Big Demo Test Suite
Samsung SSD 970 EVO Plus 250GB

Test suite with all possible test cases that creates a big report for demonstration.

March 04, 2023

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SUMMARY

Test suite with all possible test cases that creates a big report for demonstration. The NVMe tested was the Samsung SSD 970 EVO Plus 250GB with firmware 2B2QEXM7. The device was installed in a HP system, model HP Z1 Entry Tower G5 running Microsoft Windows 11 Pro.

STARTED	ENDED	DURATION
Mar 03, 2023 - 21:42:31.874	Mar 04, 2023 - 10:27:39.678	12:45:07.804

TESTS	26	
PASS	13	50.0%
FAIL	9	34.6%
SKIP	4	15.4%

A total of 26 tests completed 558 verifications for 49 unique requirements.

REQUIREMENTS	49	
PASS	36	73.5%
FAIL	13	26.5%

VERIFICATIONS	558	
PASS	541	97.0%
FAIL	17	3.0%

Manual review of test results has not been completed.

Test Summary

TEST	RESULT
Suite start info	PASS
Admin commands	PASS
Background SMART	PASS
SMART data	PASS
Timestamp	FAIL
RQMT: Timestamp shall be within 1.0 hour(s) of host timestamp	FAIL
RQMT: Timestamp shall run without stopping	FAIL
RQMT: Timestamp count is linear (Coeff > 0.99)	FAIL
RQMT: Timestamp change shall be within 1.0% of host time change	FAIL
Firmware update	SKIP
Firmware activate	SKIP
Firmware download	SKIP
Firmware security	SKIP
Short selftest	PASS
Extended selftest	FAIL
RQMT: Self-test progress is roughly linear (Coeff greater than 0.9)	FAIL
Short Burst Performance	FAIL
RQMT: IO bandwidth behaved as expected across queue depth, block size, address type	FAIL
Long Burst Performance	FAIL
RQMT: Long burst end temperature shall be within 5C of start temperature	FAIL
RQMT: Long burst, random writes, 4KiB, QD1 bandwidth shall be greater than 0.1 GB/s	FAIL
RQMT: IO bandwidth behaved as expected across queue depth, block size, address type	FAIL
Idle latency	FAIL
RQMT: IO read latency after short idle times behaves as expected.	FAIL
RQMT: Power state entry timeout shall meet drive setting	FAIL
RQMT: IO read latency within power state exit latencies	FAIL
Data deduplication	PASS
Read buffer	PASS

Big file writes	FAIL
RQMT: Bandwidth of first IO write burst should match write cache bandwidth	FAIL
Big file reads	PASS
Data compression	PASS
Short Burst Performance Full Drive	FAIL
RQMT: IO bandwidth behaved as expected across queue depth, block size, address type	FAIL
Long Burst Performance Full Drive	FAIL
RQMT: Long burst, random writes, 4KiB, QD1 bandwidth shall be greater than 0.1 GB/s	FAIL
RQMT: IO bandwidth behaved as expected across queue depth, block size, address type	FAIL
High bandwidth stress	PASS
High iops stress	PASS
Burst stress	PASS
Temperature cycle stress	PASS
Suite end info	FAIL
RQMT: Power On Hour change shall be within 1 hour of host time change	FAIL

Requirement Verification Summary

The table below lists the results for each attempt to verify a requirement.

REQUIREMENT	PASS	FAIL
Admin Command average latency shall be less than 50 mS	20	0
Admin Command maximum latency shall be less than 500 mS	20	0
Admin commands shall pass	23	0
Available Spare shall be greater than 10 %	38	0
Average latency of slowest 1,825 IO shall not increase more than 50% with concurrent SMART reads	1	0
Bandwidth of first IO write burst should match write cache bandwidth	**0**	**1**
Disk free space must be greater than 90%	3	0
Disk free space must be less than 10%	2	0
Error count shall not increase	40	0
Greater than 10,000 admin command shall complete without error	1	0
IO bandwidth behaved as expected across queue depth, block size, address type	**0**	**4**
IO read latency after short idle times behaves as expected.	**0**	**1**

IO read latency within power state exit latencies	**0**	**1**
Long burst end temperature shall be within 5C of start temperature	**7**	**1**
Long burst, random reads, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	2	0
Long burst, random writes, 4KiB, QD1 bandwidth shall be greater than 0.1 GB/s	**0**	**2**
Long burst, sequential reads, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	2	0
Long burst, sequential writes, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	2	0
Media and integrity errors shall be 0	38	0
Media in read-only shall be No	38	0
NVM Subsystem Unreliable shall be No	38	0
No data corruption shall occur running IO	15	0
No errors shall occur reading information samples	13	0
No errors shall occur running IO	54	0
Percent throttled shall be less than 1%	4	0
Percentage Used shall be less than 90%	4	0
Power On Hour change shall be within 1 hour of host time change	**0**	**1**
Power state entry timeout shall meet drive setting	**0**	**1**
Prior self-test failures shall be 0	2	0
SMART attribute Data Read shall be within 512,000 bytes of data read	1	0
SMART attribute Data Written shall be within 512,000 bytes of data written	1	0
SMART counters, such as Data Written, shall not decrement	61	0
Self-test Power-On Hours match hours reported in log page 2	4	0
Self-test progress is monotonic	4	0
Self-test progress is roughly linear (Coeff greater than 0.9)	**3**	**1**
Self-test result shall be 0 indicating no errors	4	0
Self-test run time shall be less than or equal to 2 minutes	2	0
Self-test run time shall be less than or equal to 35 minutes	2	0
Short burst, random reads, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	2	0
Short burst, random writes, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	2	0
Short burst, sequential reads, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	2	0
Short burst, sequential writes, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	2	0
Static parameters, such as Model Number, shall not change	40	0
Time operating at or above the critical temperature shall be 0	6	0
Timestamp change shall be within 1.0% of host time change	**0**	**1**
Timestamp count is linear (Coeff > 0.99)	**0**	**1**
Timestamp shall be within 1.0 hour(s) of host timestamp	**0**	**1**
Timestamp shall run without stopping	**0**	**1**
Volatile memory backup fail shall be No	38	0

NVME INFORMATION

VENDOR	MODEL	SIZE	VERSION
Samsung	Samsung SSD 970 EVO Plus 250GB		1.3.0

PARAMETER	VALUE
Serial Number	S59BNS0N708295J
Number Of Namespaces	1
Namespace 1 EUI64	002538-570140ad8d
Namespace 1 NGUID	0000000000000000-000000-0000000000
Namespace 1 Size	250 GB
Namespace 1 LBA Size	512
Firmware	2B2QEXM7
Firmware Slots	3
Firmware Activation Without Reset	Supported
Host Memory Buffer	Disabled
Autonomous Power State Transition	Supported and Disabled
Volatile Write Cache	Enabled
Host Throttle Threshold TMT1	Disabled
Host Throttle Threshold TMT2	Disabled
Drive Throttle Threshold WCTEMP	85 C
Drive Throttle Threshold CCTEMP	85 C

Power States

STATE	NOP	MAX POWER	ENTRY LATENCY	EXIT LATENCY
0	False	7.8 Watts	Not Reported	Not Reported
1	False	6 Watts	Not Reported	Not Reported
2	False	3.4 Watts	Not Reported	Not Reported
3	True	0.07 Watts	210 uS (0.000 sec)	1,200 uS (0.001 sec)
4	True	0.01 Watts	2,000 uS (0.002 sec)	8,000 uS (0.008 sec)

PCIe

PCI	VENDOR	VID	DID	WIDTH	SPEED	ADDRESS
Endpoint	Samsung	0x144D	0xA808	x4	Gen3 8.0GT/s	Bus 2, device 0, function 0
Root		0x8086	0xA32C			Bus 0, device 27, function 4

SMART Attributes

PARAMETER	START	END	DELTA
Available Spare	100 %	100 %	
Available Spare Threshold	10 %	10 %	
Controller Busy Time	14,985 Min	15,179 Min	194 Min
Critical Composite Temperature Time	0 Min	0 Min	
Data Read	559,672.625 GB	565,537.234 GB	5,864.6 GB
Data Units Read	1,093,110,596	1,104,564,910	11,454,314
Data Units Written	514,855,885	523,175,717	8,319,832
Data Written	263,606.213 GB	267,865.967 GB	4,259.8 GB
Data Written TB	263.6 TB	267.9 TB	4.3 TB
Host Read Commands	15,324,862,955	15,483,455,173	158,592,218
Host Write Commands	10,380,832,046	10,497,879,277	117,047,231
Media and Data Integrity Errors	0	0	
Minutes Throttled	0.0 Min	0.0 Min	
Number of Error Information Log Entries	1,235	1,235	
Percentage Used	48 %	48 %	
Power Cycles	273	273	
Power On Hours	754	760	6
Seconds Throttled	0	0	
Thermal Management Temperature 1 Count	0	0	
Thermal Management Temperature 1 Time	0 Sec	0 Sec	
Thermal Management Temperature 2 Count	0	0	
Thermal Management Temperature 2 Time	0 Sec	0 Sec	
Unsafe Shutdowns	38	38	
Warning Composite Temperature Time	0 Min	0 Min	
Host Time Seconds	1677908552.85	1677954459.577	45,906.0

SYSTEM INFORMATION

PARAMETER	VALUE
Supplier	HP
Model	HP Z1 Entry Tower G5
BIOS	R01 Ver. 02.15.00
Hostname	DESKTOP-AJDMMEA
OS	Microsoft Windows 11 Pro

PERFORMANCE SUMMARY

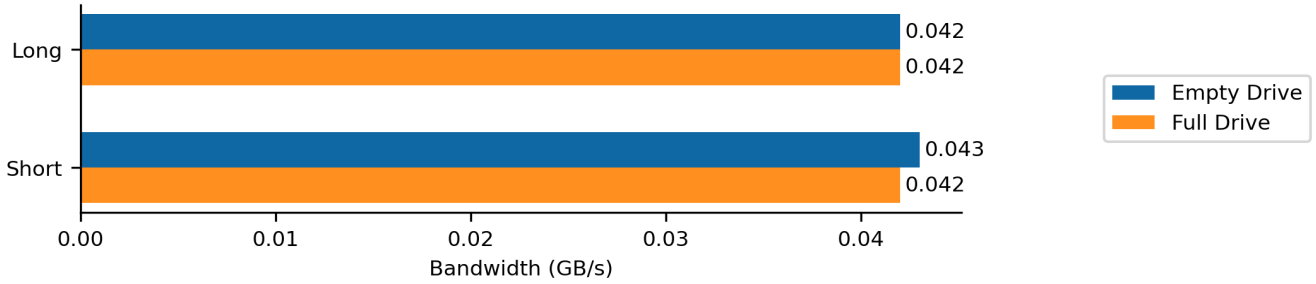
Short Burst Performance (2 seconds)

IO PATTERN	EMPTY DRIVE	DRIVE 90% FULL
Random Write, QD1, 4KiB	0.096 GB/s	0.097 GB/s
Random Read, QD1, 4KiB	0.043 GB/s	0.042 GB/s
Random Write, QD32, 4KiB	0.341 GB/s	0.340 GB/s
Random Read, QD32, 4KiB	0.511 GB/s	0.512 GB/s
Sequential Write, QD32, 128KiB	2.198 GB/s	2.222 GB/s
Sequential Read, QD32, 128KiB	3.496 GB/s	3.517 GB/s

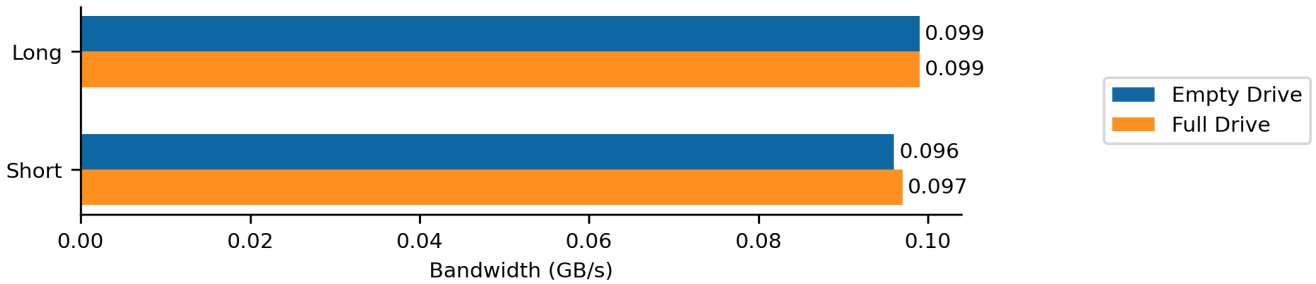
Long Burst Performance (10.0 minutes)

IO PATTERN	EMPTY DRIVE	DRIVE 90% FULL
Random Write, QD1, 4KiB	0.099 GB/s	0.099 GB/s
Random Read, QD1, 4KiB	0.042 GB/s	0.042 GB/s
Sequential Write, QD32, 128KiB	1.970 GB/s	1.727 GB/s
Sequential Read, QD32, 128KiB	2.684 GB/s	2.261 GB/s

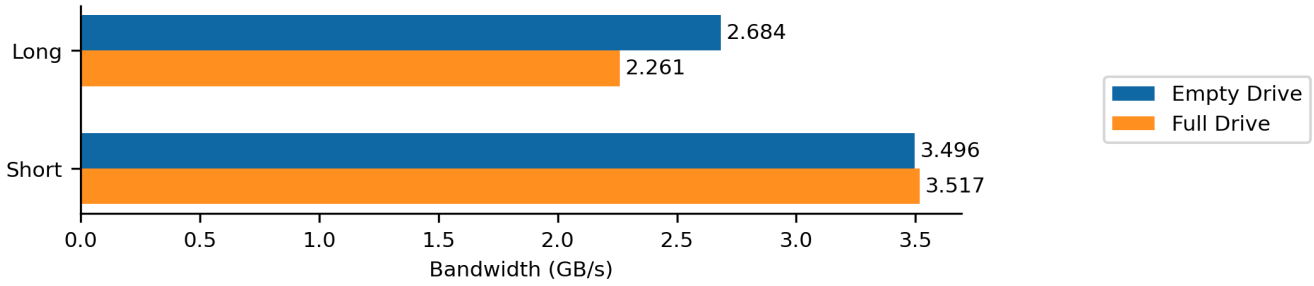
Random Reads, QD1, 4KiB



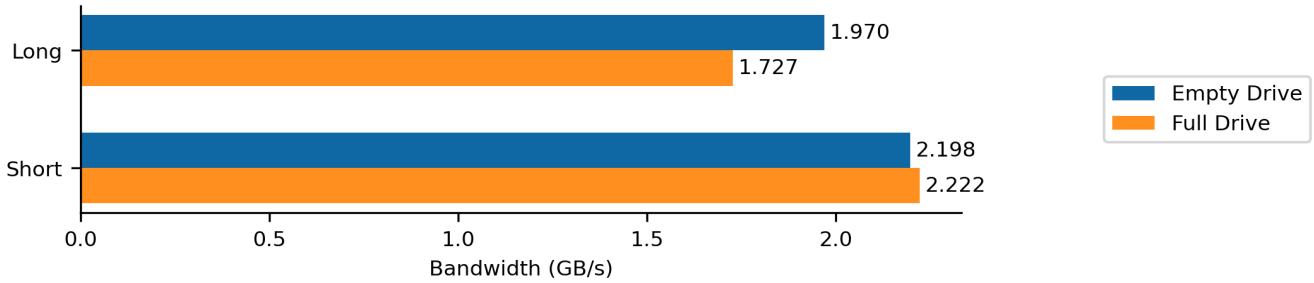
Random Writes, QD1, 4KiB



Sequential Reads, QD32, 128KiB



Sequential Writes, QD32, 128KiB



TEST 1: SUITE START INFO

VERIFICATIONS	10	
PASS	10	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 21:42:32.141	Mar 03, 2023 - 21:42:32.937	0:00:00.796

DESCRIPTION

This test reads the NVMe drive information at the start of a test suite. If the drive is unhealthy or worn out the test suite is stopped. At the end of the suite, this start information is compared with the suite end information to verify no unexpected changes occurred during the testing.

This test defines worn out as Percentage Used, Percentage Data Written, or Percentage Warranty Used exceeding 90%. This provides a guard band so no wear percentage exceeds 100% during the test suite. The percentages are determined from the SMART attributes Percentage Used, Data Written, and Power On Hours and the drive specifications TBW and Warranty Years. If TBW and Warranty Years are not provided the Percentage Data Written and Percentage Warranty Used cannot be verified.

A drive is defined as unhealthy if 1) any prior self-test results failed or 2) has critical warnings or media and integrity errors or 3) has operated above the critical temperature or 4) has had an excessive amount of thermal throttling. The self-test results are read from Log Page 6 and the SMART attributes from Log Page 2.

The information is read using the nvmecmd utility [2]. This utility uses NVMe Admin Commands Identify Controller, Identify Namespace, Get Log Page, and Get Feature to get most of the information. A small anount of information is read from the Operating System, such as the driver verison and PCIe parameters.

For additional details see Read and compare NVMe information with nvmecmd [4].

RESULTS

The table below lists the NVMe Admin Commands completed. The nvmecmd utility only supports Namespace 1 and a subset of the log pages and features.

Admin Command	Time (ms)	Return Bytes	Return Code
Identify Controller	7.453	4096	0
Identify Namespace 1	0.760	4096	0
Get Log Page 0x01	0.627	4096	0
Get Log Page 0x02	0.658	512	0
Get Log Page 0x03	0.237	512	0
Get Log Page 0x05	0.035	4096	0
Get Log Page 0x06	0.274	564	0
Get Feature 1	0.158	0	0
Get Feature 2	0.142	0	0
Get Feature 4	0.148	0	0

Get Feature 4 (0x100000)	0.144	0	0
Get Feature 4 (0x10000)	0.143	0	0
Get Feature 4 (0x110000)	0.145	0	0
Get Feature 4 (0x20000)	0.146	0	0
Get Feature 4 (0x120000)	0.130	0	0
Get Feature 5	0.066	0	0
Get Feature 6	0.085	0	0
Get Feature 8	0.084	0	0
Get Feature 10	0.086	0	0
Get Feature 11	0.087	0	0
Get Feature 12	2.162	256	0
Get Feature 14	2.474	8	0
Get Feature 16	0.142	0	0

Drive Health: Self-Test Results

The most recent 20 self-test results, short and extended, were read from Log Page 6. The drive is considered unhealthy if any prior results are failures.

