

SSD BENCHMARKING METHODOLOGY

Application Note

Document #AN0006 – Viking SSD Benchmarking Guide | Rev. C

Purpose of this Document

This application note was prepared to help OEM system designers evaluate the performance of Viking solid state drive solutions by using the same benchmarking methodology that Viking performs in its SSD test facility. The SSD performance stated in the Viking SSD datasheets can be achieved by following the same Viking approach to SSD benchmarking which has been outlined in this document.



DRAM MEMORY & FLASH STORAGE
NVDIMM, SSD, DRAM, MCP & CUSTOM
for Embedded, Industrial, Defense & Aerospace

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2 Defining and Measuring SSD Performance

2.1 Definition of SSD Performance

Viking's Solid State Drive performance is based on two important read/write metrics:

- 1) Throughput between the host and SSD for sequential writes and reads to contiguous blocks of flash memory. Sequential bandwidth speed is measured in megabytes per second, MB/s.
- 2) Operational performance between the host and SSD for writes and reads to random blocks of flash memory. Random read/write performance is measured in the # of Input/Outputs Per Second (IOPS).

The most significant metric to an SSD user will depend on the drives intended application. Applications that involve frequent transfers of small random amounts of data to the drive will benefit from high IOPS numbers which provide a quick response time to the host (i.e. operating systems, databases, OLTP etc.). Applications that involve moving large sequential amounts of data (i.e. video streaming, data acquisition, data backup/restore, image processing etc.) will benefit from high throughput (i.e. MB/s).

It is important to note that the SSD interface to the host will determine the absolute maximum performance capability for reading/writing to an SSD (i.e. SATA v2.6 is 1.5/3 gigabits per second and SATA v3.0 is 6 Gbit/sec, etc.)

2.2 SSD Factors That Affect Performance

SSD performance not only depends on the current transactions being performed on the drive, but also on the history of transactions that occurred previously on the drive. SSDs achieve the best write performance if there are large amounts of free space already in the flash array. This is the case immediately after a drive is first installed in a system, "fresh out of the box" (FOB) and before any data is written to it. This best case performance is not sustainable.

A more meaningful "real world" case for benchmarking an SSD is after the entire drive has been written to and "free space reclamation" and other background SSD processes are running. This is a realistic steady state condition that occurs in real workload applications which may fragment data storage unevenly across non-adjacent locations on the drive due to SSD "free space recycling" (a.k.a. garbage collection) and wear-leveling.

Access time (latency) in retrieving data is generally impacted by the queue depth, but not by the size of the SSD or the location of the data on the SSD. Drive performance will

be impacted by the utilized capacity and the amount of free space available on the drive, including over-provisioning. (SSD over-provisioning works like HDD short stroking).

SSD performance is also affected by the type of data and how it is being stored such as transaction size (block size), % mix of reads vs. writes, % mix of random vs. sequential read/writes, differences in data patterns and where the LBA data access begins on a drive boundary. Smaller block sizes have higher IOPS values compared to large blocks, but the IOPS value will decrease as the transactions change from 100% read to 100% write or 100% random to 100% sequential.

Internal SSD factors also affect SSD performance such as the type of controller, the NAND flash inside the drive (i.e. SLC, MLC, TLC), the interface technology of the flash (i.e. Async/Legacy, ONFI, ToggleDDR), the speed of the flash (i.e. ToggleDDR1, ToggleDDR2 etc and the clocking rate of the controller-flash bus, NAND geometry (i.e. 19nm, 15nm). Performance can vary across vendors of the flash component based on these factors and to a lesser degree across the SSD capacity.

The SSD architecture (i.e. RAID, multiple flash channels, native vs. bridging) and the complexity/efficiency of the controller (data intelligence, garbage collection, recycling, wear leveling, etc.) also have a major impact on performance.

2.2.1 Drive Life Protection (and Performance Throttling)

The firmware in Viking SSD's can be programmed to ensure that the endurance life of the SSD will not expire before a certain period of time. This is accomplished by a setting in the firmware which limits the speed of the program/erase cycles (writes) to a performance level that will not exceed the endurance level of the flash for the specified amount of time. This performance throttling is called Drive Writes Per Day (DWPD). The Viking factory default is the warranty period for the drive. Read operations are unaffected by this approach to protecting drive life. Some SSDs have software write protect enabled when the drive reaches its end of life, often called the total TeraBytes Written (TBW).

2.3 Measurement of SSD Performance

Viking's primary SSD performance measurement and characterization tool is IOMETER 06. However SSD documentation often provides CrystalDiskMark (and ATTO) performance numbers. Information on how to download and use IOMETER is available for free from the Internet as follows:

- IOMETER v2006.07.27 (known as IOMETER 06)
<http://www.iometer.org/doc/downloads.html>

There are two versions of IOMETER, and they have significant differences between them. IOMETER 06 uses a random non-repeatable data pattern and IOMETER 08 uses a quasi-random somewhat repeatable data pattern.

