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Intel® Solid State Drive 660p Series

Evaluation Guide

January 2021

Ordering Information

Contact your local Intel sales representative for ordering information.

Revision History

Revision Number	Description	Revision Date
001	• Initial release.	July 2018
002	• Updated span size in sections 5.2 & 5.3	July 2018
003	• Added performance range for Section 5.1, Table 4	October 2018
004	• Minor changes to Table 1 in Platform Configuration and Settings	December 2018
005	• Updated tools referenced to Intel® Memory and Storage Tool	January 2021

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Tool References

Product	Download Link
Intel® Memory and Storage Tool (Intel® MAS)	https://downloadcenter.intel.com/download/30058?v=t
IOMeter	http://www.iometer.org/
CrystalDiskMark	https://crystalmark.info/?lang=en

1   Overview

The Intel® SSD 660p Series, Intel's first advanced QLC (Quad-level-cell) NAND technology based SSD designed to offer the performance required for client platform usages such as web surfing, office and home productivity, media entertainment, etc. The product delivers Intel's industry leading quality and reliability, giving a 1.6 million hour mean time between failures (MTBF) under a 5-year limited warranty.

This guide outlines the best know practices and configuration for evaluating Intel® SSD 660p Series performance in the Windows environment.

This guide provides a high-level overview of different measurement and benchmarking methods and describes Intel's recommended method to evaluate the Intel SSD 660p Series.

This guide is intended for publications, OEM, technical analysts, and individuals who plan to test or evaluate the Intel SSD 660p Series performance, security, and manageability features.

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2 Intel® SSD 660p Series – SLC Cache Architecture

In common PC usage scenarios such as windows search, web surfing, e-mail composition, writing project reports or delivering a presentation, the storage device on the PC is mostly idle for a significant portion of time. Intel® SSD 660p, built using Intel® QLC (Quad-Level-Cell) NAND technology, is designed to thrive in these common PC usage scenarios. Intel® SSD 660p offers a large SLC span, which boosts performance of common PC workloads that are clustered in bursts between lengthy storage idles, while also providing higher capacity benefits of QLC NAND technology.

Intel® SSD 660p Series SLC Cache Architecture

Intel® SSD 660p, built using Intel® QLC NAND technology, enables 4-bits of storage per cell. The QLC NAND allows 33% more storage in the same area compared to TLC NAND. Compared to TLC NAND cell, the QLC NAND cell has a higher write and read latency. To mitigate the impact of higher latency of the QLC NAND in Intel® SSD 660p, Intel has designed and implemented an innovative SLC cache, which is variable based on available unused capacity on the SSD, that delivers faster sequential and random data writes.

Data writes from the host will be directed through the variable size, high speed SLC cache and offer faster data writes through the full span of the SLC cache. When the SLC cache is reaching its full capacity, the drive firmware moves the contents of the SLC cache into the available QLC cells. The firmware also has an intelligent algorithm to opportunistically move the data from SLC cache to QLC cells during the drive idles. This feature allows the user to experience a smoother and refreshed experience from the SSD. The variable SLC adjusts in size bi-directionally based on the available capacity of drive. The drive is also designed with a dedicated static SLC cache to provide faster write performance when the drive is limited available capacity.

Testing Methodology Recommendation

Some traditional benchmarks and tests may involve pre-filling the SSD with data, and immediately followed by further writes to evaluate performance. Although it is a good way to stress the SSD to understand its characteristics, the testing methodology may not reflect the actual use case scenarios. Intel recommends that sufficient idle times be given, to mimic the common PC usages, especially on tests that expect a heavy pre-fill condition. The idle time, will refresh the SLC cache by transferring the data into available QLC media and will ensure a better user experience. Please refer to the following image for SLC cache size per SSD capacity.