PARAMETER	VALUE	NOTE
Prior self-test results	20	Logs up to 20
Prior self-test failures	0	

Drive Health: Errors and Warnings

The drive is considered unhealthy if the SMART attributes contain critical warnings or media and integrity errors.

PARAMETER	VALUE	NOTE
Media and Integrity Errors	0	

Drive Health: Temperature Throttling

The drive is considered unhealthy if it has operated above the critical temperature or the percentage throttled is above 1%.

Percentage Throttled is defined as 100 * (Hours Throttled / Power On Hours) where Hours Throttled is the cumulative time of all throttle states.

PARAMETER	VALUE	NOTE
Percentage Throttled	0.0%	
Thermal Management Temperature 1 Time	0 sec	0.00 Hours
Thermal Management Temperature 2 Time	0 sec	0.00 Hours
Warning Composite Temperature Time	0 min	0.00 Hours
Critical Composite Temperature Time	0 min	0.00 Hours

Drive Wear

The Percentage Used SMART attribute is the primary reference for drive wear. If the drive Warranty and TBW are specified the Percentage Data Written and Percentage Warranty Used are calculated and verified.

Percentage Data Written is defined as 100 * (Data Written / TBW) where TBW (Terabytes Written) is the total amount of data that can be written to the drive during the warranty period. Data Written is the SMART attribute that reports the data written to the drive.

Percentage Warranty Used is defined as 100 * (Power On Hours / Warranty Hours) where warranty hours is the number of days in the warranty multiplied by 8 hours for client drives or 24 hours for enterprise drives.

PARAMETER	VALUE	NOTE
Percentage Used	48%	SMART attribute
Data Written	263,606.213 GB	SMART attribute
Power On Hours	754	SMART attribute
Terabytes Written (TBW)	150 TB	User Input
Percentage Data Written	175.7%	Calculated
Warranty Years	5 years	User input
Warranty Hours	14,600	Calculated
Percentage Warranty Used	5.2%	Calculated

VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Read info : PASS

Read NVMe information using nvmecmd.

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS

Step 2: Verify info : PASS

Verify drive is healthy and not worn out.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Time operating at or above the critical temperature shall be 0	0 min	PASS
Percent throttled shall be less than 1%	0.0%	PASS
Percentage Used shall be less than 90%	48%	PASS
Prior self-test failures shall be 0	0	PASS

TEST 2: ADMIN COMMANDS

VERIFICATIONS	6	
PASS	6	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 21:42:32.954	Mar 03, 2023 - 22:03:52.265	0:21:19.311

DESCRIPTION

This test verifies the reliability and performance of Admin Commands that provide information about the drive: Identify Controller, Identify Namespace, Get Log Page, and Get Feature. Each Admin Command is run several thousand times with no interval between the commands. This quickly builds a large sample to assess reliability and performance.

The test verifies the Admin Command average and maximum latencies. Admin command latency is dependent on multiple factors including OS interrupts, power states, concurrent drive activity, and others. This test measures latencies without concurrent IO and only in the active power state. The latencies reported by the test serve as a standard reference but are likely not the worst case values.

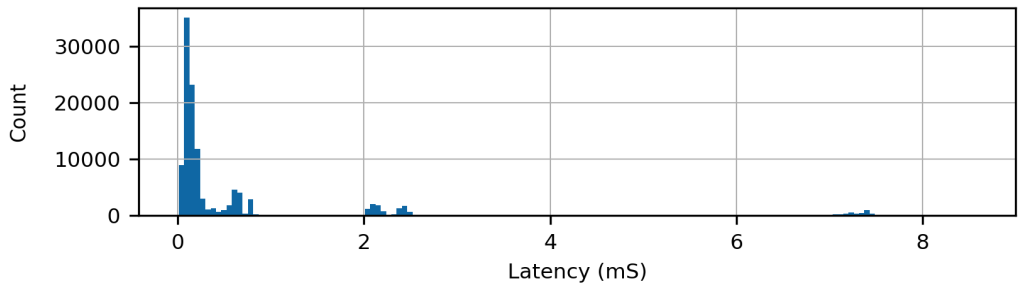
Each command is verified to complete without error. The information returned by each command is compared against the initial reading to verify no unexpected changes occurred. Static parameters, such as Model Number, were verified not to change. SMART counters, such as Data Read, were verified not to decrement. Dynamic parameters, such as Timestamp, are expected to change and are not verified.

RESULTS

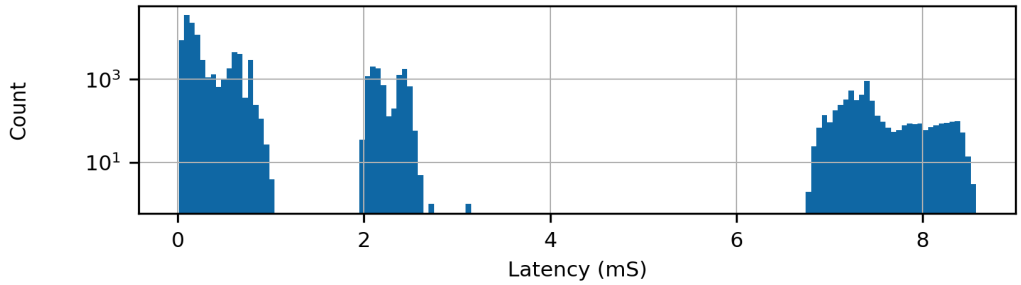
A total of 115,000 Admin Commands were completed with 0 reported errors. Each of the 23 command types was run 5,000 times. The latency was measured for each command and the average and maximum is reported in the table below.

PARAMETER	VALUE	LIMIT
Average Latency (All Commands)	0.7 mS	50 mS
Maxmimum Latency (All Commands)	8.6 mS	500 mS

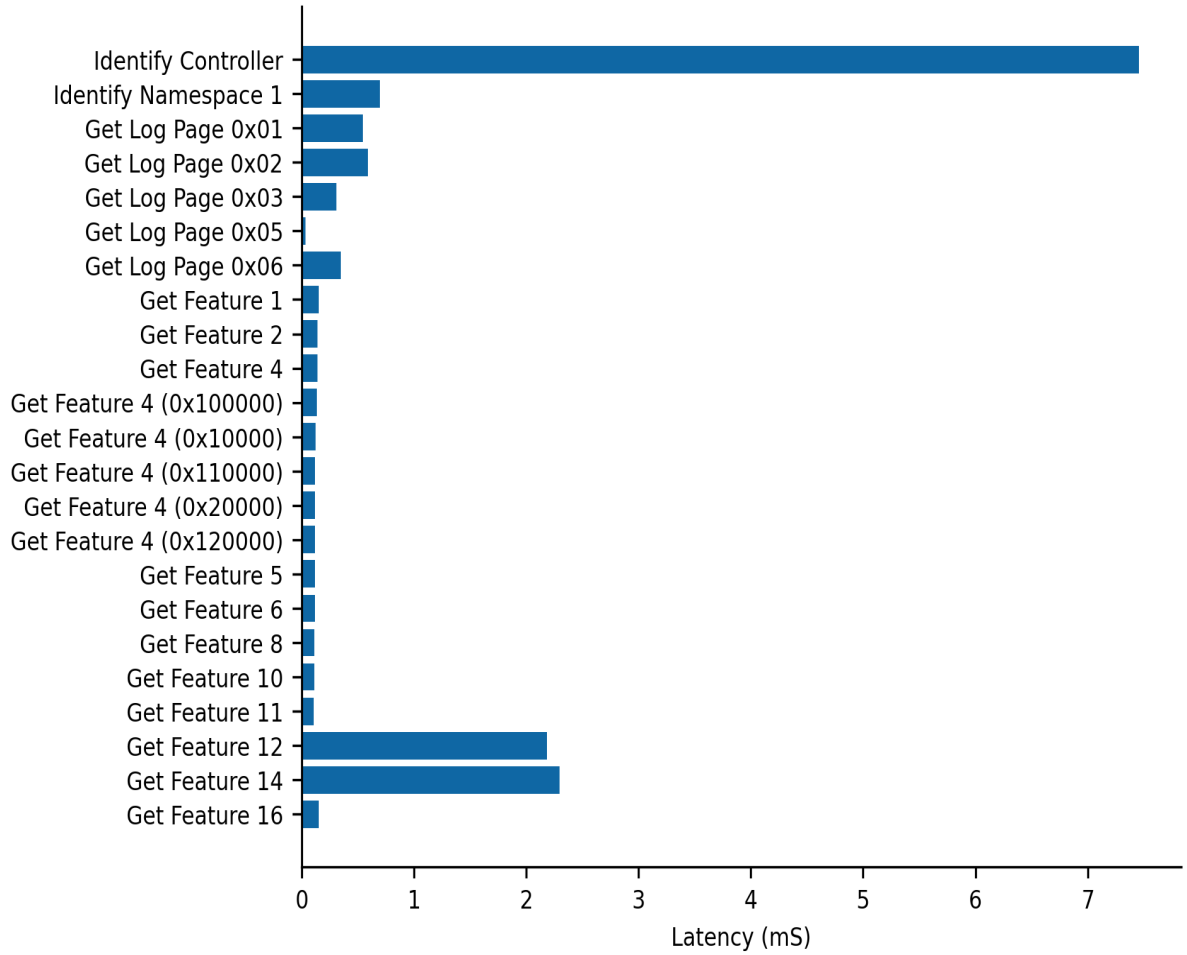
This histogram shows the distribution of Admin Command latencies for all command types.



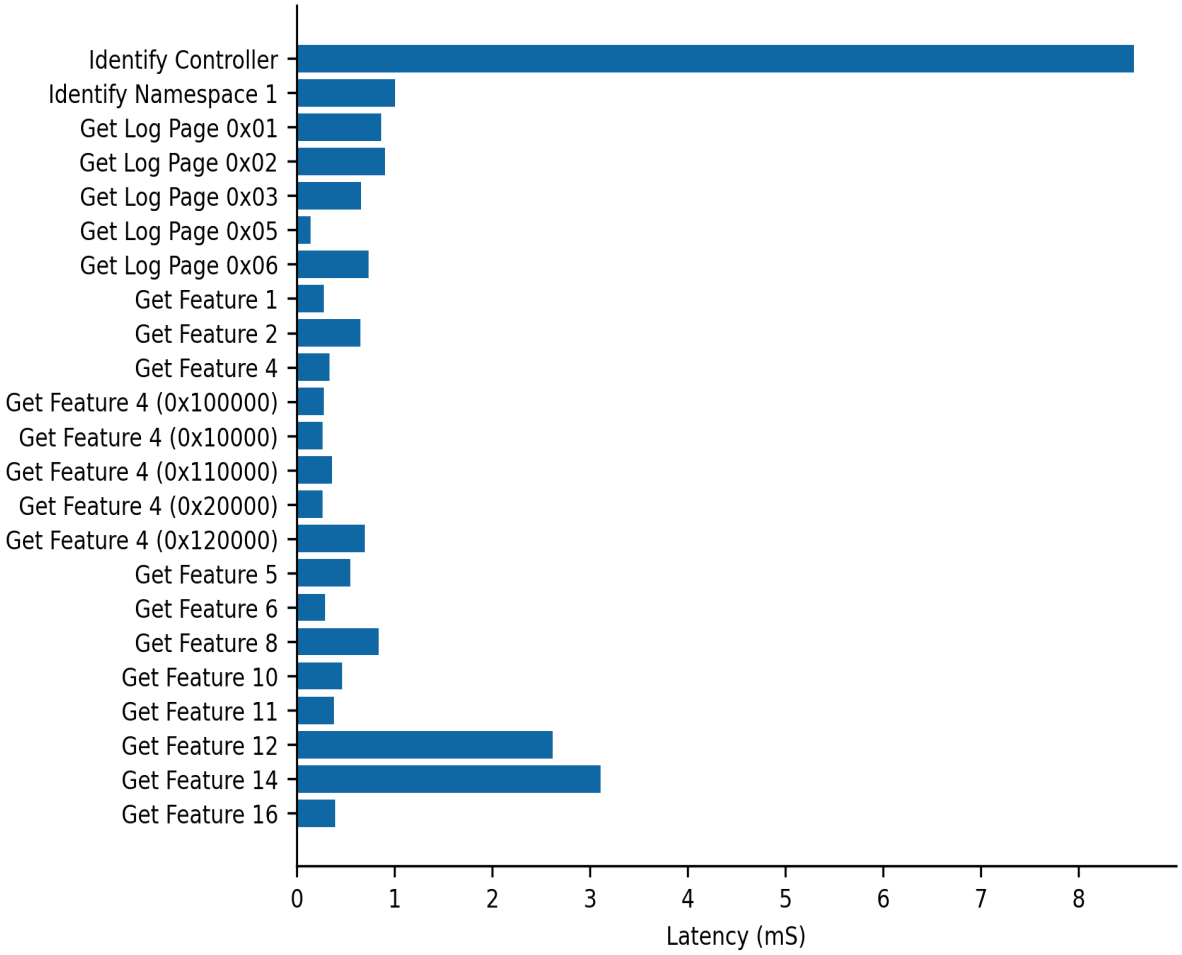
This histogram shows the distribution above on a log scale to better show outliers.



This bar chart shows the average Admin Command latencies for each command type.



This bar chart shows the maximum Admin Command latencies for each command type.



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Run commands : PASS

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Greater than 10,000 admin command shall complete without error	0 / 115,000	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	0.7 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.6 mS	PASS

TEST 3: BACKGROUND SMART

VERIFICATIONS	25	
PASS	25	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 22:03:52.280	Mar 03, 2023 - 22:56:13.656	0:52:21.376

DESCRIPTION

This test verifies reading SMART attributes during normal operation has no adverse effects on IO read and writes. Adverse effects are defined as functional errors, data integrity loss, or an unacceptable increase in IO latency. A typical Enterprise Use Case [10] reads SMART attributes regularly to identify issues that may predict drive failures. Suspect drives can then be replaced prior to actually failing.

This test runs a total of 1,825 Get Log Page 2 commands to simulate one read per day for 5 years. The Get Log Page 2 commands are run at intervals of 500mS to ensure significant idle time between commands which is closer to the actual use case.

The concurrent IO workload is a 50/50 mix of reads and writes, random addressing, 4 KiB block size, and queue depth 2. This workload ensures an IO is always in flight but should not swamp the controller.

RESULTS

A total of 3,650 Get Log Page 2 Commands were completed with 0 reported errors. Get Log Page 2 latency was measured on 1,825 commands run standalone and another 1,825 commands run concurrent with IO reads and writes.

PARAMETER	STANDALONE	CONCURRENT	DELTA
Average Get Log Page 2 Latency	7.58 mS	0.44 mS	-7.15 mS
Maxmimum Get Log Page 2 Latency	8.78 mS	4.59 mS	-4.19 mS

A total of 0 errors occured running IO standalone and 0 errors running concurrent.

A total of 16,194,176 reads were completed standalone. Another 16,281,856 reads were completed concurrent with Log Page 2. In the tables and charts below the slowest IO are defined as the slowest 1,825 IO.

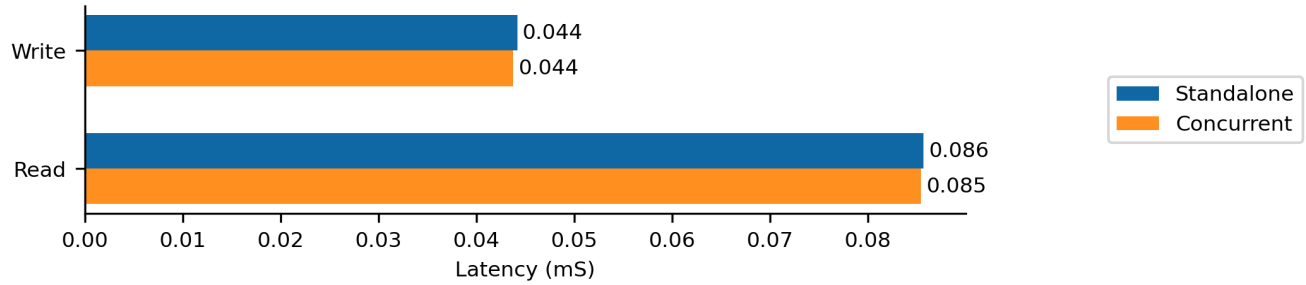
PARAMETER	STANDALONE	CONCURRENT	DELTA
Read Average Latency	0.09 mS	0.09 mS	-0.00 mS (-0.3%)
Read Average Commit Latency Slowest IO	4.23 mS	4.22 mS	-0.01 mS (-0.2%)
Read Maximum Latency	7.00 mS	8.15 mS	1.14 mS (16.3%)

A total of 8,128,448 writes were completed standalone. Another 8,157,415 writes were completed concurrent with Log Page 2.