IOMETER 06 is considered a worse case performance measurement because its data pattern requires that all host data be treated uniquely and thus requires all data to be written to the flash. IOMETER 08 is considered a best case performance measurement since the data pattern means that all data may not need to be written to flash. Some SSDs, such as the Viking SSD, have the ability to detect repeatable data patterns and prevent a rewrite of duplicate data. This is effectively a form of data compression which removes repeatable data patterns that increases performance. Viking uses only IOMETER 06. It is also important to know, that results might not be comparable for the same versions of IOMETER, with different revisions. For example, if there was a software bug/error in an older revision, there might be a performance difference using a newer and later version of IOMETER 06.

2.3.1 Benchmarking SSD's

For the purpose of benchmarking and comparing SSD performance results, it is necessary to test SSD's on the same type of platform using identical test conditions. This puts SSD's on the same "playing field" and eliminates any apparent performance differences attributed to non-SSD items. These include:

- Hardware test system (including southbridge chipset that interfaces to the SSD)
- Host operating system and version/revision of the host operating system
- Host software drivers for the SSD
- Configuration settings for the software driver (i.e. AHCI)
- Environmental conditions (especially temperature)
- Version and revisions of test software
- Data patterns written to the SSD

In addition to using an identical test platform under the same test conditions, SSD's should be of equal capacity with similar usage/wear and rated at the same interface speed (i.e. SATA 3Gb/s, 6Gb/s etc..).

3 Viking Benchmarking of SATA SSD's

3.1 Benchmarking Setup for SATA SSD's

This section explains the setup required for getting consistent results on SATA SSD benchmarking. It is important to select, and properly configure a number of different elements in the test system to achieve the maximum sustained SSD performance.

- AHCI Driver type
- Enable AHCI to allow NCQ to the maximum Queue Depth

- Offset and Alignment of disk partition
- Operating System setup
- SSD Selection and Configuration

3.2 Selecting the Benchmarking Platform

Select a high performance host (CPU, memory, I/O) and configure it with high performance drivers. Make sure that the SSD interface of the host is at least equal to or greater than the rated speed for the SSD being tested (i.e. SATA v2.6 1.5/3Gbit/sec, SATA v3.0 6Gbits/sec, etc.)

Viking is currently testing SATA SSD's at room temperature (20-25°C) on an Intel motherboard using DDR3 memory and an Intel ICH10 southbridge chipset with AHCI SATA-3 6Gb/s ports & Native Command Queuing (NCQ).

3.3 Install Intel Matrix Storage Manager AHCI Driver

The **Advanced Host Controller Interface (AHCI)** is a programming-specification which defines the operation of Serial ATA host-controllers in a non implementation-specific manner. The specification describes a system memory structure for computer hardware vendors to exchange data between host system DMA memory and attached storage-devices. AHCI offers software developers and hardware designers a standard method for detecting, configuring, and programming SATA/AHCI adapters. AHCI is separate from the SATA 3Gb/s standard, although it exposes SATA's advanced capabilities (such as hot-plugging and native command queuing) such that host-systems can utilize them.

Native Command Queuing (NCQ) is a technology designed to increase performance of SATA storage devices under certain situations by allowing the individual storage device to internally optimize the order in which received read and write commands are executed.

Most importantly AHCI enables native command queuing (NCQ), providing significant measured performance improvements by keeping the drive busy. To enable optimal performance, run the system with Intel AHCI, NCQ enabled and a Queue Depth of at least 8 and preferably 32 for SATA. The figures below shows how command queue depth can impact IOPS performance and latency under different workloads.