Figure 1:   SLC Cache Size per SSD Capacity

SLC CACHE SIZE IN GB VS USED CAPACITY PER SKU

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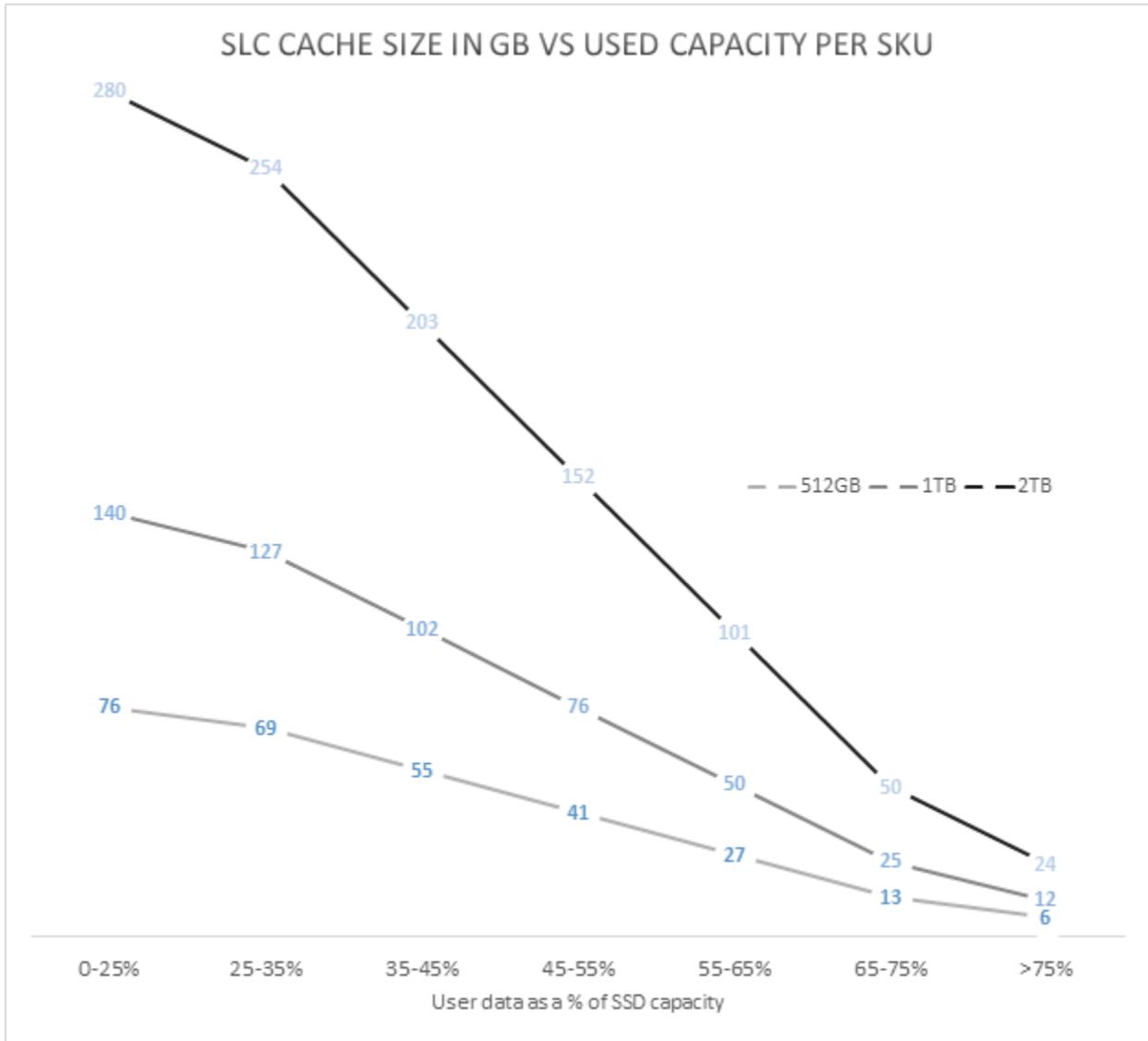
3 System Tuning for Optimum Performance

In order to obtain consistent and repeatable data, a stable and deterministic environment is necessary. To ensure stability and the deterministic nature of the testing environment, it is important to constrain the variables (platform, device, and OS settings, etc.). The variables are categorized as:

- Platform Configuration and Settings
- Operating System Settings
- Operating System Preparation Steps
- Device Preparation Steps

3.1 Platform Configuration and Settings

The following table shows the platform configuration and BIOS settings for evaluating the storage device.