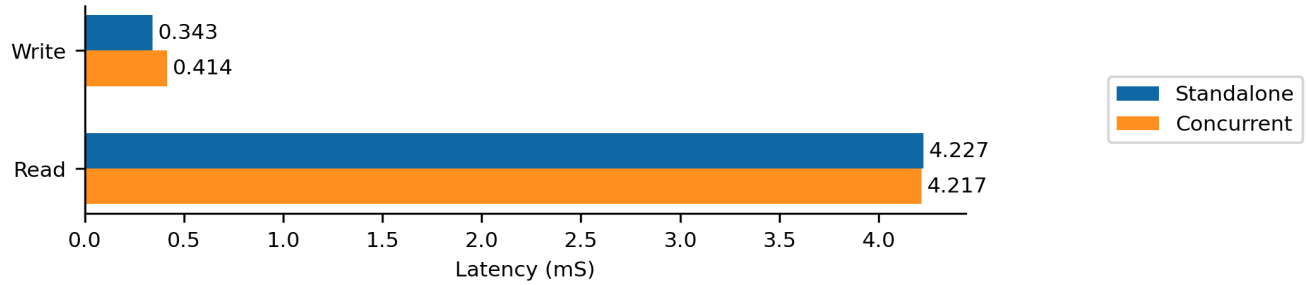
PARAMETER	STANDALONE	CONCURRENT	DELTA
Write Average Latency	0.04 mS	0.04 mS	-0.00 mS (-1.0%)

Write Average Commit Latency Slowest IO	0.34 mS	0.41 mS	0.07 mS (20.8%)
Write Maximum Latency	9.38 mS	8.87 mS	-0.51 mS (-5.4%)

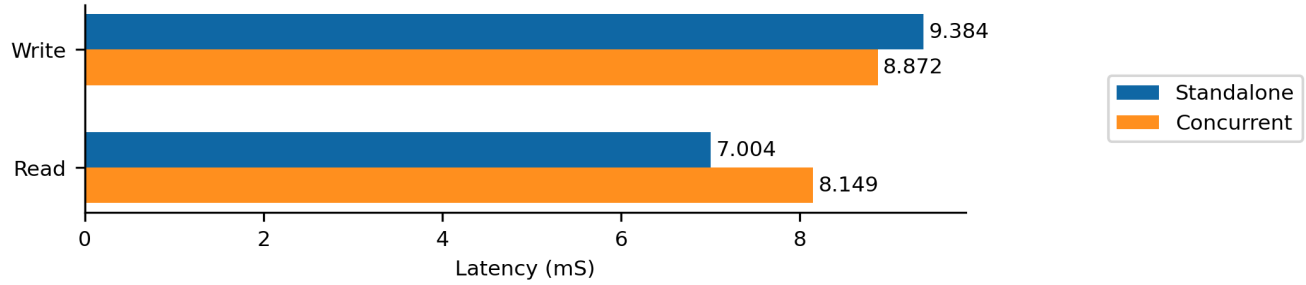
Average IO Latency



Slowest IO Latency



Maximum IO Latency



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Get fio file : PASS

Get or create small file with verification headers.

Step 2: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.6 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.6 mS	PASS

Step 3: SMART baseline : PASS

Run Get Log Page 2 command 1,825 times

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.6 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.8 mS	PASS

Step 4: IO baseline : PASS

Baseline IO reads and writes using fio

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 5: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.4 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 6: SMART and IO : PASS

Run IO and Get Log Page 2 concurrently

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	0.4 mS	PASS
Admin Command maximum latency shall be less than 500 mS	4.6 mS	PASS
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS
Average latency of slowest 1,825 IO shall not increase more than 50% with concurrent SMART reads	20.815%	PASS

TEST 4: SMART DATA

VERIFICATIONS	21	
PASS	21	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 22:56:13.666	Mar 03, 2023 - 22:59:25.611	0:03:11.945

DESCRIPTION

This test verifies the accuracy of the Data Read and Data Written SMART attributes. The SMART attributes are compared against the disk counters reported by the python psutil package. To ensure a large enough sample for comparison, IO read and writes are run for three minutes in a high bandwidth configuration.

The SMART attribute resolution is 512,000 bytes according to the NVMe Specification [1]. The current test limit has been set to the resolution of the SMART attributes.

RESULTS

PARAMETER	VALUE	DELTA	LIMIT
Bytes written from psutil counter	138,966,347,776		
Bytes written reported by SMART	138,966,016,000	-331,776	512,000
Bytes read reported by psutil counter	269,204,062,208		
Bytes read reported by SMART	269,203,968,000	-94,208	512,000

The tables below include fio reported data to determine if anything other than fio was reading or writing the drive during the test. If the drive under test is the OS drive than additional read and writes are likely.

PARAMETER	VALUE	DELTA
Bytes read reported by fio	269,204,062,208	0
Bytes written reported by fio	138,965,680,128	-667,648

VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Get fio file : PASS

Get or create small file without verification headers.

Step 2: Start info : PASS

Verify not in error state

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS

Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Time operating at or above the critical temperature shall be 0	0 min	PASS

Step 3: IO : PASS

Run IO to generate read and write data

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 4: End info : PASS

Verify no unexpected changes during test

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Time operating at or above the critical temperature shall be 0	0 min	PASS
Percent throttled shall be less than 1%	0.0%	PASS
Percentage Used shall be less than 90%	48%	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
SMART attribute Data Read shall be within 512,000 bytes of data read	94,208	PASS
SMART attribute Data Written shall be within 512,000 bytes of data written	331,776	PASS

TEST 5: TIMESTAMP

VERIFICATIONS	25	
PASS	21	84.0%
FAIL	4	16.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 22:59:25.626	Mar 03, 2023 - 23:09:35.948	0:10:10.322

DESCRIPTION

Timestamp Feature Identifier 0Eh is an optional feature that reports the number of milliseconds that have elapsed since the epoch: midnight, 01-Jan-1970, UTC. The timestamp is set to the current time by the host and then the drive increments the timestamp every millisecond. The test reads the Get Feature data structure to get the timestamp info and verify the timestamp has been set by the host and matches the current time.

On some drives, the timestamp may stop under some conditions such as entering into non-operational power states. This test verifies the timestamp has not stopped by reading the synch attribute in the Get Feature data structure.

The test samples the host and drive timestamps every second for several minutes of idle and IO traffic. This verifies the drive timestamp is accurate in multiple power states which is especially important since some stop in non-operational states.

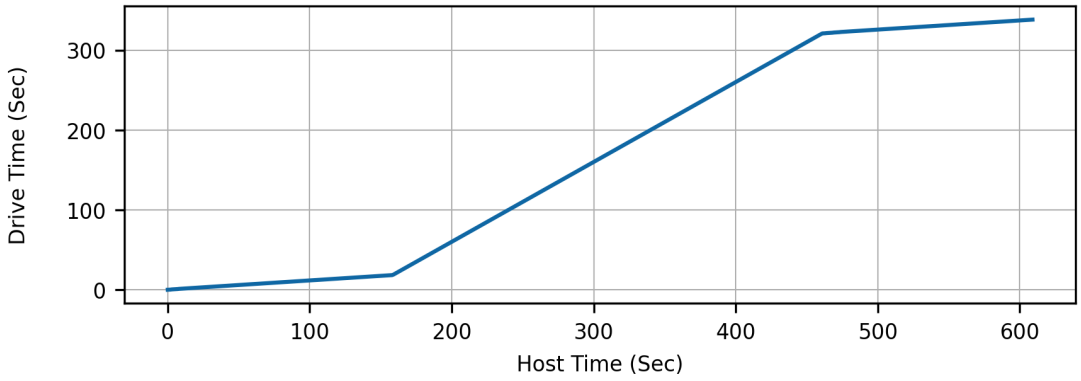
This test uses the host timestamp as the reference. Therefore, any issues with the host timestamp may cause this test to fail.

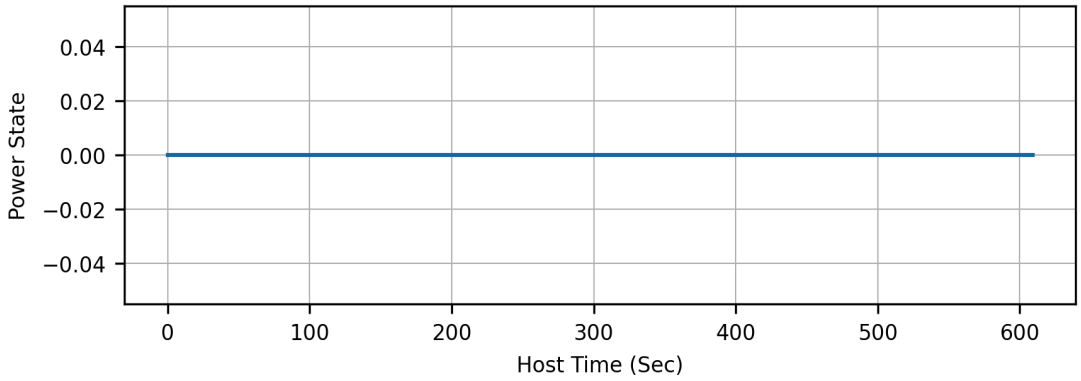
RESULTS

The timestamp synch attribute in the Get Feature data structure was set indicating the timestamp has stopped and may not be valid.

PARAMETER	HOST	DRIVE	DELTA	LIMIT
Starting Timestamp	1,677,905,648,765 mS	1,677,913,165,897 mS	2.1 hrs	1.0 hrs
Timestamp Change	609,817 mS	338,443 mS	44.50%	1.0%

The plot below shows the linearity between the drive and host timestamps. The measured Pearson product-moment correlation coefficent was: 0.980. Anything less than 0.99 indicates the host and drive timestamps do not track as expected. If the tracking is erratic it can be cross-referenced againt the power states in the second plot.





VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : FAIL

Read NVMe information using nvmecmd

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Time operating at or above the critical temperature shall be 0	0 min	PASS
Percent throttled shall be less than 1%	0.0%	PASS
Percentage Used shall be less than 90%	48%	PASS
Timestamp shall be within 1.0 hour(s) of host timestamp	2.09 hours	FAIL

Step 2: Get fio file : PASS

Get or create small file with verification headers.

Step 3: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 4: Wait and IO : PASS

Wait then run IO then wait again.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

Step 5: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

Step 6: Verify timestamp : FAIL

REQUIREMENT	VALUE	RESULT
Timestamp shall run without stopping	Fail	FAIL
Timestamp count is linear (Coeff > 0.99)	0.98	FAIL
Timestamp change shall be within 1.0% of host time change	44.5%	FAIL

TEST 6: FIRMWARE UPDATE

VERIFICATIONS	0	
PASS	0	0.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 23:09:35.967	Mar 03, 2023 - 23:09:36.014	0:00:00.047

DESCRIPTION

This test updates the NVMe drive firmware. The test downloads and activates the latest firmware version and verifies if does not effect IO traffic, no parameters change, firmware information is updated. All firmware slots are tested.

For additional details see Update firmware with nvmecmd [7].

RESULTS

The test was not completed because the firmware files needed for the update were not found.

TEST 7: FIRMWARE ACTIVATE

VERIFICATIONS	0	
PASS	0	0.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 23:09:36.029	Mar 03, 2023 - 23:09:36.092	0:00:00.063

DESCRIPTION

This test verifies the performance and reliability of firmware activation. Different firmware versions are downloaded to multiple slots. While running a moderate IO stress workload the test continuously activates different slots (versions). The test completes one thousand activations.

Reliability is defined as no IO errors, data corruption, parameter changes, or failed firmware activations.

Performance is defined as the activation time and the maximum IO latency.

For additional details see Update firmware with nvmecmd [7].

RESULTS

The test was not completed because the firmware files needed for the update were not found.

TEST 8: FIRMWARE DOWNLOAD

VERIFICATIONS	0	
PASS	0	0.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 23:09:36.092	Mar 03, 2023 - 23:09:36.155	0:00:00.063

DESCRIPTION

This test verifies the performance and reliability of firmware download. Different firmware versions are downloaded to multiple slots. While running a moderate IO stress workload the test continuously downloads firmware to different slots (versions). The test completes 100 downloads.

Reliability is defined as no IO errors, data corruption, parameter changes, or failed firmware downloads.

Performance is defined as the download time and the maximum IO latency.

For additional details see Update firmware with nvmecmd [7].

RESULTS

The test was not completed because the firmware files needed for the update were not found.

TEST 9: FIRMWARE SECURITY

VERIFICATIONS	0	
PASS	0	0.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 23:09:36.171	Mar 03, 2023 - 23:09:36.250	0:00:00.079

DESCRIPTION

This test verifies the firmware update process is secure. It verifies invalid files cannot be downloaded and actived.

Invalid files tested are corrupted files, files for different devices, etc...

For additional details see Update firmware with nvmecmd [7].

RESULTS

The test was not completed because the firmware files needed for the update were not found.

TEST 10: SHORT SELFTEST

VERIFICATIONS	27	
PASS	27	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 03, 2023 - 23:09:36.250	Mar 03, 2023 - 23:29:21.674	0:19:45.424

DESCRIPTION

Self-test is a diagnostic testing sequence that tests the integrity and functionality of the controller and may include testing of the media associated with namespaces. The self-test is run using the Device Self-Test Admin Command. There is a short self-test and an extended self-test. This test verifies the short self-test.

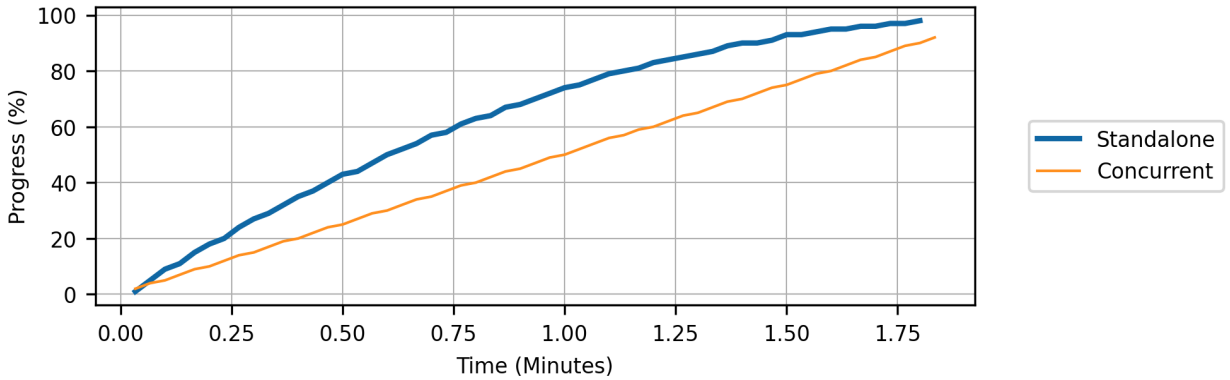
The self-test diagnostic is run standalone and concurrent with a light IO workload. In both cases the diagnostic must pass, complete within 2 minutes as specified in the NVMe specification [1], and report progress in Log Page 6 that is monotonic and roughly linear.

The NVMe specification states the IO performance can be degraded during the self-test but does not specify any limits. The performance difference between standalone and concurrent operation is reported to help determine if running the diagnostic during normal operation is practical.

RESULTS

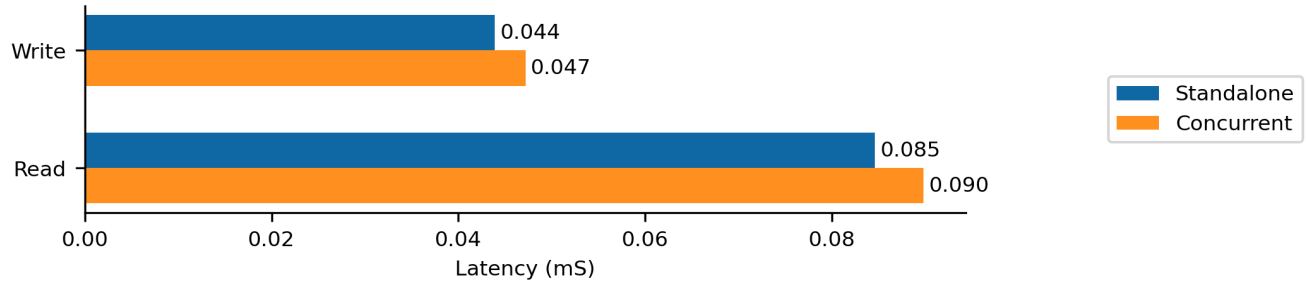
PARAMETER	STANDALONE	CONCURRENT	LIMIT
Run Time	1.834 Min	1.867 Min	2 Min
Progress Monotonocity	Monotonic	Monotonic	Monotonic
Progress Linearity	0.978	1.000	> 0.9

This plot shows the self-test progress reported in Log Page 6 which should be monotonic and roughly linear.

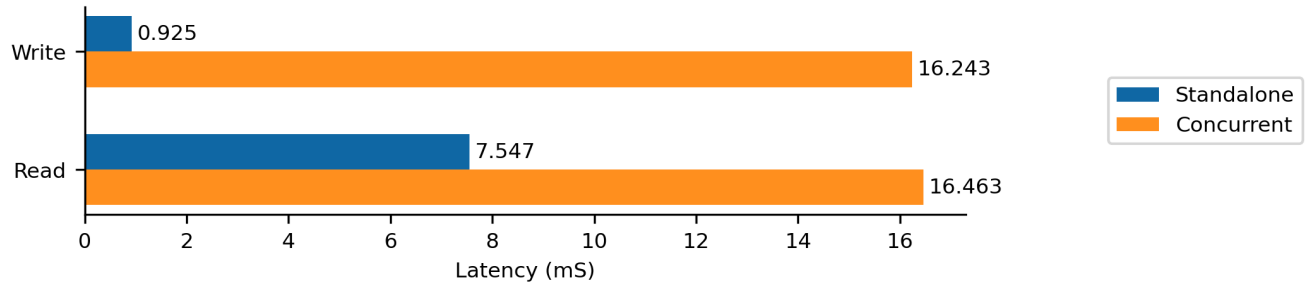


These bar charts show the difference in IO latency between stand-alone and concurrent operation. The tester must determine if the latency difference is acceptable since the NVMe specification does not define any limits.