Figure 3-1: Queue Depth

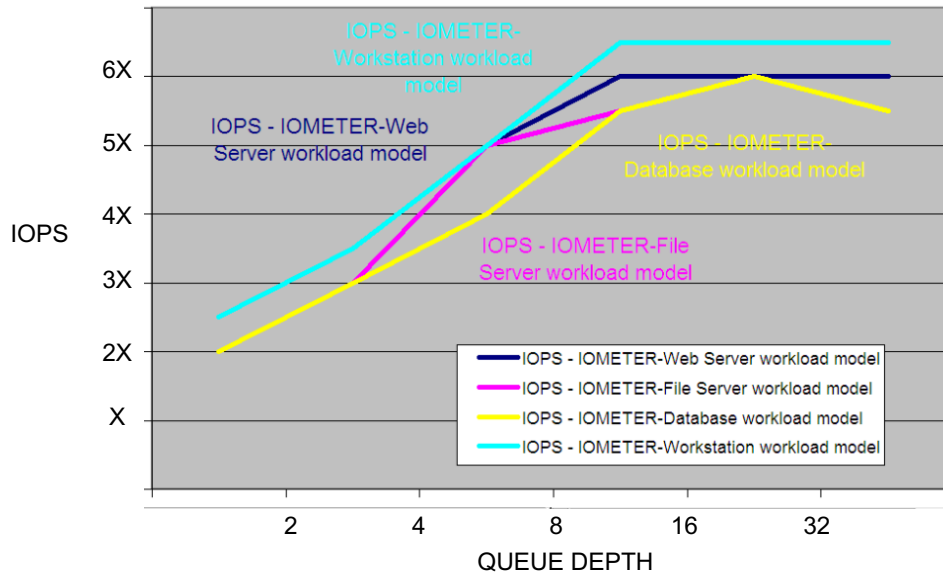
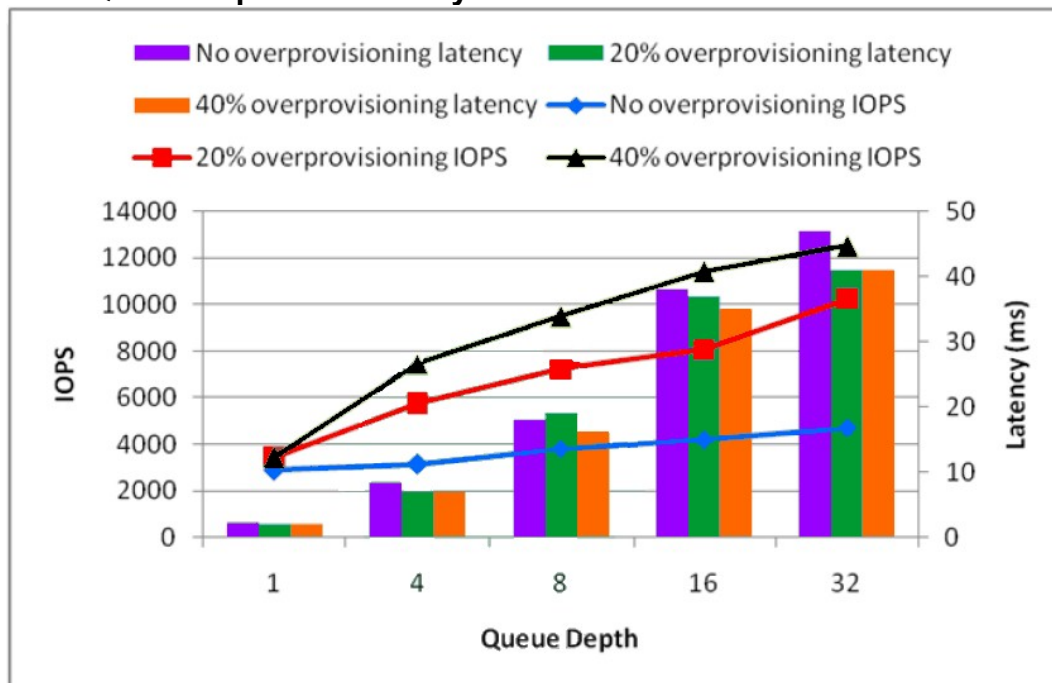


Figure 3-2: Queue Depth vs. Latency and IOPS



3.3.1 Intel SATA AHCI Driver

Through the course of our testing, Viking has found that the Intel AHCI driver generally delivers better performance than the Microsoft AHCI driver for most SSD's when AHCI mode is enabled to allow NCQ. AHCI is a BIOS setting that can be enabled at boot up.

The Windows 7 AHCI driver is significantly improved over the Windows XP and Vista AHCI drivers, however testing shows that the Intel AHCI driver still out performs the Microsoft AHCI driver.

The Intel AHCI driver is also known as the Intel Matrix Storage Manager and is available as a free download here:

http://downloadcenter.intel.com/Detail_Desc.aspx?agr=Y&ProductID=2101&DwnldID=17412&str_OSs=150&OSFullName=Windows%20Vista*%2064&lang=eng

Note: The product name was changed from Intel® Matrix Storage Manager to Intel® Rapid Storage Technology beginning with version 9.5

3.4 Configuring an Operating System for Performance Testing

Spot testing has shown that different operating systems yield different performance results. Viking recommends using the same operating system throughout all testing unless you are only benchmarking the differences in the OS. Viking has benchmarked SSD's with the Microsoft Windows XP operating system which is a leaner OS with less overhead than Microsoft Windows 7. Although some operating systems (i.e. Windows 7) automatically enable SATA TRIM command to reclaim blocks no longer in use by the file system, TRIM is not available on Windows XP, so testing with Microsoft Windows 7 is preferred.