Table 1:   System Configuration for Performance Analysis

Type	Configuration	
CPU	Intel® Core™ i7-8700K @ 3.70GHz	
Chipset	Intel® INF 10.1.1.42	
Motherboard	Gigabyte Z370 AORUS Gaming 5 motherboard	
Memory	16GB (4X4GB) DDR4-2667, Crucial	
BIOS version	American Megatrends Inc. F6 4/3/2018	
BIOS configuration	Hyper threading:	Enabled
	EIST (Enhanced Intel Speed Step Technology):	Enabled
	Intel Turbo Mode:	Enabled
	PCIe ASPM (Active State Power Management):	Disabled
	C-States:	Disabled
	P-States:	Disabled
Windows version	Microsoft Windows 10 Enterprise 64-bit Redstone 4 (10.0.17134) or later operating system on the primary drive	
	Native NVMe storage driver	
Storage	Secondary Drive: **Intel® SSD 660p Series (512GB, 1TB)** • Recommend to test performance on Intel® SSD 660p Series as secondary drive if possible. • Perform secure erase on the Intel® SSD 660p Series drive for out of box performance.	

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3.2   Operating System Settings

Set the desired OS settings before reading the device and installing the benchmark. These desired settings usually address the disabling of background processes, changing priority for IO, and ensuring that there aren't any unfinished tasks running that could invalidate benchmark results. When setting up the OS for benchmarking, configure these general settings to ensure stable, consistent, and repeatable results.

- Intel recommends a clean Windows 10 or later versions, x64 OS install on the machine(s) that will be used for testing/benchmarking.
- Run Windows Update to ensure all drivers are current and updated
- Install all chipset drivers for the motherboard and all peripheral drivers manually if required from the link below – http://downloadcenter.intel.com/default.aspx?lang=eng

The following recommended OS settings enable stable, consistent, and repeatable benchmark results.

Table 2:   Recommended OS Settings

Setting	Status
Power Scheme	High Performance mode
Power Options > Turn off hard disk after	0 Minutes (Never)
Power Options > Internet Explorer > JavaScript Timer Frequency	Maximum Performance
Power Options > Desktop background settings > Slide show	Paused
Power Options > Wireless Adapter Settings > Power Saving Mode	Maximum Performance
Power Options > Sleep > Sleep after	0 Minutes (Never)
Power Options > Sleep > Allow wake timers	Enabled
Power Options > USB settings > USB selective suspend setting	Disabled
Power Options > Intel Graphics Power Plan	Maximum Performance
Power Options > Power buttons and lid > Power button action	Do nothing
Power Options > Power buttons and lid > Sleep button action	Do nothing
Power Options > PCI Express > Link Power Management	Off
Power Options > Processor power management > Minimum processor state	100%
Power Options > Processor power management > System cooling policy	Active
Power Options > Processor power management > Maximum processor state	100%
Power Options > Display > Turn off display after	0 Minutes (Never)
Power Options > Display > Display Brightness	100%
Power Options > Display > Dimmed display brightness	100%
Power Options > Display > Enable adaptive brightness	Off
Indexing Service Windows search **Indexing Options** > Modify > uncheck the drive under test	Disabled
Scheduled Defragmentation Windows search > This PC > Right click on the drive > Properties >Tools > Optimize > Change Settings > uncheck Run on schedule	Disabled

Setting	Status
System Protection (System Restore) Right click on start > system > system protection > configure > Select Disable system protection	Disabled
Paging File (Swap File) Right click on start > system > Advanced system settings > Advanced > Settings > Advanced > change > Uncheck Automatically manage paging file size for all drive	Disabled
Prefetch Right Click on Start > Run > Enter services.msc and OK > Scroll and select Superfetch > stop > change startup type to Disabled	Disabled
Superfetch Right Click on Start > Run > enter regedit > Registry Editor Navigate to HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\Session Manager\Memory Management\PrefetchParameters > Double click on EnablePrefetcher and change value to 0	Disabled
Hibernate and Sleep Mode Settings > system > Power and Sleep > Sleep > Never Settings > system > Power and Sleep > Hibernate > Never	Disabled
Screen Saver Settings > Personalization > Lock screen > screen saver settings > None	Disabled
Windows Defender Start > Settings > Update and Security > Windows Defender > Disable	Disabled
Automatic Windows Updates Start > Settings > Update and Security > Windows Update > Disable	Disabled
Virus Protection	Disabled