Average IO Latency

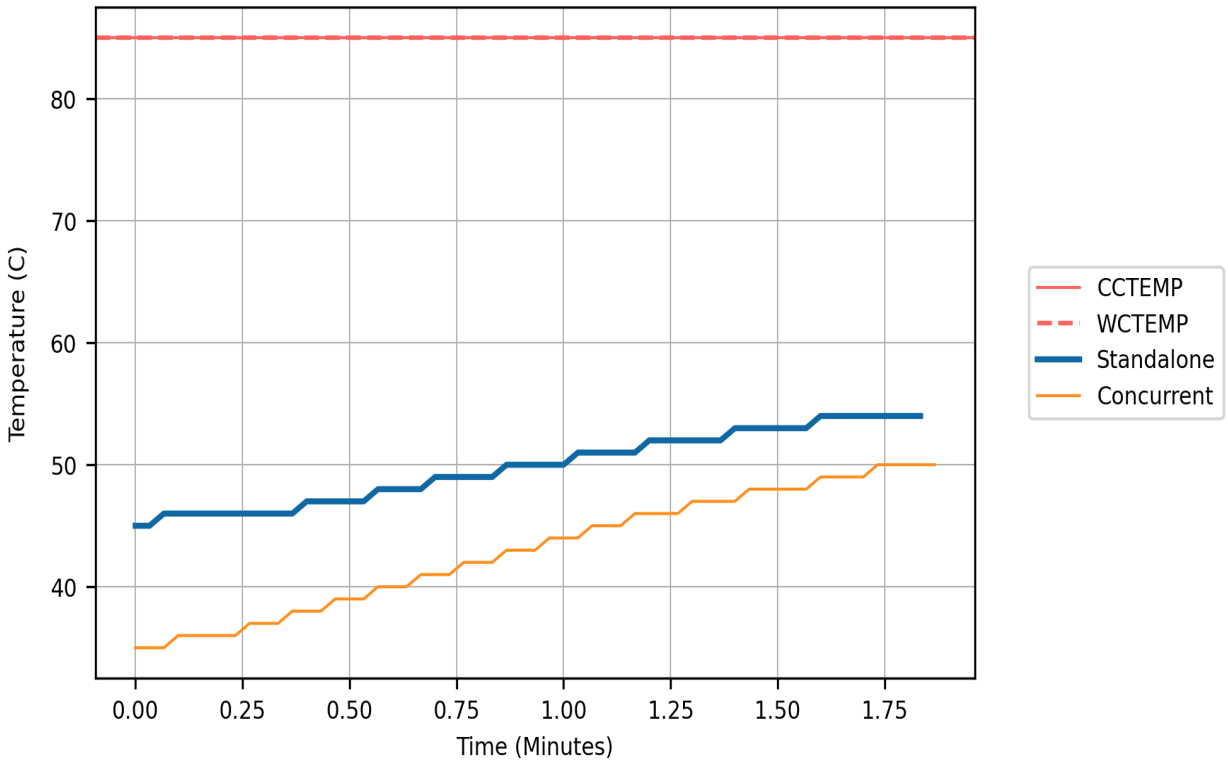


Maximum IO Latency



COMPOSITE TEMPERATURE

This plot shows the drive's composite temperature during the self-test to determine if over-heating is a concern. Thermal throttle limits are shown as red horizontal lines.



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read NVMe information using nvmecmd

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file with verification headers.

Step 3: Selftest standalone : PASS

REQUIREMENT	VALUE	RESULT
Self-test result shall be 0 indicating no errors	0	PASS
Self-test run time shall be less than or equal to 2 minutes	1.83 min	PASS
Self-test progress is monotonic	Monotonic	PASS
Self-test progress is roughly linear (Coeff greater than 0.9)	0.98	PASS
Self-test Power-On Hours match hours reported in log page 2	Match	PASS

Step 4: IO standalone : PASS

Baseline the light IO workload

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 5: Selftest and IO : PASS

Run selftest and IO concurrently

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS
Self-test result shall be 0 indicating no errors	0	PASS
Self-test run time shall be less than or equal to 2 minutes	1.87 min	PASS
Self-test progress is monotonic	Monotonic	PASS
Self-test progress is roughly linear (Coeff greater than 0.9)	1.00	PASS
Self-test Power-On Hours match hours reported in log page 2	Match	PASS

Step 6: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 11: EXTENDED SELFTEST

VERIFICATIONS	28	
PASS	27	96.4%
FAIL	1	3.6%

STARTED	ENDED	DURATION
Mar 03, 2023 - 23:39:21.694	Mar 04, 2023 - 00:59:17.959	1:19:56.265

DESCRIPTION

Self-test is a diagnostic testing sequence that tests the integrity and functionality of the controller and may include testing of the media associated with namespaces. The self-test is run using the Device Self-Test Admin Command. There is a short self-test and an extended self-test. This test verifies the extended self-test.

The self-test diagnostic is run standalone and concurrent with a light IO workload. In both cases the diagnostic must pass, complete within the run time limit, and report progress in Log Page 6 that is monotonic and roughly linear.

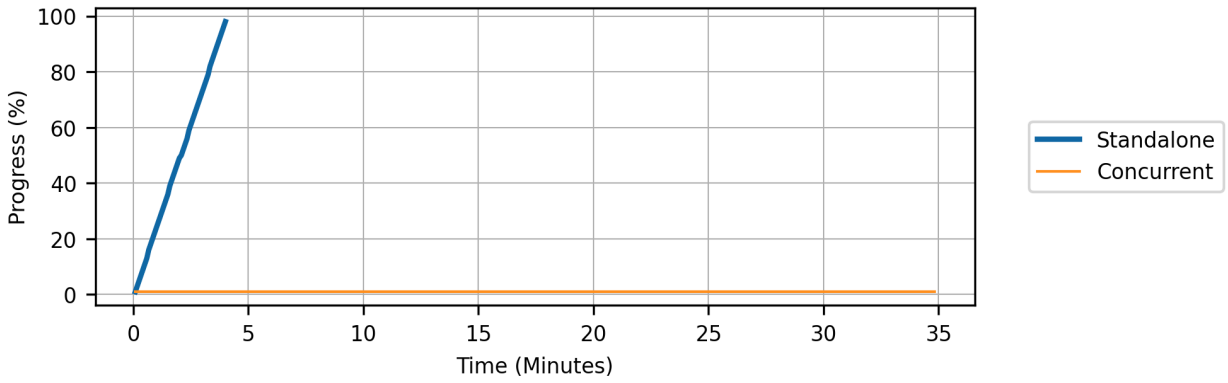
The extended self-test run time limit is from the Extended Device Self-test Time (EDSTT) field. The NVMe specification states EDSTT “this field indicates the nominal amount of time in one-minute units that the controller takes to complete an extended device self-test operation when in power state 0”. There is no maximum run time value defined in the specification therefore it is possible for an extended self-test to take longer than EDSTT and still comply with the specification. However, this test uses the EDSTT as the run time limit. The EDSTT field is 35 minutes for this NVMe drive.

The NVMe specification states the IO performance can be degraded during the self-test but does not specify any limits. The performance difference between standalone and concurrent operation is reported to help determine if running the diagnostic during normal operation is practical.

RESULTS

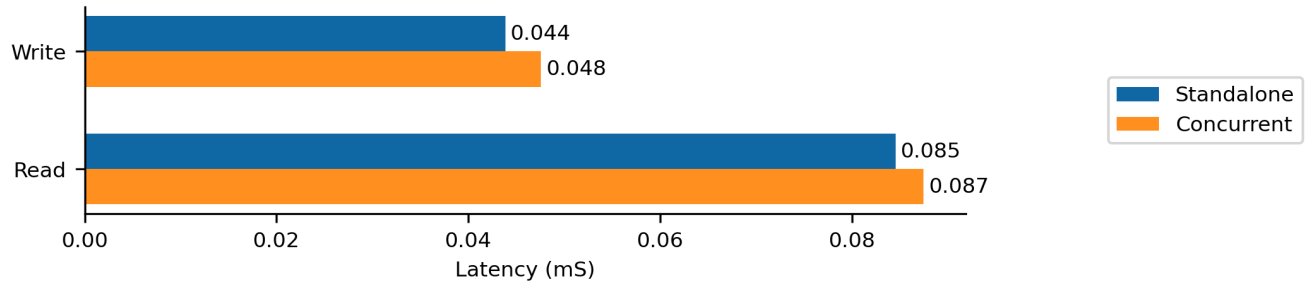
PARAMETER	STANDALONE	CONCURRENT	LIMIT
Run Time	4.017 Min	34.867 Min	35 Min
Progress Monotonocity	Monotonic	Monotonic	Monotonic
Progress Linearity	1.000	0.085	> 0.9

This plot shows the self-test progress reported in Log Page 6 which should be monotonic and roughly linear.

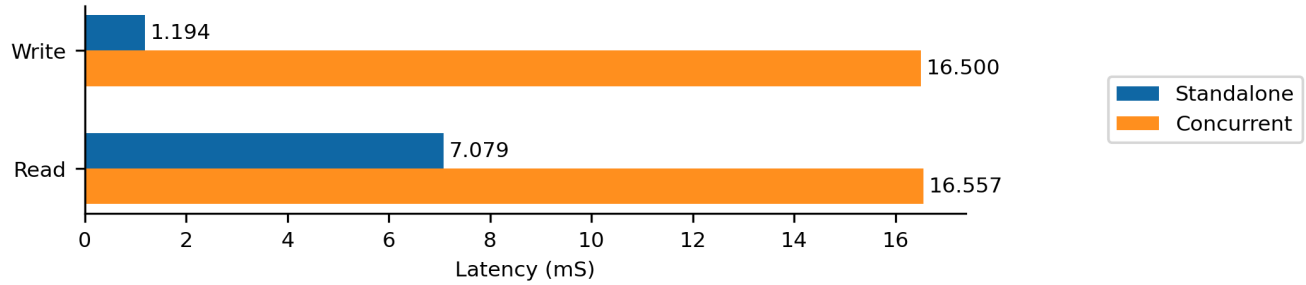


These bar charts show the difference in IO latency between stand-alone and concurrent operation. The tester must determine if the latency difference is acceptable since the NVMe specification does not define any limits.

Average IO Latency

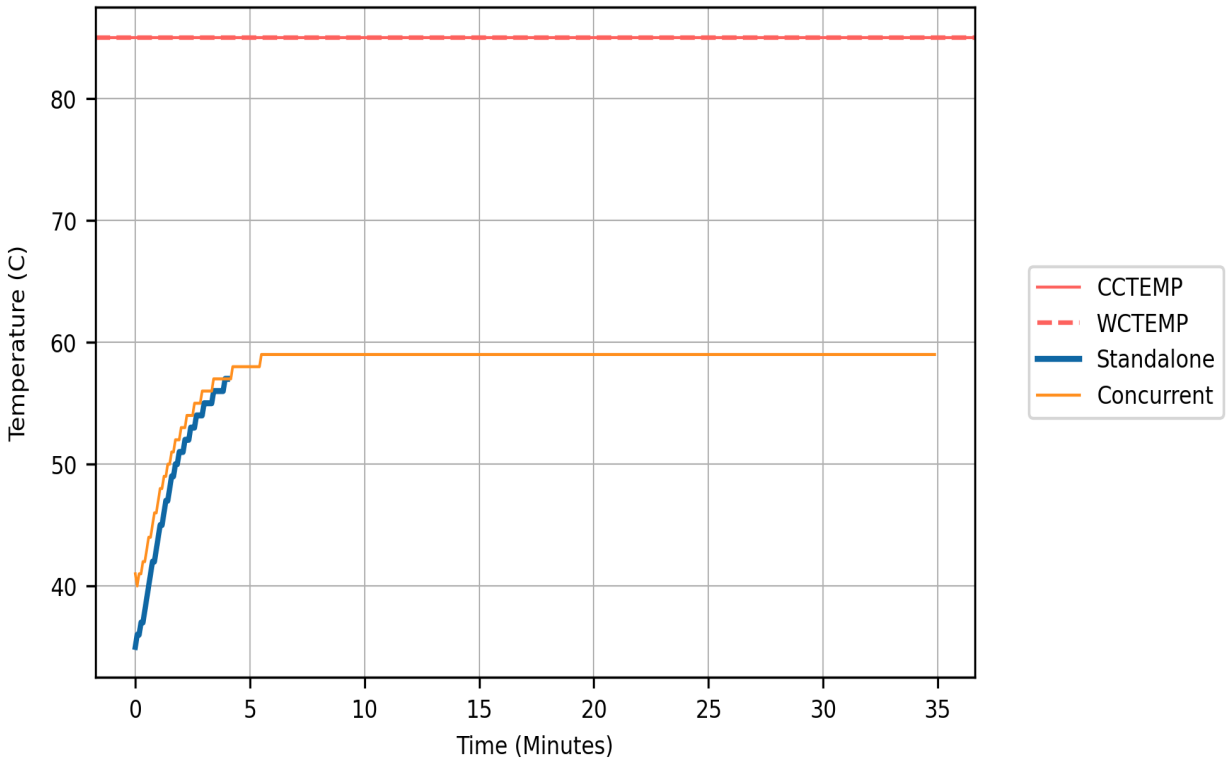


Maximum IO Latency



COMPOSITE TEMPERATURE

This plot shows the drive's composite temperature during the self-test to determine if over-heating is a concern. Thermal throttle limits are shown as red horizontal lines.



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read NVMe information using nvmecmd

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Time operating at or above the critical temperature shall be 0	0 min	PASS

Step 2: Get fio file : PASS

Get or create small file with verification headers.

Step 3: Selftest standalone : PASS

Run selftest without IO

REQUIREMENT	VALUE	RESULT
Self-test result shall be 0 indicating no errors	0	PASS
Self-test run time shall be less than or equal to 35 minutes	4.02 min	PASS
Self-test progress is monotonic	Monotonic	PASS

Self-test progress is roughly linear (Coeff greater than 0.9)	1.00	PASS
Self-test Power-On Hours match hours reported in log page 2	Match	PASS

Step 4: IO standalone : PASS

Run IO workload without selftest

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 5: Selftest and IO : FAIL

Run selftest and IO concurrently

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS
Self-test result shall be 0 indicating no errors	0	PASS
Self-test run time shall be less than or equal to 35 minutes	34.87 min	PASS
Self-test progress is monotonic	Monotonic	PASS
Self-test progress is roughly linear (Coeff greater than 0.9)	0.08	FAIL
Self-test Power-On Hours match hours reported in log page 2	Match	PASS

Step 6: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 12: SHORT BURST PERFORMANCE

VERIFICATIONS	31	
PASS	30	96.8%
FAIL	1	3.2%

STARTED	ENDED	DURATION
Mar 04, 2023 - 00:59:18.006	Mar 04, 2023 - 01:22:39.804	0:23:21.798

DESCRIPTION

This test reports the bandwidth for short bursts of IO reads and writes. Short bursts avoid performance reducing behavior such as thermal throttling, excessive SLC write cache misses, and shortage of erased blocks for future writes. Short IO bursts result in high bandwidth measurements ideal for datasheet comparisons and benchmarking applications such as spreadsheets and word processors that intermittently read and write small to medium files.

This test runs a variety of block sizes and queue depths across four common IO patterns: random writes, random reads, sequential writes and sequential reads. The bandwidth should increase as block size and queue depth increase until the bandwidth saturates. This maximum bandwidth is expected to be different between reads and writes but not between random and sequential access types. There is no standard performance specification for drive datasheets so refer to the datasheet of the drive under test to determine the block size and queue depth to compare. No data integrity checking is done to avoid any effect the performance numbers.

Each burst lasts for 2.5 seconds and is followed by an idle period to allow the drive temperature and background activity to return to the initial state. During the idle state the drive is likely to enter a non-operational power state. The latency to exit the non-operational power state would effect the measured bandwidth. To avoid the effects of exiting the power state, this test excludes the first 0.5 seconds of the burst.

The test uses the standard OS software stack which may limit the maximum block size or queue depth. For example, some Linux versions limit the block size to 128KiB.

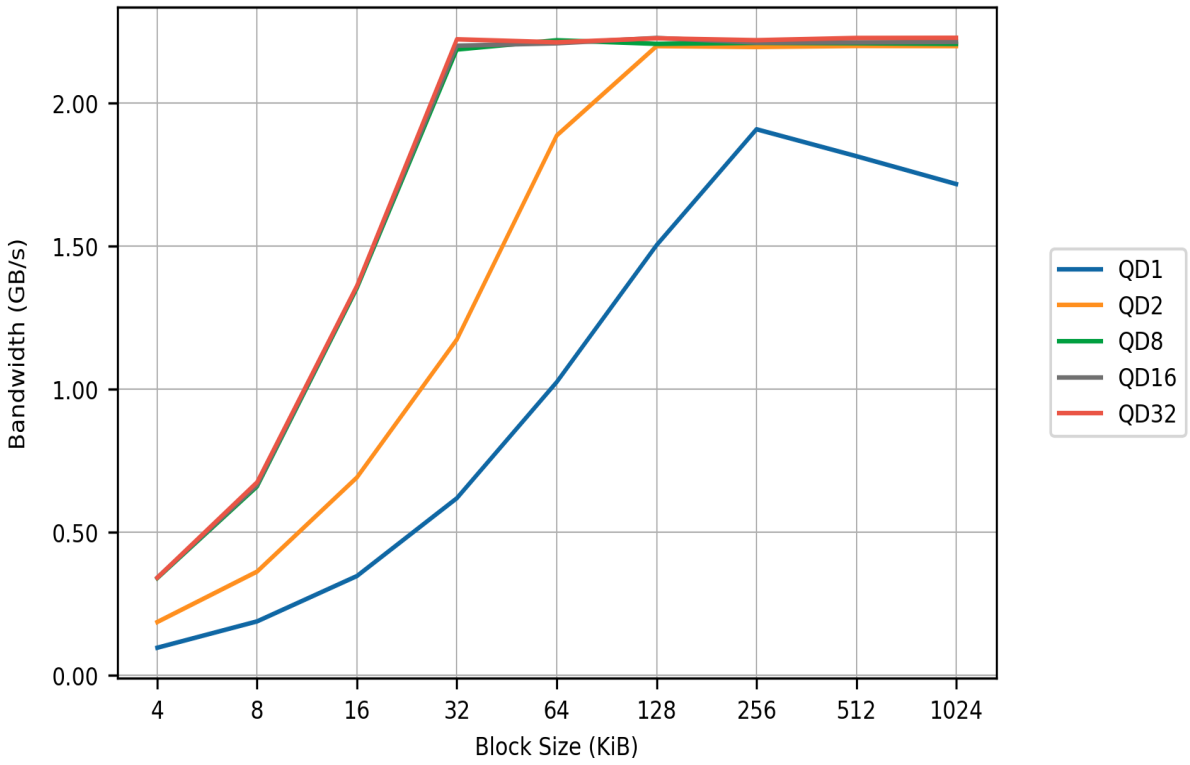
For additional details see NVMe IO performance measurement with fio and nvmecmd [8].