Disable any background applications to reduce throttling the SSD with overhead and computer housekeeping tasks. Also disable a number of features by making a few changes to the settings of the typical default OS installation to remove as much randomness as possible from test procedures. After a complete analysis of the SSD performance, these features can then be turned on individually to better understand their individual impact on the overall performance of the system. The changes are listed below:

1. Disable sidebar and startup menu
2. Disable user account control
3. Disable automatic updates
4. Disable remote access
5. Disable automatic defragmentation of drive
6. Disable system restore
7. Disable screen saver
8. Set power option to
 - Sleep: never
 - Turn off HDD: never
9. Disconnect from the network
10. Disable or uninstall antivirus software

3.4.1 Notes on enabling and using TRIM in Windows 7

The Microsoft AHCI driver v6.1.7600 Rev.16385 currently shipping with Windows 7 as of December 2010, does not support the DSMcap (maximum supported TRIM sectors) provided by an SSD; the Windows AHCI driver uses a default value of eight sectors and the Viking SSD only supports a maximum of one TRIM sector. The result is TRIM does not function on Viking SSDs in the above configuration. Without making the change shown below, the SSD may not operate at peak efficiency.

To enable TRIM in Microsoft Windows 7 using the Microsoft AHCI driver, a Windows 7

registry change will correct the issue. Detailed below are instructions for users to modify the registry and add the maximum supported TRIM sectors to support TRIM on Viking drives using the Microsoft AHCI driver.

Note: These instructions are only valid if you are running Windows 7 under AHCI mode, and are using the Microsoft AHCI driver.

IMPORTANT: This section contains steps that tell you how to modify the registry. Serious problems might occur if this is done incorrectly. Therefore, make sure you are comfortable making changes to the registry and follow these steps carefully. For added protection, back up the registry before you modify it. You can later restore it if a problem occurs. For more information about how to back up and restore the registry, follow this link to the Microsoft Knowledge Base: <http://support.microsoft.com/kb/322756/>

Instructions

1. Exit all Windows-based programs.
2. Click **Start**, type regedit in the **Start Search** box, and press **Enter** to open Registry Editor.
3. If you receive the **User Account Control** dialog box, click **Continue**.
4. Locate and then click on the following registry sub-key:

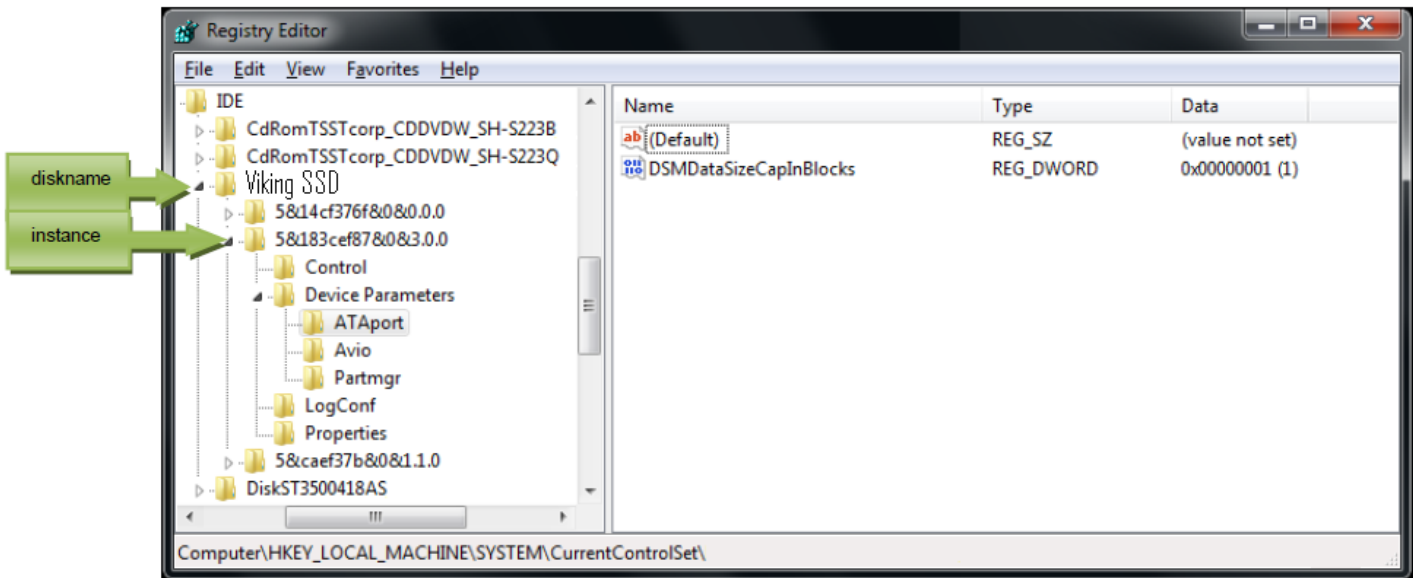
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Enum\IDE\<diskname>\<instance>\ DeviceParameters\ATAport

The <diskname> will be seen as "Disk???" where ??? matches the model name of the SSD being modified, like "DiskSF-1560TS6MFC".