3.3   Operating System Preparation Steps

These steps detail the necessary procedure to prepare the OS so that it is in a true idle state before executing the measurements. Once the OS is installed and configured properly there are further steps necessary to ensure that the system is ready to execute performance measurements. The following steps should be followed to enable a proper starting state:

- Close all applications that are not necessary for measurement.
- Open the Task Manager and close/Kill all the unrelated tasks and process
- Allow the system to idle for 15 minutes to ensure a true idle.

3.4   Device Preparation Steps

These steps will detail the procedures necessary in order to prepare the devices so that they are updated and in a steady state before executing the measurements.

- Verify that the Intel® 660p SSD has the latest firmware applied.
    - To view and update the current firmware installed on the SSD, use Intel® Memory and Storage Tool (Intel® MAS). The Intel® Memory and Storage Tool can be downloaded from: https://downloadcenter.intel.com/download/30058?v=t

- Perform Secure Erase on the drive for out-of-the box performance
- Install the latest Microsoft Windows 10 x64 build.
    - Ensure the storage device is partitioned and formatted in NTFS.

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4 Benchmarks

Benchmarks are designed to mimic a particular type of workload on a component or system, and provide an indicator of performance. This section provides an overview of three basic types of benchmarks that can be used to measure system storage performance:

- Application-based Benchmarks
- Trace-based Benchmarks
- Synthetic Benchmarks

4.1 Application-based Benchmarks

Application-based benchmarks run real-world programs on a system and measure the application performance as it uses the system.

Application-based benchmarks emulate end-user usage with the help of scripted execution of real-world programs on a system. Application-based benchmarks measure the load and execution time of these applications and present the results as a score. Individual subsystem scores are created by grouping those applications that are common to a type of user and are then reported as subsystem scores.

SYSmark 2014 SE is an example of an application-based benchmarking tool. It provides results in the form of four sub scores and one overall score.

Application-based benchmarks are helpful in determining the user experience (UX) for a given system. In particular, the scores from an application-based workload are more likely to reflect the real world UX than the results from a purely synthetic workload.

Application-based benchmarks may also result in a single measure for system performance, which can be used as a product ranking index.

One disadvantage of application-based benchmarks when trying to determine storage device speed is that they traditionally focus on CPU, memory, and graphics performance and may not properly weigh storage sub-system speed in the final results. They also may not take into account end-user perceivable delays such as application loads. Another disadvantage is that the scripted nature of an application-based benchmark is fixed and the application workload may not be representative of an end-user usage model, especially when multiple iterations are repeatedly in sequence. Lastly, due to practical considerations that constrain the total allowable runtime and total size of the benchmark (e.g., download based distribution, total amount of disk space required to run), many application-based benchmarks have a short-run duration and limited storage device usage. Therefore, as a practical basis, these benchmarks will not be representative of storage device usage over time.

4.2 Trace-based Benchmarks

Trace-based benchmarks are based on traces, or recordings, of disk I/O operations executed during a certain period of time of real use or script-based use. The trace is then used to "play back" the system I/O sequence on the particular drive to be tested. Trace-based benchmark results vary in format.

PCMark 8 Storage test is an example of a trace-based benchmarking tool.

Trace-based benchmarking has many of the advantages of application-based benchmarking, when the trace is collected from real-use or a realistic script-based activity. It has the further advantage of highlighting disk I/O behavior while avoiding the bottlenecks caused by the CPU, graphics, and memory subsystems. It is also possible to run long traces, so performance over time can be measured.

One disadvantage of trace-based benchmarking is that third-party tools required for testing are not as readily available as those for synthetic and application-based benchmarking. Additionally, the recorded trace may not reflect the true long term usage of the storage device over weeks or months of time.