RESULTS

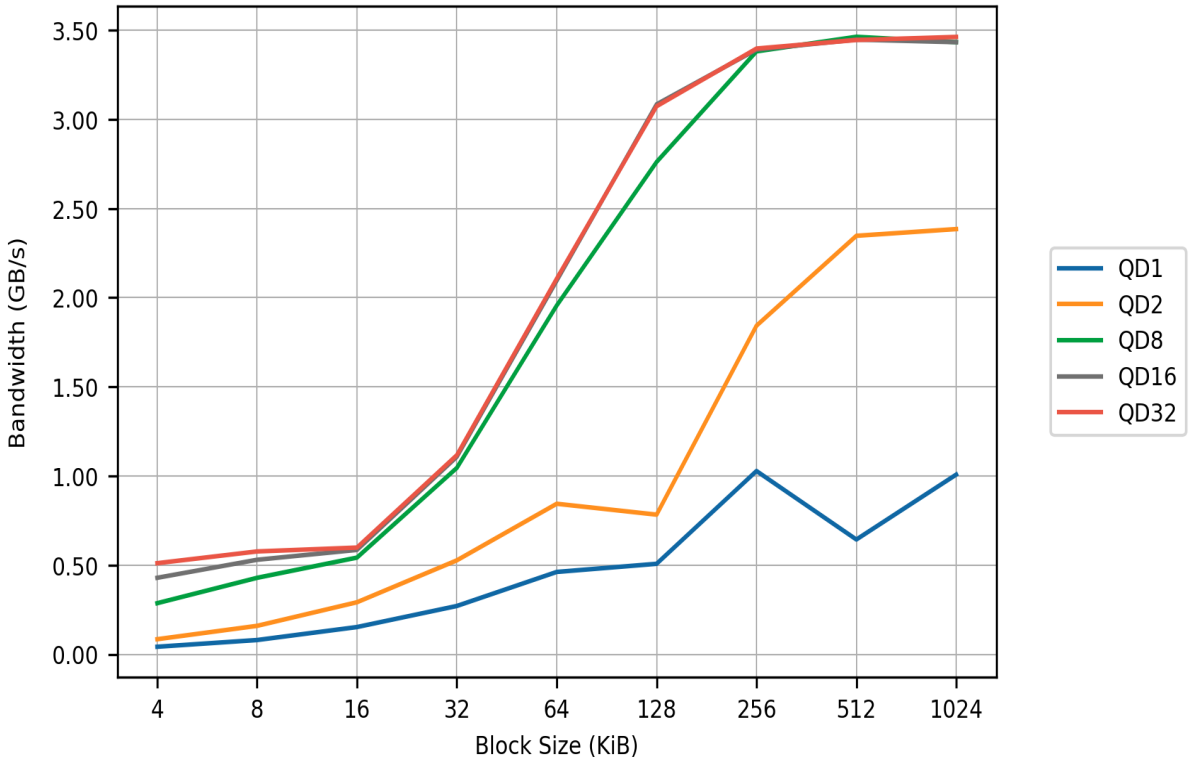
This table shows the bandwidth for several common datasheet and IO benchmark queue depths and block sizes.

IO PATTERN	IOPS	BANDWIDTH	LIMIT	RESULT
Sequential Write, QD32, 128KiB	16,772	2.198 GB/s	1.000 GB/s	PASS
Sequential Read, QD32, 128KiB	26,673	3.496 GB/s	1.000 GB/s	PASS
Random Write, QD1, 4KiB	23,488	0.096 GB/s	0.010 GB/s	PASS
Random Read, QD1, 4KiB	10,412	0.043 GB/s	0.010 GB/s	PASS
Random Write, QD32, 4KiB	83,235	0.341 GB/s	0.250 GB/s	PASS
Random Read, QD32, 4KiB	124,832	0.511 GB/s	0.250 GB/s	PASS

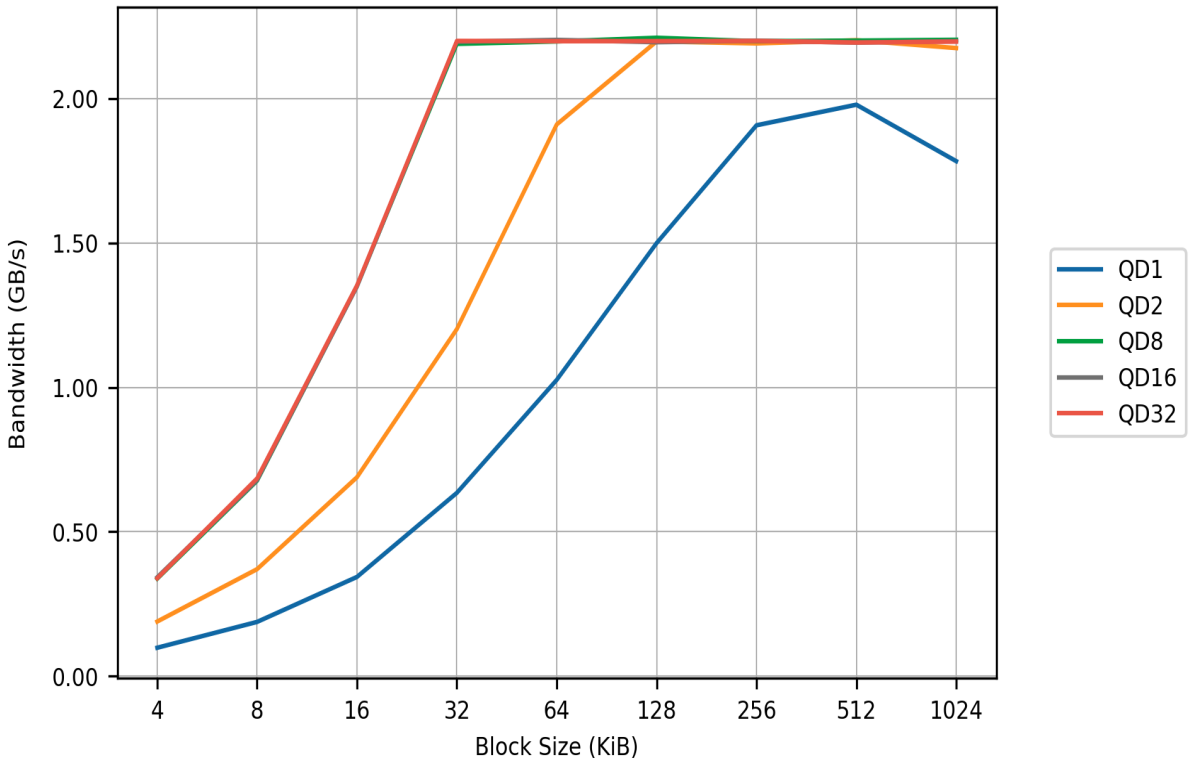
Random Write Bandwidth



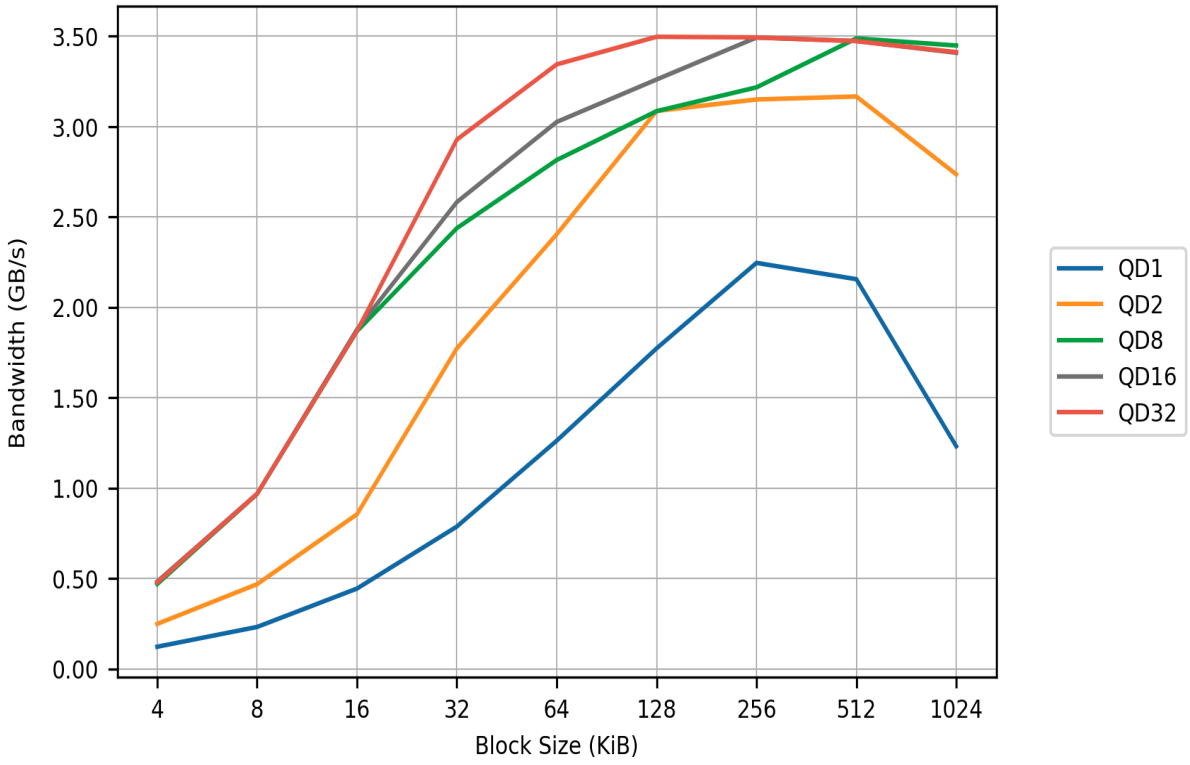
Random Read Bandwidth



Sequential Write Bandwidth



Sequential Read Bandwidth



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file without verification headers.

Step 3: Empty drive : PASS

Verify the drive free space.

REQUIREMENT	VALUE	RESULT
Disk free space must be greater than 90%	99.1%	PASS

Step 4: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.4 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 5: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 6: Sequential write : PASS

Measure performance of short burst of sequential writes.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 7: Sequential read : PASS

Measure performance of short burst of sequential reads.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 8: Random write : PASS

Measure performance of short burst of random writes.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 9: Random read : PASS

Measure performance of short burst of random reads.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 10: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 11: Verify performance : FAIL

Verify short burst performance.

REQUIREMENT	VALUE	RESULT
Short burst, random reads, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	0.043 GB/s	PASS
Short burst, random writes, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	0.096 GB/s	PASS
Short burst, sequential reads, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	3.496 GB/s	PASS
Short burst, sequential writes, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	2.198 GB/s	PASS
IO bandwidth behaved as expected across queue depth, block size, address type	REVIEW	FAIL

Step 12: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS

NVM Subsystem Unreliable shall be No	No	**PASS**
Media in read-only shall be No	No	**PASS**
Volatile memory backup fail shall be No	No	**PASS**
Media and integrity errors shall be 0	0	**PASS**
Error count shall not increase	0	**PASS**
Static parameters, such as Model Number, shall not change	0	**PASS**
SMART counters, such as Data Written, shall not decrement	0	**PASS**

TEST 13: LONG BURST PERFORMANCE

VERIFICATIONS	40	
PASS	37	92.5%
FAIL	3	7.5%

STARTED	ENDED	DURATION
Mar 04, 2023 - 01:22:39.819	Mar 04, 2023 - 04:13:46.800	2:51:06.981

DESCRIPTION

This test measures performance of long bursts of IO. There are four IO patterns: random writes, random reads, sequential writes, and sequential reads. The plots are useful for gaining insight into drive behavior such as write caching, thermal throttling, and background garbage collection. For example, if thermal throttling occurs the plot can tell the time and amount of data read or written before the throttling started. It can also tell the reduction in bandwidth for each level of throttling.

The test reports different bandwidths for each IO pattern. The average bandwidth for the entire IO burst, first second, first 15 seconds, and last 120 seconds. The initial bandwidth is more relevant for use cases that do not continuously access the drive, such as office computing. The end bandwidth is more relevant for uses cases that continuously access the drive.

RESULTS

This table shows the bandwidth for several common datasheet and IO benchmark queue depths and block sizes.

IO PATTERN	IOPS	BANDWIDTH	LIMIT	RESULT
Sequential Write, QD32, 128KiB	15,032	1.970 GB/s	1.000 GB/s	PASS
Sequential Read, QD32, 128KiB	20,477	2.684 GB/s	1.000 GB/s	PASS
Random Write, QD1, 4KiB	24,191	0.099 GB/s	0.100 GB/s	FAIL
Random Read, QD1, 4KiB	10,287	0.042 GB/s	0.010 GB/s	PASS

The table below provides the average and ending bandwidth. The ending bandwidth could be significantly lower if thermal throttling or excessive garbage collection occurs.

IO PATTERN	AVERAGE	FIRST SEC	FIRST 15 SEC	LAST 120 SEC
Random Write, QD1, 4KiB	0.099 GB/s	0.099 GB/s	0.099 GB/s	0.099 GB/s
Random Read, QD1, 4KiB	0.042 GB/s	0.041 GB/s	0.042 GB/s	0.042 GB/s
Sequential Write, QD32, 128KiB	1.970 GB/s	2.257 GB/s	2.260 GB/s	1.837 GB/s
Sequential Read, QD32, 128KiB	2.684 GB/s	3.499 GB/s	3.524 GB/s	2.410 GB/s

This table below reports the composite temperature during the IO burst. The expectation is the end and start temperatures should be within the delta limit. A higher temperature could indicate background operations are ongoing.

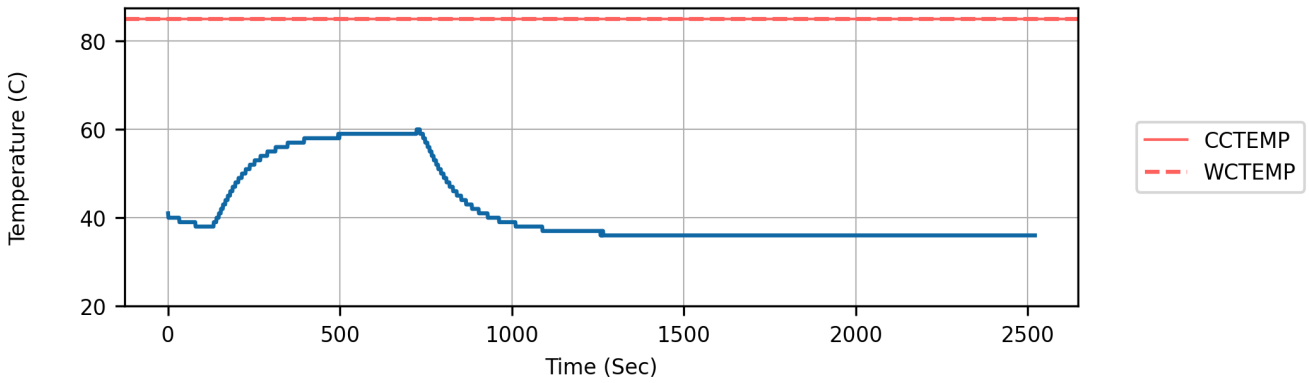
The table also includes the Throttle Time which is the sum for all throttle levels. Note that the units for throttle levels WCTEMP and CCTEMP is in minutes. Therefore, throttling for less than one minute may not be indicated for these levels.

IO PATTERN	THROTTLE	MAX	START	END	DELTA	LIMIT
Random Write, QD1, 4KiB	0 sec	60 C	41	36	-5 C	5 C
Random Read, QD1, 4KiB	0 sec	58 C	36	35	-1 C	5 C
Sequential Write, QD32, 128KiB	0 sec	83 C	35	35	0 C	5 C
Sequential Read, QD32, 128KiB	0 sec	83 C	35	35	0 C	5 C

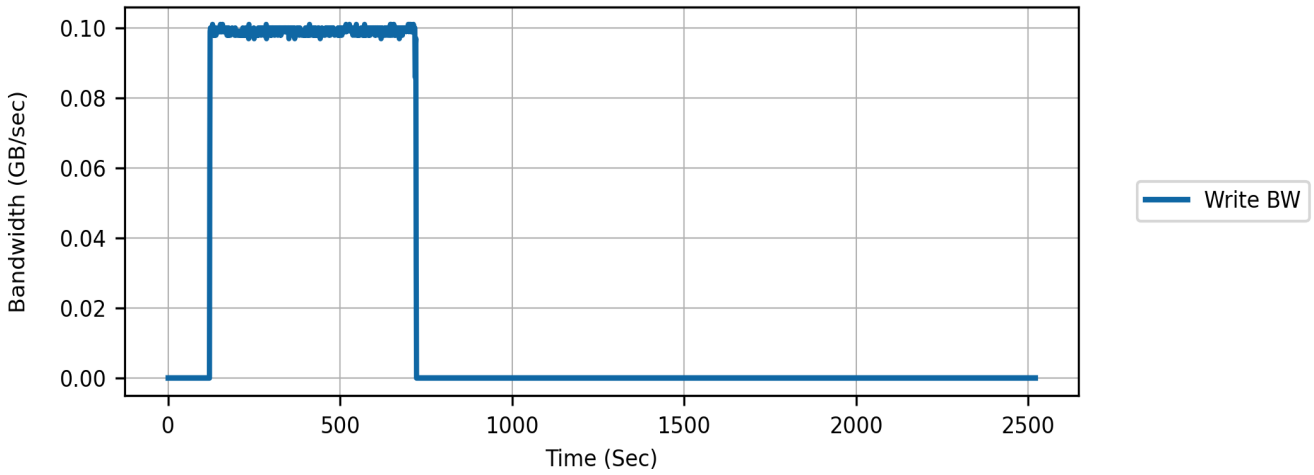
RANDOM WRITES

These plots are for writes using random addressing, block size of 4 KiB, and queue depth of 1.

