst	align	reply								
11	131072	100	100	0	0	1	131072	0								
12	'End access specifications															
13	'Results															
14	'Target Ty	Target Na	Access Sp	# Manage	# Workers	# Disks	IOps	Read IOps	Write IOp	MiBps (Bi	Read MiB	Write MiB	MBps (De	Read MBp	Write MB	Transac
15	ALL	All	Untitled 1	1	1	1	20731.16	20731.16	0	2591.396	2591.396	0	2717.275	2717.275	0	20731.
16	MANAGEF	NSG	Untitled 1		1	1	20731.16	20731.16	0	2591.396	2591.396	0	2717.275	2717.275	0	20731.
17	PROCESSC	CPU 0														