4.3   Synthetic Benchmarks

Synthetic benchmarks measure raw drive input/output (I/O) transfer rates. These benchmarks typically use well-defined, synthetic workloads and target only specific components such as storage devices. These benchmarks format results as raw megabytes (MBs) in Input / Output Operations per Second (IOPS).

Storage subsystem synthetic benchmarks focus on drive performance without taking into account bottlenecks from other subsystems such as CPU, memory, or graphics. This makes these benchmarks useful for measuring drive performance for changing parameters such as transfer sizes. However, because these benchmarks exercise components and systems in ways that do not reflect system usage models, the results may not reflect real-usage cases. For example, one SSD might have better synthetic benchmark scores for 512 KB random reads than other SSDs, but 512 KB random reads may not be a good indicator of overall system performance because of the rarity of that particular I/O access size in what is important to a given end user experience.

Examples of synthetic benchmarking tools include IOMeter, CrystalDiskMark.

4.4   Summary of Benchmark Types

Table 3:   Benchmark Summary

Feature	Synthetic Benchmark	Application-Based Benchmark	Trace-Based Benchmark
Measures drive I/O performance in MB/s or IOPS	Yes	No	Possibly
Measures application performance	No	Yes	No
Measures overall system performance	No	Yes	No
Represents real-world use cases	No	Possibly	Possibly
Represents user experience	No	Yes	No
Avoids system bottlenecks	Yes	No	Yes

4.5   Selecting the Benchmark

Evaluating the performance of the SSD starts with understanding which storage performance characteristics are important for you – sequential read performance, random write performance, low latency, mixed read/write workload and under what conditions – do you need these parameters measured in usage case scenario considering all the system components and latencies, or in a controlled synthetic environment?

To understand which storage performance characteristics and conditions are important to you, it is required for you to understand your workload. The workload, performance characteristics and usage case scenarios should be considered to select the appropriate benchmark that represents a case closer to the actual usage scenario.

4.6   Running a Benchmark

After prepping the device, and configuring the BIOS and OS settings, install the benchmark on the system. Configure the benchmark to match your workload and run the test multiple times and collect the results. Please note the median score of the runs and use that for the reporting purposes.

4.7   Testing Methodology Recommendation

Traditional testing involves pre-filling the SSD with data and writing the data to the drive for hours to evaluate the performance but this testing methodology doesn't reflect the actual use case scenarios. The common PC usages the usage scenarios such as web surfing, writing a report, e-mails, delivering a presentation involves significant drive idle times. So it is recommended that the PC usage scenarios be considered while running synthetic tests.

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5   *Performance Results*

This section provides an example of performance results that Intel measured when testing the Intel SSD 660p. The results shown are based on specific system hardware configurations and may vary depending on the system used. If results vary considerably, contact your Intel representative.

5.1   IOMeter

IOMeter 1.1.0 is a very flexible synthetic benchmark that measures sequential and random workload on an SSD. The span size set is 8 GB. IOMeter is run for duration of 10 minutes.

Table 4:   IOMeter Test Results

Performance Parameters	512 GB Scores	1 TB Scores
Sequential Read (MB/s) (T=1 QD=64)	1500 - 1770	1800 - 1930
Sequential Write (MB/s) (T=1 QD=64)	1000 - 1200	1800 - 1900
Random Read (KIOPS) (T=4 QD=256)	90 - 110	150 - 165
Random Write (KIOPS) (T=4 QD=256)	220 - 240	220 - 250

Note:

The results depend on the specific platform configurations and workloads utilized in the testing, and may not be applicable to any particular user's components, computer system or workloads. The results are not necessarily representative of other benchmarks and other benchmark results may show greater or lesser impact from mitigations

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.

5.2   PCMark 8 Storage Test

The following table shows the storage performance results for the PCMark 8 benchmark.

Table 5:   PCMark 8 Storage Test Results

PCMark 8 Storage Test Score	512GB	1TB
	5,067	5,074

Note:

The benchmark results may need to be revised as additional testing is conducted. The results depend on the specific platform configurations and workloads utilized in the testing, and may not be applicable to any particular user's components, computer system or workloads. The results are not necessarily representative of other benchmarks and other benchmark results may show greater or lesser impact from mitigations.

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