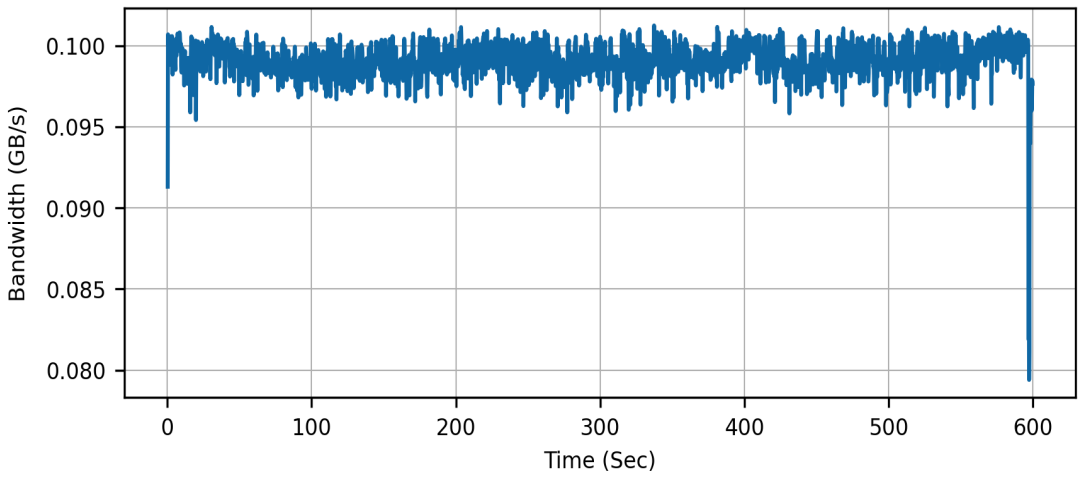
Temperature (Including Idle)



IO Write Bandwidth (Including Idle)



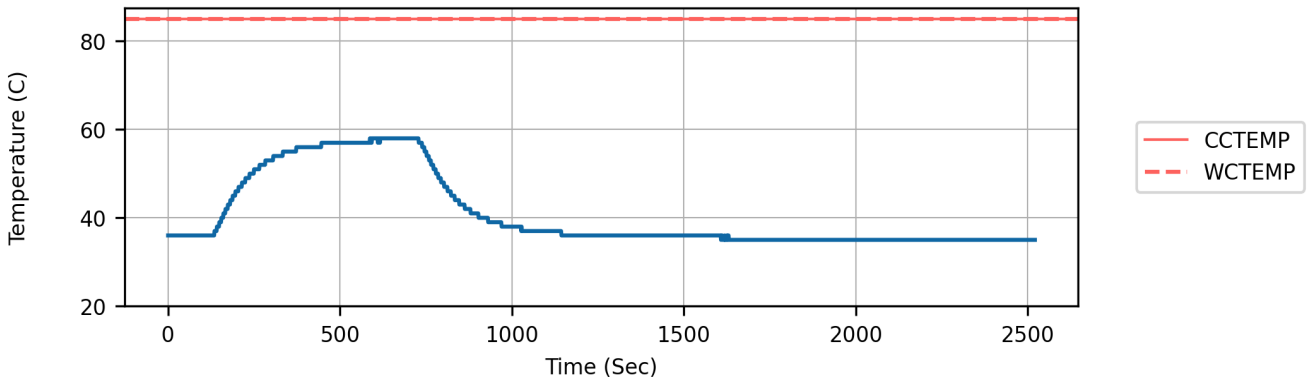
IO Write Bandwidth (Excluding Idle)



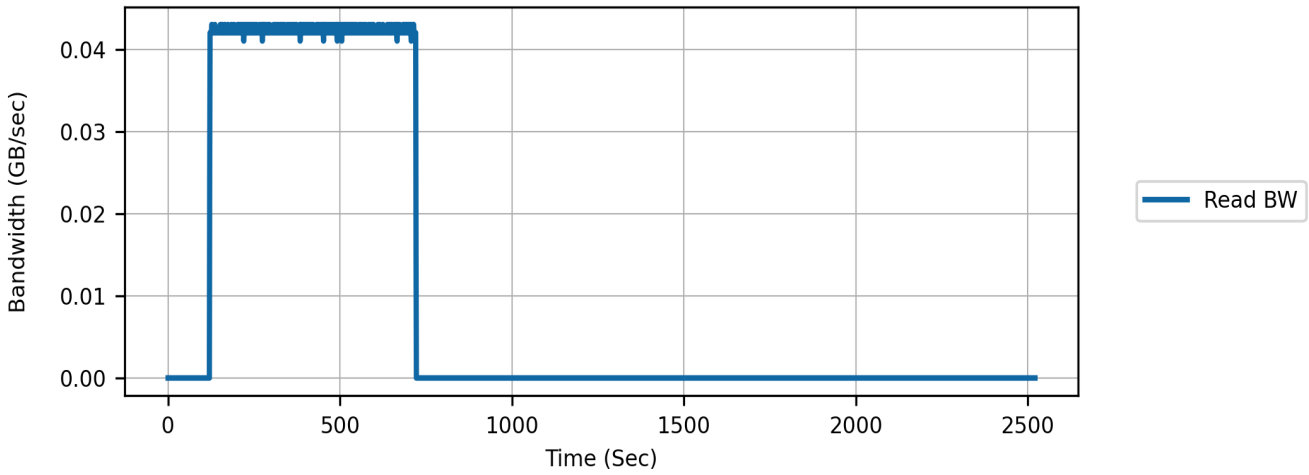
RANDOM READS

These plots are for reads using random addressing, block size of 4 KiB, and queue depth of 1.

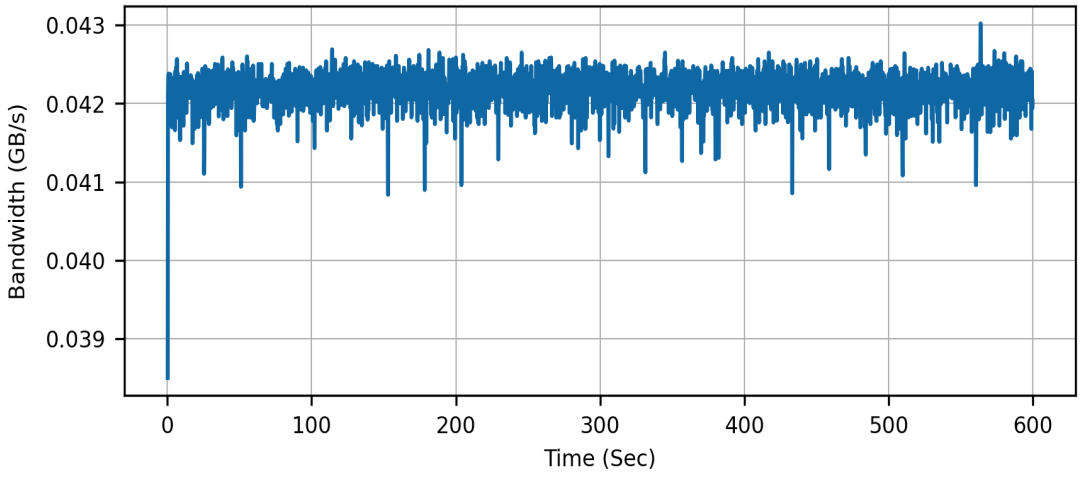
Temperature (Including Idle)



IO Read Bandwidth (Including Idle)



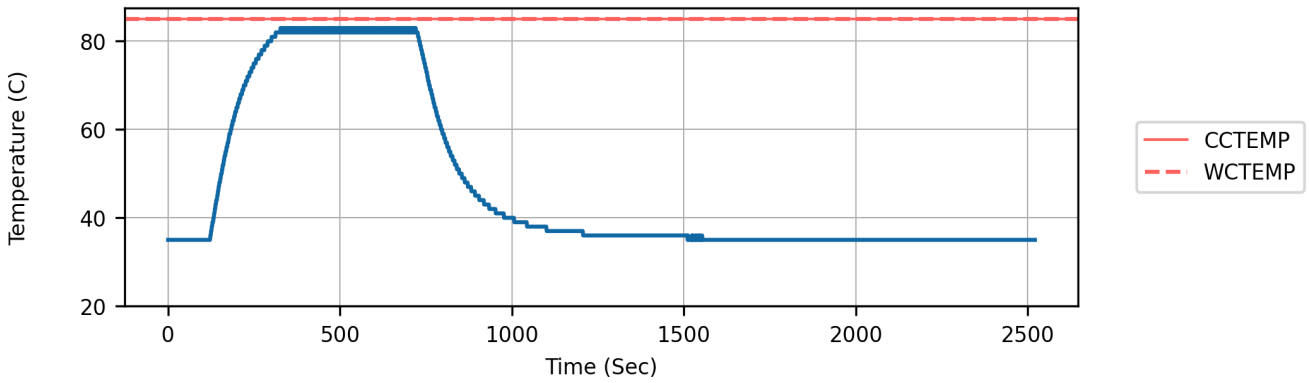
IO Read Bandwidth (Excluding Idle)



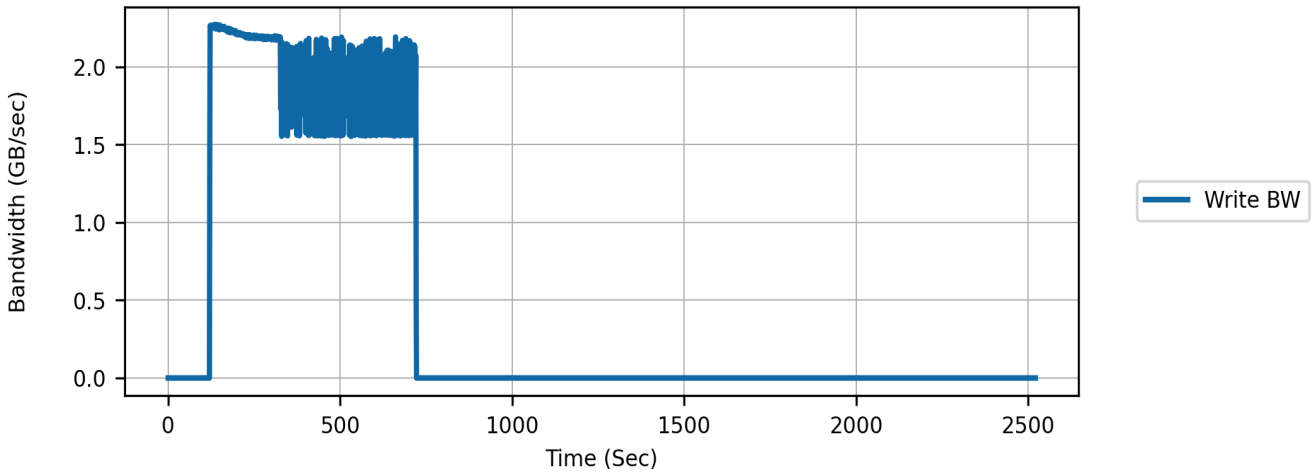
SEQUENTIAL WRITES

These plots are for writes using sequential addressing, block size of 128 KiB, and queue depth of 32.

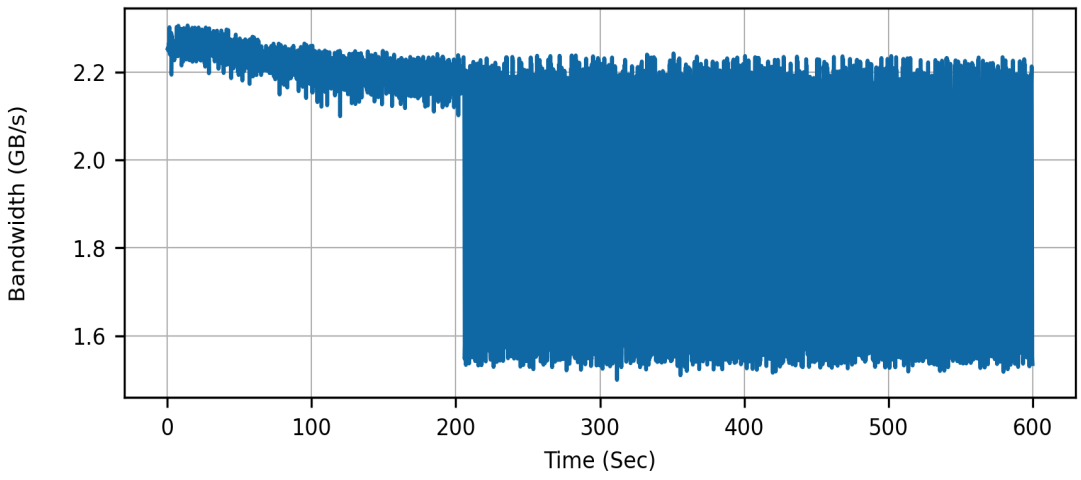
Temperature (Including Idle)



IO Write Bandwidth (Including Idle)



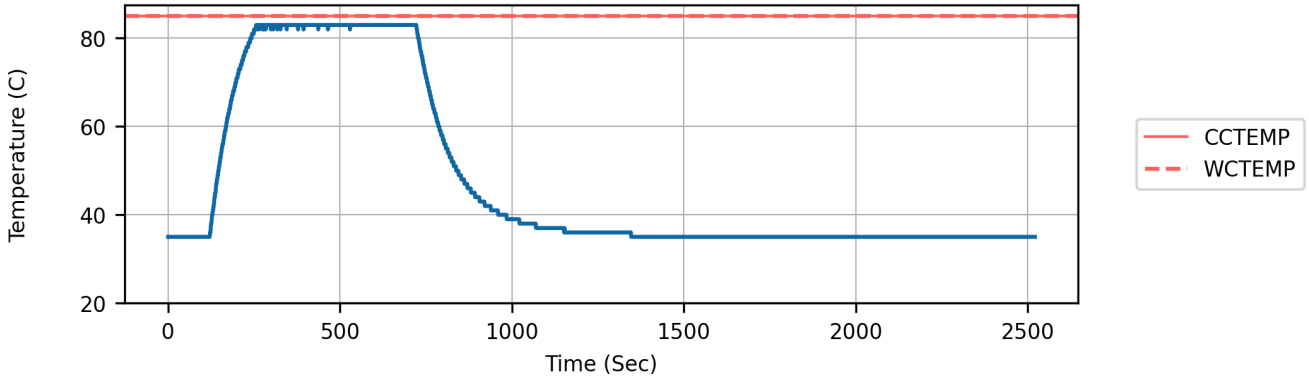
IO Write Bandwidth (Excluding Idle)



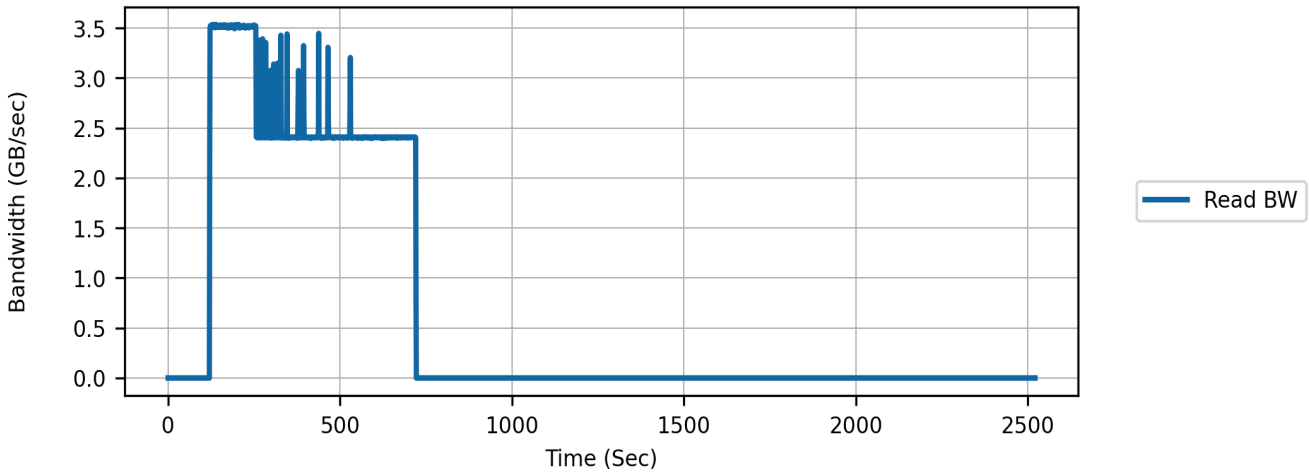
SEQUENTIAL READS

These plots are for reads using sequential addressing, block size of 128 KiB, and queue depth of 32.

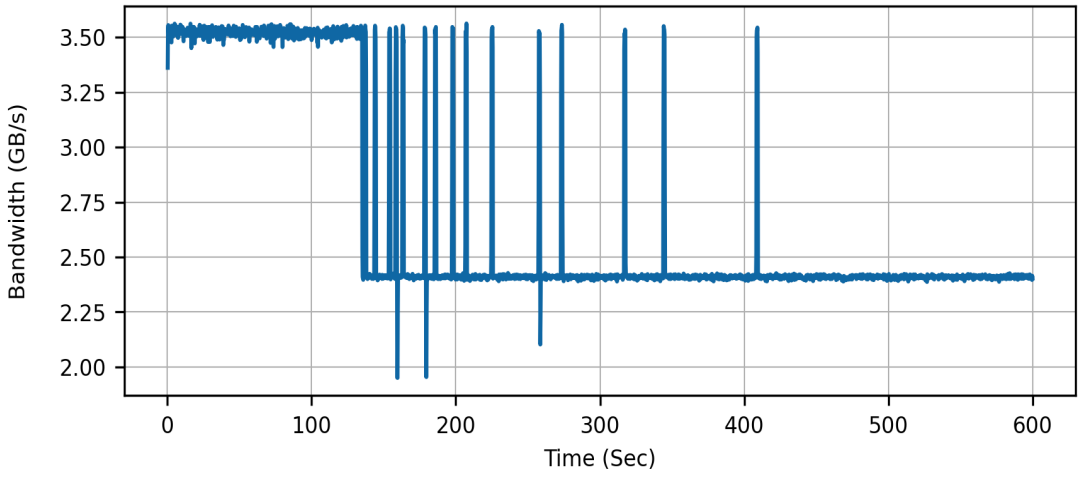
Temperature (Including Idle)



IO Read Bandwidth (Including Idle)



IO Read Bandwidth (Excluding Idle)



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file without verification headers.