The <instance> will be seen as "5&???" where ??? stands for a registry sub-folder created when a drive is connected to the machine, like "5&183cef87&0&3.0.0". Note that if the same drive is connected to different ports over time, multiple instances will show up under the <diskname>. If the user is unaware of which <instance> is currently active, the registry modification needs to be applied to every <instance>.

Please refer to the left pane of the figure below for clarification:

Figure 3-3: Making a registry change to enable TRIM in Windows 7



5. In the right pane, right-click on the blank area.
 6. Under the **New** submenu, select **DWORD (32-bit) Value**.
 7. Under the **Name** column type `DSMDDataSizeCapInBlocks`.
 8. Right click on the newly created `DSMDDataSizeCapInBlocks` and click **Modify**.
 9. In the **Value Data** box, type 1, and then click **OK**.
 10. On the **File** menu, click **Exit** to close Registry Editor.
 11. Reboot the system.
- The system will now support TRIM on the Viking SSD with the Microsoft AHCI driver.

3.5 Selecting an SSD for Benchmarking

Drive performance is not generally impacted with usage once the SSD has been filled to capacity, so benchmarking can be conducted on SSD's with prior usage or on new SSD's that have been pre-conditioned by a write operation that fills the entire drive. The procedure for SSD pre-conditioning a new drive to bring it to a steady state condition will be discussed later in this document.

3.6 Set the Test SSD as a Secondary Drive (not a boot drive)

Viking recommends a test platform with a separate boot drive from where the operating system and test software can be executed, and configuring the test SSD as a secondary "data" drive. There are periodic housekeeping tasks associated with a boot

disk (e.g. disk/memory page swapping, virtual memory, windows registry file updates) that can cause degraded performance results. Benchmarked performance on a secondary data drive is almost always better than on a primary boot drive. The purpose of isolating the SSD under test is to ensure consistent performance measurements for comparison and remove any variability from the OS functions.

3.7 Configuring a SATA SSD for Benchmarking

3.7.1 Setting the Partition Alignment and Offset on a SATA SSD

After the SSD is setup as a secondary drive and not the system boot drive, it will be necessary to partition the SSD.

Viking SSDs are designed to reach optimum performance when issuing transfers at starting LBAs which align the data access on 4K boundaries, except for SSD larger than 256 GB, which should align on 8K boundaries. This can easily be arranged in a properly configured system, but is not always done correctly or automatically by every operating system, AHCI driver, and benchmarking application. Additionally, even if the alignment is done correctly it is possible to be misaligned because a misaligned initial offset can cause boundary misalignment.

For Linux, special care is needed to ensure the offset of the partition is properly aligned.

For Microsoft Windows 7, the default alignment is correctly set for testing Viking SATA SSD's.

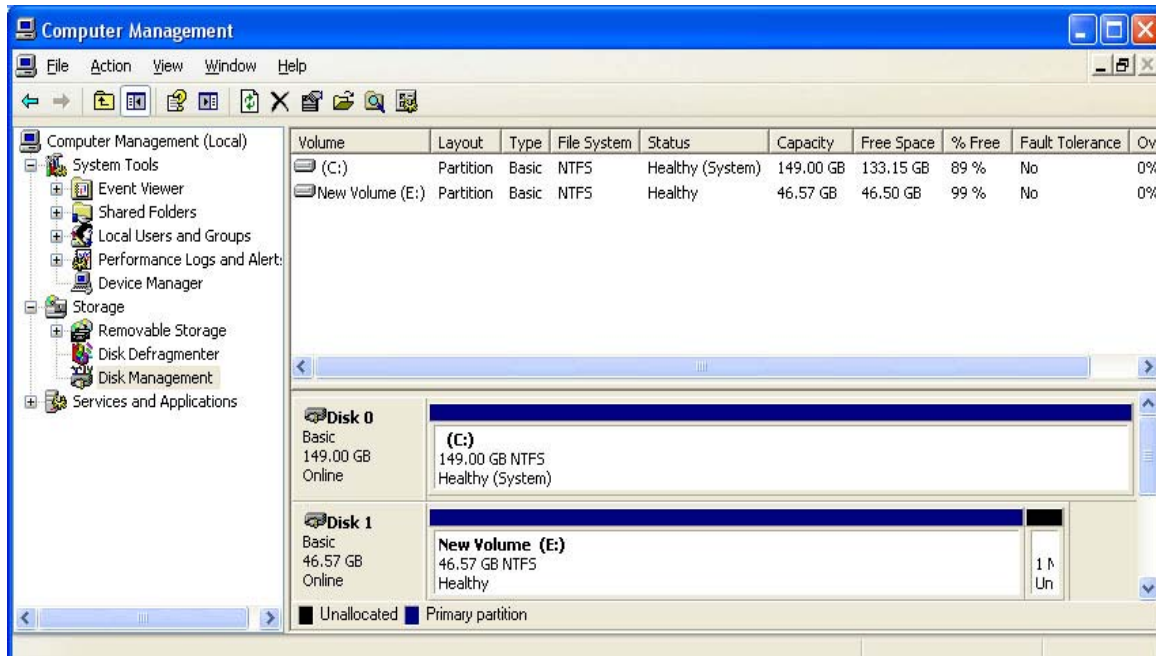
3.7.2 Formatting the Partition on an SATA SSD