Step 3: Empty drive : PASS

Verify the drive free space.

REQUIREMENT	VALUE	RESULT
Disk free space must be greater than 90%	99.1%	PASS

Step 4: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.5 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.6 mS	PASS

Step 5: Random write : FAIL

Start reading NVMe information for random write, size=4096, depth=1

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur running IO	0	PASS
Long burst end temperature shall be within 5C of start temperature	5C	FAIL

Step 6: Random read : PASS

Start reading NVMe information for random read, size=4096, depth=1

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS

Error count shall not increase	0	PASS
No errors shall occur running IO	0	PASS
Long burst end temperature shall be within 5C of start temperature	1C	PASS

Step 7: Sequential write : PASS

Start reading NVMe information for sequential write, size=131072, depth=32

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur running IO	0	PASS
Long burst end temperature shall be within 5C of start temperature	0C	PASS

Step 8: Sequential read : PASS

Start reading NVMe information for sequential read, size=131072, depth=32

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur running IO	0	PASS
Long burst end temperature shall be within 5C of start temperature	0C	PASS

Step 9: Verify performance : FAIL

Verify long burst performance.

REQUIREMENT	VALUE	RESULT
Long burst, random reads, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	0.042 GB/s	PASS
Long burst, random writes, 4KiB, QD1 bandwidth shall be greater than 0.1 GB/s	0.099 GB/s	FAIL
Long burst, sequential reads, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	2.684 GB/s	PASS
Long burst, sequential writes, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	1.970 GB/s	PASS
IO bandwidth behaved as expected across queue depth, block size, address type	REVIEW	FAIL

Step 10: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS

Media in read-only shall be No	No	**PASS**
Volatile memory backup fail shall be No	No	**PASS**
Media and integrity errors shall be 0	0	**PASS**
Error count shall not increase	0	**PASS**
Static parameters, such as Model Number, shall not change	0	**PASS**
SMART counters, such as Data Written, shall not decrement	0	**PASS**

TEST 14: IDLE LATENCY

VERIFICATIONS	18	
PASS	15	83.3%
FAIL	3	16.7%

STARTED	ENDED	DURATION
Mar 04, 2023 - 04:13:46.816	Mar 04, 2023 - 05:06:20.948	0:52:34.132

DESCRIPTION

This test measures the time to enter and exit power states. Power state timing is determined by reading the latency of the first IO read after an idle period that is long enough to enter a lower power state. When a lower power state is entered, the time to exit the power state is added to the normal IO read latency. The time to enter a power state is measured by increasing the idle period until a change in read latency is observed.

The first part of this test measures read latency for small idle periods up to 1mS. These small idle periods activate low-level hardware power features such as PCIe ASPM and processor power states. The second part measures read latency for idle periods up to several seconds. These longer idle periods activate the NVMe power states in addition to the low-level power states.

Systems with NVMe drives typically have multiple power saving features that can interact. These features have several settings that can be configured in the BIOS or Operating System (OS). Therefore it is important to run this test with the same settings as the end-user.

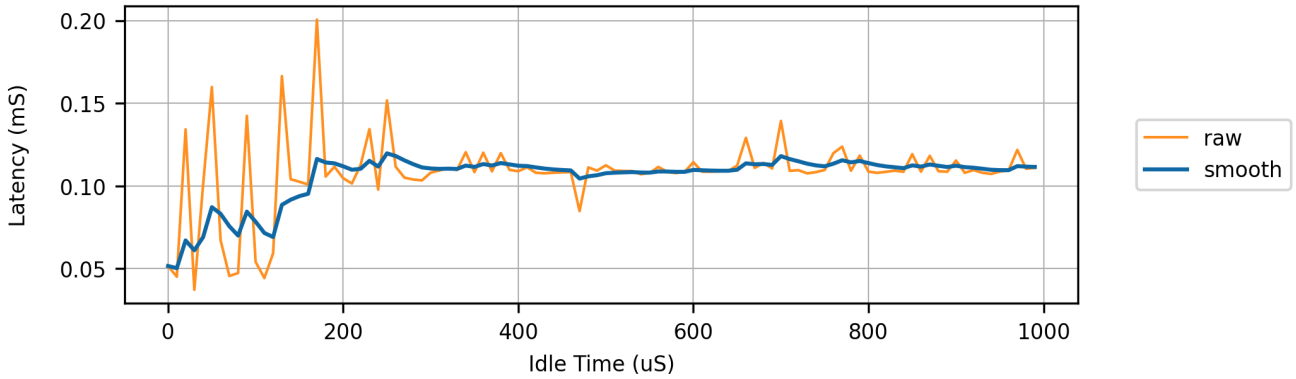
NVMe power states are controlled by either the OS or the NVMe drive itself. If Autonomous Power State Transition (APST) is enabled, the drive will automatically transition to a non-operational power state. The value of Idle Time Prior to Transition (ITPT) defines the idle time required before transitioning. The Idle Transition Power State (ITPS) defines the state to transition to. Each Power State can have it's own ITPT and ITPS value.

If APST is disabled, the host OS will transition the drive to the lower power states. This appears to be the case for the inbox Windows driver. The Windows driver uses four parameters to determine the timeout and which state to transition to. The Primary and Secondary NVMe Idle Timeouts work the same as ITPT above. The Primary and Secondary NVMe Power State Transition Latency Tolerance define the state to transition to. The driver transitions to the lowest state where the sum of the entry and exit latency is less than the NVMe Power State Transition Latency Tolerance.

RESULTS

Short idle periods can activate low-level hardware features, such as PCIe ASPM, that autonomously transition to power saving states. These low-level power states typically have very small enter and exit times that typically have no significant effect on IO performance. For reference, this test plots IO read latency for short idle periods of 0 to 1mS to determine if anything unexpected is occuring.

In the plot below, verify the latency behaves as expected. For details see Analyze idle latency plots with fio [9]



NVMe Power States

Autonomous Power State Transition (APST) is disabled therefore the host OS is changing power states.

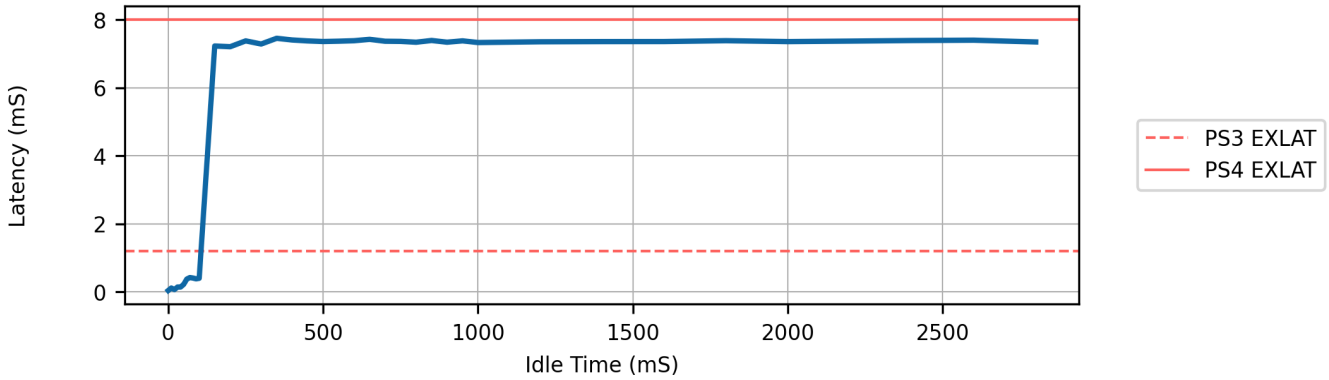
The table below lists the Windows OS power plan settings.

PARAMETER	AC POWER	DC POWER
ASPM	0	2
NOPPME	0	0
Primary Latency	50 mS	5 mS
Primary Timeout	100 mS	100 mS
Secondary Latency	100 mS	100 mS
Secondary Timeout	800 mS	1000 mS

The table below lists the NVMe power states.

POWER STATE	NOP	ENTRY LATENCY	EXIT LATENCY	TOTAL LATENCY
0	False			
1	False			
2	False			
3	True	0.21 mS	1.2 mS	1.41 mS
4	True	2.0 mS	8.0 mS	10.0 mS

In the plot below, verify the power state entry and exit latencies match those defined above.



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file without verification headers.

Step 3: Short idle : FAIL

Measure read latency after short idle periods.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
IO read latency after short idle times behaves as expected.	REVIEW	FAIL

Step 4: Long idle : FAIL

Measure read latency after long idle periods.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
Power state entry timeout shall meet drive setting	REVIEW	FAIL
IO read latency within power state exit latencies	REVIEW	FAIL

Step 5: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS

SMART counters, such as Data Written, shall not decrement	0	**PASS**

TEST 15: DATA DEDUPLICATION

VERIFICATIONS	29	
PASS	29	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 04, 2023 - 05:06:20.957	Mar 04, 2023 - 05:18:53.078	0:12:32.121

DESCRIPTION

This test attempts to determine if the drive implements data deduplication. Data deduplication is a feature that reduces the amount of duplicate data written to the NAND flash resulting in lower write latency, extended drive life, and reduced garbage collection overhead.

This test reports the average latency for 2 GiB of writes with repeating and non-repeating data. Drives with data deduplication should have much lower latency for the repeating data pattern. The repeating data pattern uses the same psuedo-random pattern for every block. The non-repeating pattern uses a unique psuedo-random pattern every block. For example, the repeating pattern is a psuedo-random data pattern that is 4 KiB in size when the block size is 4 KiB.

The writes are completed with a queue depth of 1 and block sizes of 4 KiB, 8 KiB, 32 KiB, and 128 KiB. Different block sizes are tried because any data deduplication chunk size is unknown.

RESULTS

Write Latency vs Data Repeatability

IO PATTERN	NONREPEATING	REPEATING	DELTA	% DELTA
Sequential Write, 4 KiB, QD1	40.681 mS	40.742 mS	-0.061 mS	-0.1%
Sequential Write, 8 KiB, QD1	42.407 mS	42.159 mS	0.249 mS	0.6%
Sequential Write, 32 KiB, QD1	51.407 mS	51.729 mS	-0.322 mS	-0.6%
Sequential Write, 128 KiB, QD1	82.127 mS	82.628 mS	-0.501 mS	-0.6%

VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file without verification headers.

Step 3: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.6 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 4: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 5: 4K unique writes : PASS

Writing unique patterns with block size of 4K.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 6: 8K unique writes : PASS

Writing unique patterns with block size of 8K.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 7: 32K unique writes : PASS

Writing unique patterns with block size of 32K.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 8: 128K unique writes : PASS

Writing unique patterns with block size of 128K.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 9: 4K duplicate writes : PASS

Writing duplicate patterns with block size of 4K.

REQUIREMENT	VALUE	RESULT

No errors shall occur running IO	0	PASS

Step 10: 8K duplicate writes : PASS

Writing duplicate patterns with block size of 8K.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 11: 32K duplicate writes : PASS

Writing duplicate patterns with block size of 32K.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 12: 128K duplicate writes : PASS

Writing duplicate patterns with block size of 128K.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 13: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 14: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 16: READ BUFFER

VERIFICATIONS	19	
PASS	19	100.0%
FAIL	0	0.0%

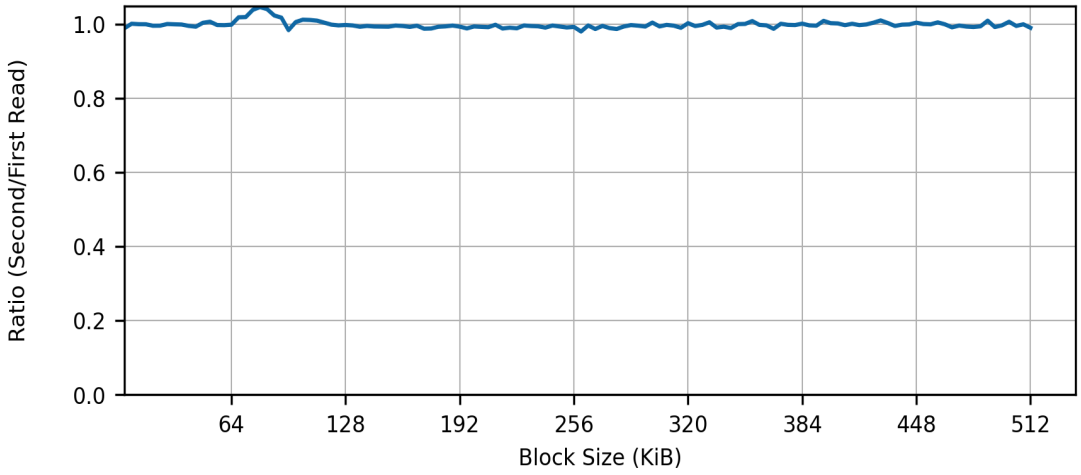
STARTED	ENDED	DURATION
Mar 04, 2023 - 05:18:53.096	Mar 04, 2023 - 05:22:24.076	0:03:30.980

DESCRIPTION

This test attempts to determine if the drive implements a read buffer by reporting the difference in read latency for two subsequent reads to the same address. Drives that have a read buffer should report much lower latency for the second read. Since these are performance measurements no data verification is done.

RESULTS

This plot shows the ratio of two reads to the same address at different block sizes. Devices that buffer reads will have a faster second read. A ratio of 0.5 indicates the second read was twice as fast as the first read.



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file without verification headers.

Step 3: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.5 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 4: IO : PASS

Run IO trace file using fio

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 5: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 17: BIG FILE WRITES

VERIFICATIONS	43	
PASS	42	97.7%
FAIL	1	2.3%

STARTED	ENDED	DURATION
Mar 04, 2023 - 05:22:24.076	Mar 04, 2023 - 06:09:02.787	0:46:38.711

DESCRIPTION

This test measures IO bandwidth while continuously writing a big file with high queue depth, large block, sequential writes. Continuous write bandwidth can identify the performance of features such as write caching, logical to physical mapping, erased block starvation, and thermal throttling.

The test starts with an less than 5% space used and creates a big file by continuously writing it several times. During the first write the logical addresses are "new" and may not be cached. If the logical to physical mapping is read from the NAND flash instead of the host or device DRAM the first write bandwidth maybe lower.

Drives with a write cache, such as SLC cache, will have much higher bandwidth at the start of the writes but, when the write cache fills up, the bandwidth drops significantly. The continuous writes will likely prevent the cache from being flushed. Some drives dynamically adjust the size of the write cache based on the amount of free space. The free space on the first write is >95% but on subsequent writes the free space is <5%. Therefore the write cache size may appear to decrease after the first write.

After the initial file write, the test waits a significant amount of time to allow the write cache to be flushed. The big file is read once more but starting at the 50% offset of the file. If the write cache was flushed as expected the initial bandwidth will be much higher even though the writes are starting at the midpoint of the file.

The test then runs several write bursts with varying amounts of idle time between them. The different idle times between bursts can identify how fast the write cache is flushed.

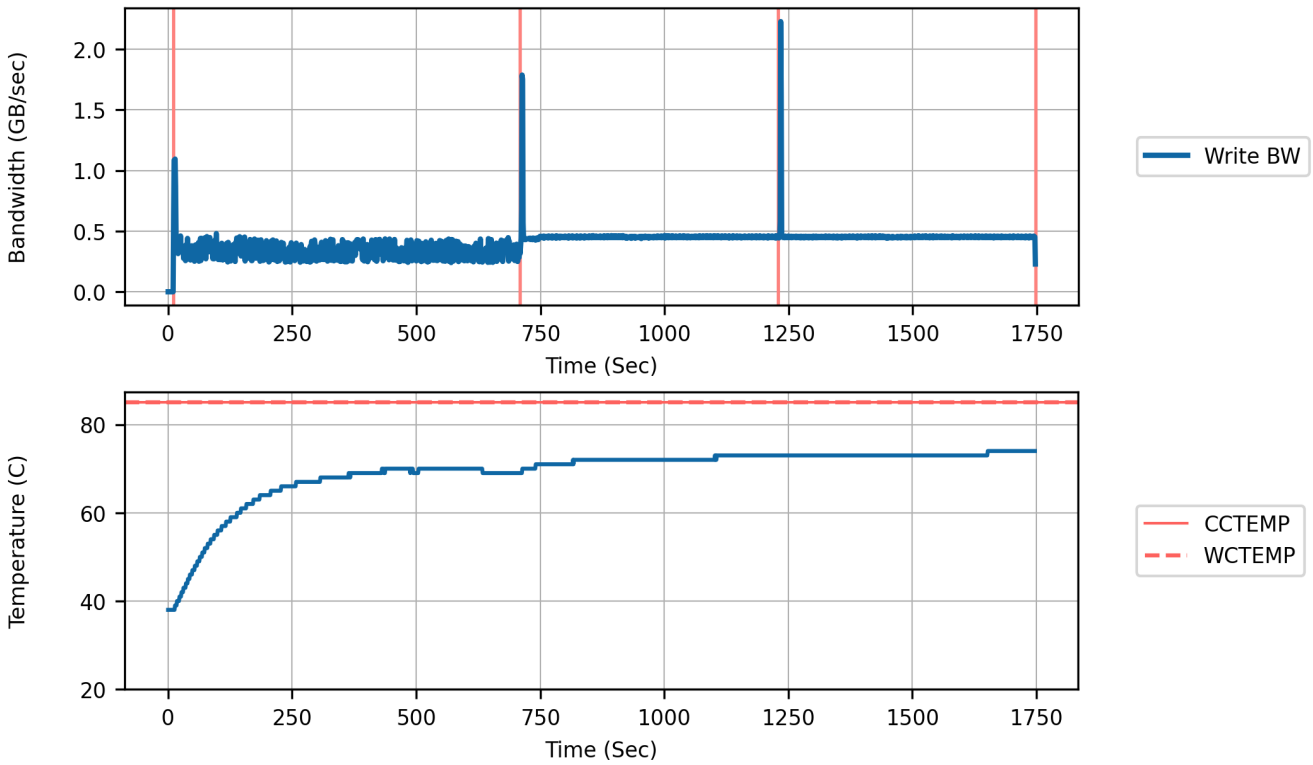
RESULTS

The file size tested was 237.3 GB which is 95% of the disk size of 250.1 GB. The continuous writes used sequential addressing, block size of 128KiB, and queue depth of 32.