IOMETER has the ability to write and read to a raw unformatted drive so it is not necessary to format the drive to benchmark with IOMETER. Note however, that IOMETER 06 will only work on port 0 for raw unformatted drives, so if other ports are being used for testing, they need to be partitioned and formatted. The SSD's can be formatted using Disk Manager utility as follows:

1. Click on Start (bottom left corner of the screen on the taskbar for Windows 7)
2. Right click on "My Computer"
3. Click on "Manage"
4. Click on "Disk Management" which is under "Storage"
5. Right click on the rectangular box which says "New Volume" next to **DISK 1**
(See Figure below for guidance.)
6. Click on "Format..."

7. Choose “Perform Quick Format” and press OK.

Figure 3-4: Formatting the Partition on an SSD



3.7.3 Setting the SSD parameters

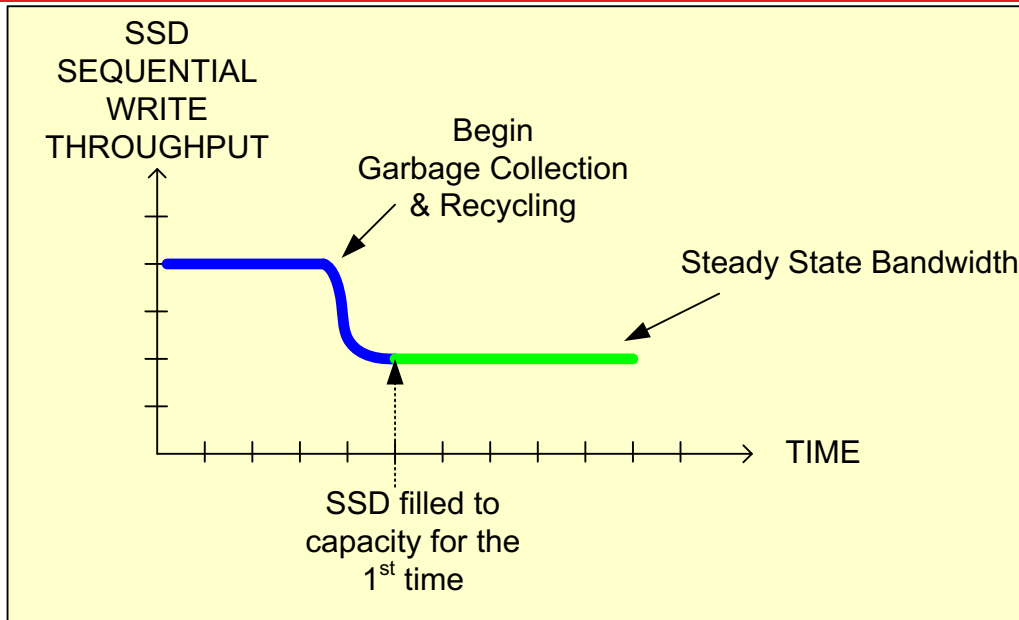
Many SSD parameters related to performance are automatically configured by the controller (firmware) and are not alterable by the user. These include items such as:

- % of over-provisioning for bad block management and garbage collection
- Cache (always enabled)
- Clock speed of the flash bus between the controller the flash components
- SSD background operations such as wear leveling, block recycling (garbage collection), recovery, etc.. (always enabled)

3.8 Pre-Conditioning a new SATA SSD before Benchmarking

As mentioned earlier, SSD’s “fresh out of the box” achieve the highest performance. However, this is not a sustainable performance level since performance will drop to a more realistic steady-state level, once the entire SSD has been written to as shown in the figure below:

Figure 3-5: Pre-Conditioning a New SSD



Note:

1. "Recycling" is also known as garbage collection to free empty space ("holes") on the flash inside the SSD
2. The performance drop can be in a range of up to -50% after pre-conditioning with IOMeter06 (worst case data patterns with 100% entropy/randomness). SSD's with 0% entropy will perform at similar performance levels, for both pre and post conditioning. Consult your local Viking Field Application Engineer for details.

Once an SSD has been filled to capacity, it will reach a steady state performance condition that remains the same for the life of the drive.

3.8.1 Steps to Pre-Condition an SSD

To bring a new SSD to a consistent/sustainable steady-state performance level, Viking pre-conditions an SSD with a 2-3 hour burn-in while sequentially writing to the drive using IOMETER 06.

3.9 Viking SATA SSD Benchmarking Methodology

Most available benchmarks do not provide a comprehensive picture of performance across different types of data patterns and block sizes. Viking tests with v2006.07.27 using random data patterns for worst case performance.

3.9.1 IOMETER Scripts

This section outlines the Viking SSD benchmarking procedure using IOMETER06 scripts. (IOMETER 08 is not used).

The table below shows the 4 tests that will produce the maximum performance numbers for the flash drive. These tests are conducted with an alignment on 4K boundaries with ACHI enabled to allow NCQ to a command depth for 32.

Table 3-1: IOMETER Maximum Performance Parameters

Test Name	Test Description	Performance Metric	Units
128k_seq_100rd	128K block size, 100% read	Sequential Read (Max)	MB/s
128k_seq_100wr	128K block size, 100% write	Sequential Write (Max)	MB/s
4k_ran_100rd	4K block size, 100% random read	Random Read (Max)	IOPS
4k_ran_100wr	4K block size, 100% random write	Random Write (Max)	IOPS

(Note: the script is a text file with a file extension of xxxx.icf)

Table 3-2: Example of an IOMETER Test Script

IOMETER Test Script.inf							
Version 2006.07.27							
TEST SETUP =====							
'Test Description							
Viking DVT Performance Test							
'Run Time							
hours	minutes	seconds					
0	0	30					
'Ramp Up Time (s)							
10							
'Default Disk Workers to Spawn							
NUMBER_OF_CPUS							
'Default Network Workers to Spawn							
0							
'Record Results							
ALL							
'Worker Cycling							
start	step	step	type				
1	1	LINEAR					
'Disk Cycling							
start	step	step	type				
1	1	LINEAR					
'Queue Depth Cycling							
start	end	step	step	type			
1	32	2	EXPONENTIAL				
'Test Type							
NORMAL							
'END test setup							
RESULTS DISPLAY =====							
'Update Frequency	Update Type						
0	WHOLE_TEST						

'Bar chart 1 statistic							
Total I/Os per Second							
'Bar chart 2 statistic							
Total MBs per Second							
'Bar chart 3 statistic							
Average I/O Response Time (ms)							
'Bar chart 4 statistic							
Maximum I/O Response Time (ms)							
'Bar chart 5 statistic							
% CPU Utilization (total)							
'Bar chart 6 statistic							
Total Error Count							
'END results display							
ACCESS SPECIFICATIONS =====							
'Access specification name	default assignment						
128k_seq_100rd	ALL						
'size	% of size	% reads	% random	delay	burst	align	reply
131072	100	100	0	0	1	4096	0
'Access specification name	default assignment						
128k_seq_100wr	ALL						
'size	% of size	% reads	% random	delay	burst	align	reply
131072	100	0	0	0	1	4096	0
'Access specification name	default assignment						
4k_ran_100rd	ALL						
'size	% of size	% reads	% random	delay	burst	align	reply
4096	100	100	100	0	1	4096	0
'Access specification name	default assignment						
4k_ran_100wr	ALL						
'size	% of size	% reads	% random	delay	burst	align	reply
4096	100	0	100	0	1	4096	0
'END access specifications							
MANAGER LIST =====							
Manager ID	manager name						
1	DMTEST6						
'Manager network address							
172.31.125.165							
'Worker							
Worker 1							
'Worker type							
DISK							
'Default target settings for worker							
'Number of outstanding IOs	test connection rate		transactions per connection				
32	DISABLED		1				
Disk maximum size	starting sector						
0	0						
'End default target settings for worker							
'Assigned access specs							

'End assigned access specs							
'Target assignments							
'End target assignments							
'End worker							
'End manager							
'END manager list							
Version 2006.07.27							

3.9.2 IOMETER Script Test Report

The output of IOMETER can be exported to a Microsoft CSV file for analysis and charting. The table below is an example of the type of data that is reported. (Note that the data in this table is actually placed horizontally across the CSV spreadsheet but is displayed here vertically to make it easy to see the all the test parameters.)

Table 3-3: Example of an IOMETER Test Report

'Test Type	Test Description				
'Version					
2006.07.27					
'Time Stamp					
2010-10-14 06:28:37:406					
'Access specifications					
'Access specification name	default assignment				
0.5k_seq_100rd	1				
'size	% of size	% reads	% random	delay	burst
512	100	100	0	0	1
'End access specifications					
'Results					
'Target Type	Target Name	Access Specification Name			
ALL	All	0.5k_seq_100rd			
MANAGER	DMTEST6	0.5k_seq_100rd			
PROCESSOR	CPU 0				
PROCESSOR	CPU 1				
PROCESSOR	CPU 2				
PROCESSOR	CPU 3				
PROCESSOR	CPU 4				
PROCESSOR	CPU 5				
PROCESSOR	CPU 6				
PROCESSOR	CPU 7				
WORKER	Worker 1	0.5k_seq_100rd			
DISK	D:SATA DIMM 128offset				
# Managers	1				
# Workers	1				
# Disks	1				
IOps	46227.62202				
Read IOps	46227.62202				
Write IOps	0				
MBps	22.572081				
Read MBps	22.572081				
Write MBps	0				
Transactions per Second	46227.62202				

Connections per Second	0				
Average Response Time	0.69196				
Average Read Response Time	0.69196				
Average Write Response Time	0				
Average Transaction Time	0.69196				
Average Connection Time	0				
Maximum Response Time	7.495195				
Maximum Read Response Time	7.495195				
Maximum Write Response Time	0				
Maximum Transaction Time	7.495195				
Maximum Connection Time	0				
Errors	0				
Read Errors	0				
Write Errors	0				
Bytes Read	710908416				
Bytes Written	0				
Read I/Os	1388493				
Write I/Os	0				
Connections	0				
Transactions per Connection	-1				
Total Raw Read Response Time					
Total Raw Write Response Time					
Total Raw Transaction Time					
Total Raw Connection Time					
Maximum Raw Read Response Time					
Maximum Raw Write Response Time					
Maximum Raw Transaction Time					
Maximum Raw Connection Time					
Total Raw Run Time					
Starting Sector	0				
Maximum Size	0				
Queue Depth	32				
% CPU Utilization	14.05168				
% User Time	0.325678				
% Privileged Time	13.750119				
% DPC Time	2.03223				
% Interrupt Time	6.643828				
Processor Speed	2670000000				
Interrupts per Second					
CPU Effectiveness	3289.828927				
Packets/Second	0.300145				
Packet Errors	0				
Segments Retransmitted/Second	0				

4 Viking Benchmarking of SAS SSD's

4.1 Viking SAS SSD Benchmarking Methodology

The Viking procedure for benchmarking a SAS drive is the same as for SATA drives with the exception of the using a SAS HBA and using Windows Server 2008 R2.

The default alignment of the partition does not need to be altered for benchmarking Viking SSD performance when using this operating system.

5 Reference Documents

- Viking SSD Product Datasheets
<http://www.vikingtechnology.com/products/ssd/ssd.html>
- IOMETER 06 User's Guide:
<http://www.iometer.org/doc/documents.html>
- IOMETER 08 User's Guide.
http://iometer.cvs.sourceforge.net/*checkout*/iometer/iometer/Docs/Iometer.pdf

6 About Viking Technology

Viking Technology develops and delivers innovative high-technology products that optimize the value and performance of our customers' applications. Founded in 1989, Viking Technology has been providing Original Equipment Manufacturers (OEMs) with industry leading designs, engineering, product support and customer service for over 25 years. For more information, visit <http://www.vikingtechnology.com>.

7 Revision History

Related Products		Viking SSD Datasheets
8/11/11		Added note on Intel Rapid Storage Technology
8/17/11		Added notes that performance measurement is based on SSD pre-conditioning
9/27/11		Added figure on Queue Depth vs. Latency and IOPS
9/1/17		Revise format, logo and company address
9/21/17		Remove Element SSD. Change to "for over 25 years". Remove all references to IOMETER08. Add CrystalDiskMark (and ATTO). Add DWPD, TBW and software write protect. Remove Windows XP info. Remove all SATA-2 test results and charts

Global Locations

US Headquarters	India Office	Singapore Office
2950 Red Hill Ave. Costa Mesa, CA 92626 Main: +1 714 913 2200 Fax: +1 714 913 2202	A 3, Phase II, MEPZ-Special Economic Zone NH 45, Tambaram, Chennai-600045 India	No 2 Chai Chee Drive Singapore, 109840

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