Initial File Writes

The big file was written 3 times for a total of 711.9 GB. The average bandwidth was 0.47 GB. The plots below show the write bandwidth and temperature during the multiple file writes. The vertical red lines indicate the start of the file.

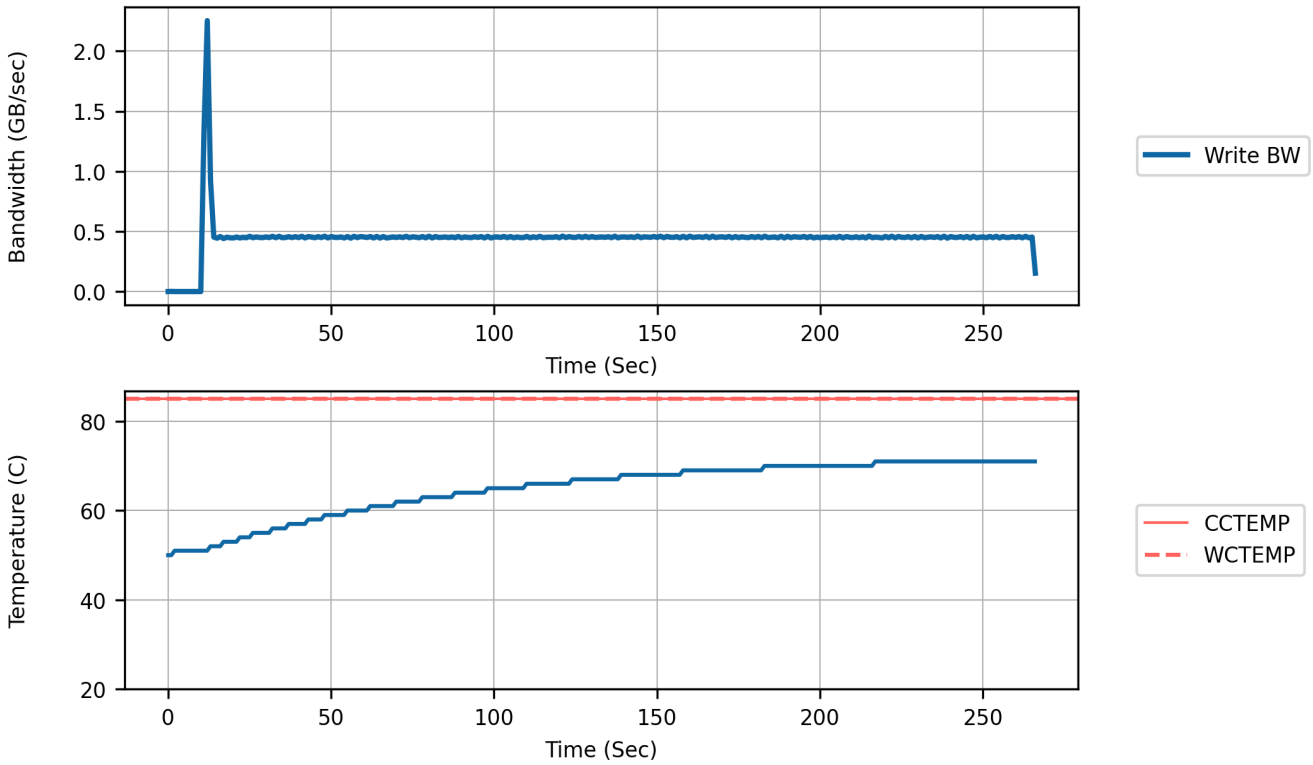
If a write cache exists, verify the initial bandwidth is higher than the average indicating the writes are going to the cache.



Half File Write

The plots below shows the write bandwidth and temperature for writing the second half of the big file after a long delay. The long delay allows the write cache to flush so the next writes are high bandwidth. These writes began at the 50% offset of the file and continue to the end of the file.

If write cache exists, verify the initial bandwidth is higher than the average indicating the writes are going to the cache.



Write Cache Info

In the bandwidth plots above, writes with a bandwidth greater then twice the average are assumed to be going to the write cache. The table below summarizes the measured write cache size and bandwidth based on this assumption.

Verify any average bandwidth difference between file writes is acceptable.

File Write	Data Written	Average Bandwidth	Cache Written	Cache Bandwidth
1	237.3 GB	0.340 GB/s	4.5 GB	1.087 GB/s
2	237.3 GB	0.458 GB/s	4.0 GB	1.755 GB/s
3	237.3 GB	0.459 GB/s	3.9 GB	2.145 GB/s
4	119.0 GB	0.467 GB/s	4.2 GB	2.119 GB/s

Cache Size Burst Writes

Several cache size burst writes were completed with varying amount of idle time before the bursts. This idle time allows drive to flush the write cache Each burst was 4.2 GB. Writes with a bandwidth above 0.933 GB/s were assumed to be going to the write cache.

Burst	Pre-Burst Idle	Average Bandwidth	Cache Written	Cache Bandwidth
1	180 sec	1.831 GB/s	3.8 GB	2.229 GB/s
2	1 sec	0.497 GB/s	0.5 GB	1.722 GB/s
3	2 sec	0.451 GB/s	0.0 GB	0.000 GB/s
4	4 sec	0.642 GB/s	1.5 GB	2.211 GB/s
5	8 sec	0.722 GB/s	2.0 GB	2.167 GB/s
6	16 sec	1.753 GB/s	3.8 GB	2.208 GB/s
7	32 sec	2.209 GB/s	4.2 GB	2.209 GB/s
8	64 sec	1.793 GB/s	3.8 GB	2.259 GB/s

VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get big file info but don't create.

Step 3: Empty drive : PASS

Verify the drive free space.

REQUIREMENT	VALUE	RESULT
Disk free space must be greater than 90%	99.1%	PASS

Step 4: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.5 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 5: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 6: Multiple file writes : PASS

Write big file multiple times.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 7: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 8: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.0 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.6 mS	PASS

Step 9: Active wait : PASS

Intermittent reads to avoid low power states.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 10: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 11: Half file write : PASS

Write second half of big file.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 12: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 13: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.0 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.6 mS	PASS

Step 14: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 15: Burst writes : FAIL

Write big file in several bursts.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
Bandwidth of first IO write burst should match write cache bandwidth	REVIEW	FAIL

Step 16: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 17: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 18: BIG FILE READS

VERIFICATIONS	28	
PASS	28	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 04, 2023 - 06:09:02.799	Mar 04, 2023 - 06:31:18.087	0:22:15.288

DESCRIPTION

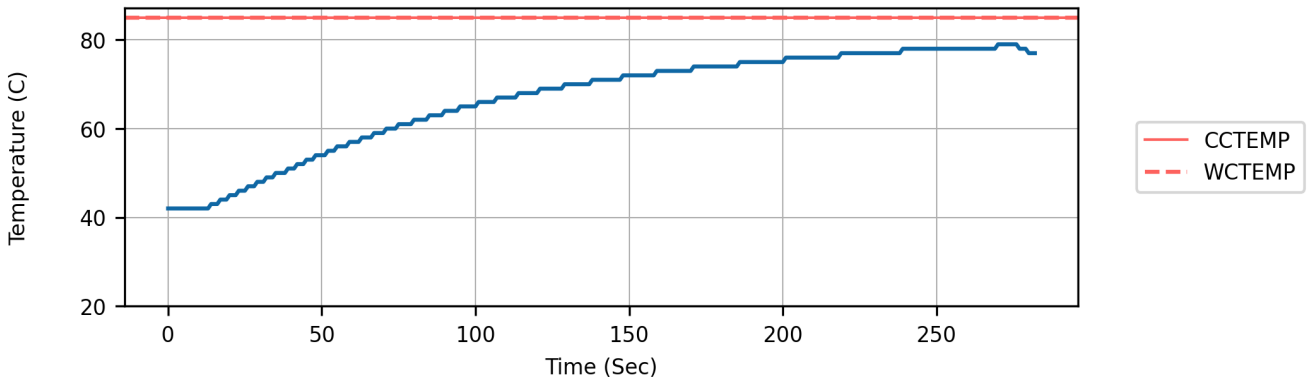
This test reports the bandwidth and distribution of continuous large block sequential and random reads to a big file. The big file is approximately 95% of the disk size. The file is reads 2 times for each addressing mode. This allows comparison of the different addressing modes: sequential and random. Since this test reports performance measurements no data verification is done.

RESULTS

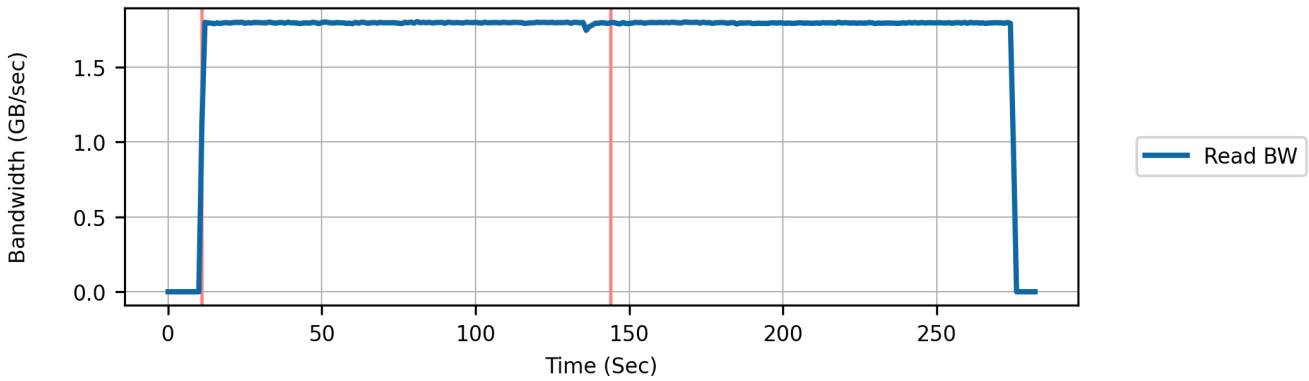
The file size tested was 237.3 GB which is 95% of the disk size of 250.1 GB.

Sequential Reads

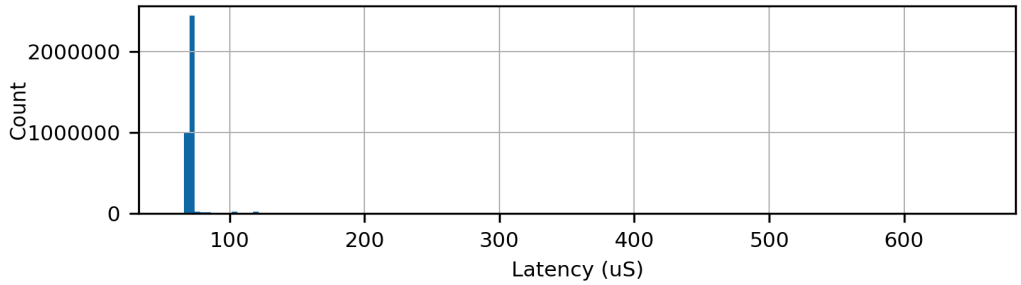
The plot below shows the composite temperature of the drive during the test along with the thermal throttle limits.



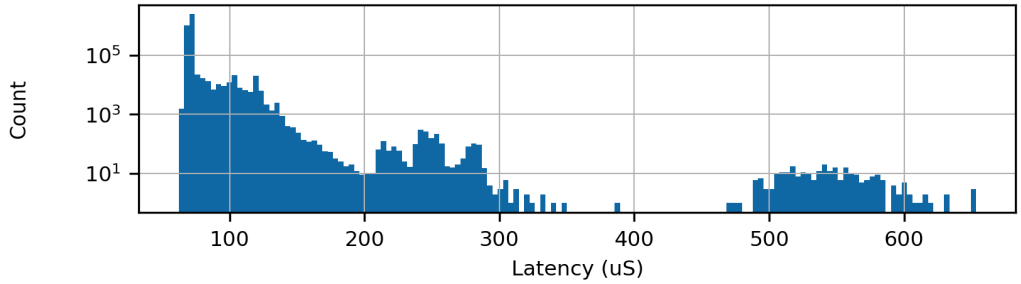
The plot below shows the read bandwidth during the sequential reads.



This histogram shows the latency distribution for 3,620,848 sequential reads. The reads have a block size of 128 KiB and queue depth of 1.

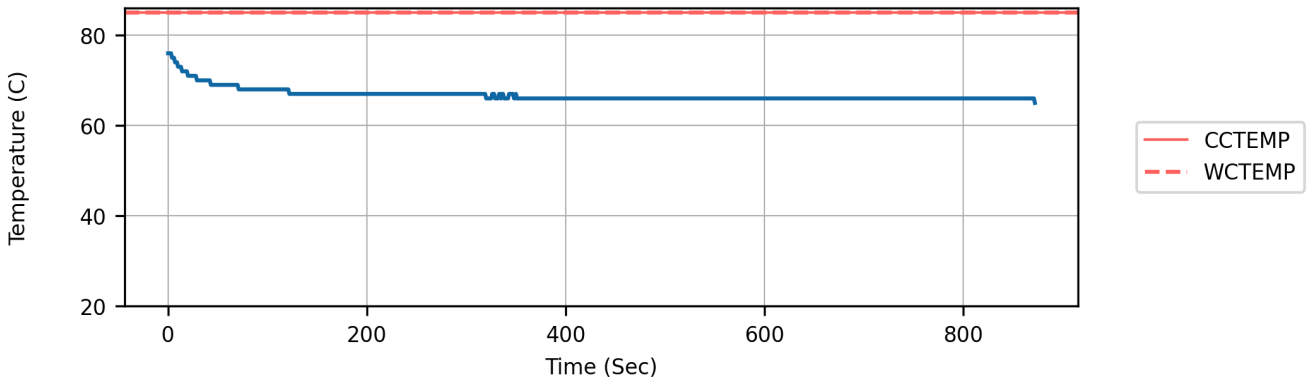


This histogram shows the same data as above except on a log scale to provide better visibility of outliers.

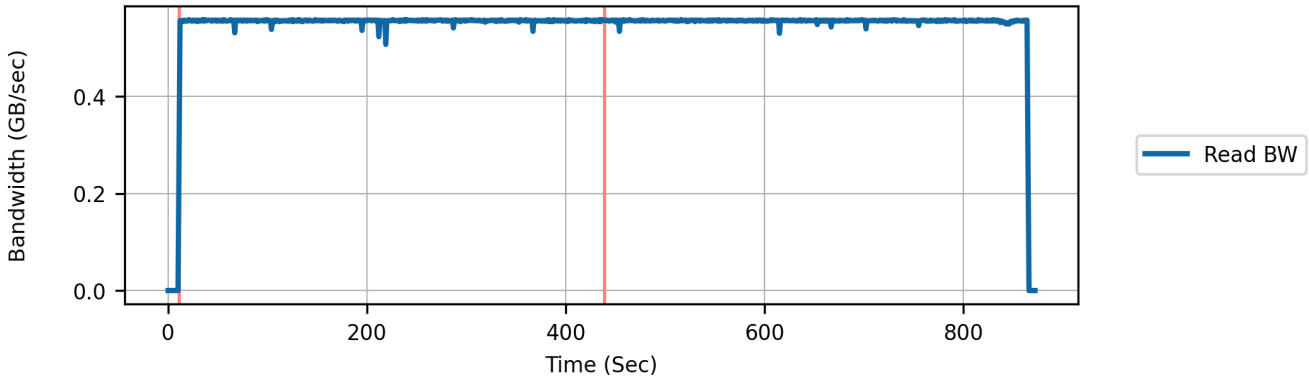


Random Reads

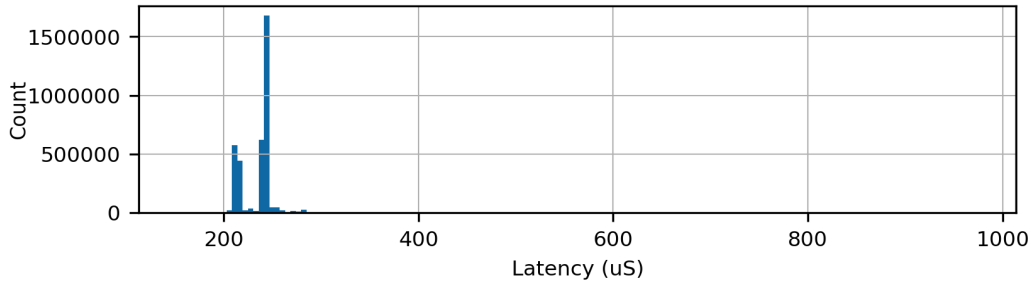
The plot below shows the composite temperature of the drive during the test along with the thermal throttle limits.



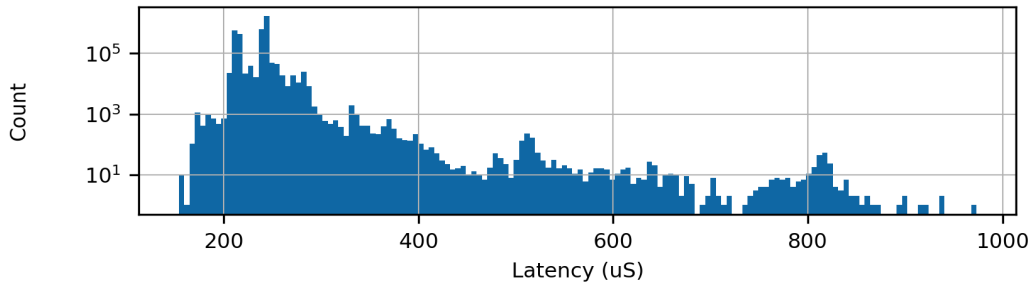
The plot below shows the read bandwidth during the random reads.



This histogram shows the latency distribution for 3,620,848 random reads. The reads have a block size of 128 KiB and queue depth of 1.



This histogram shows the same data as above except on a log scale to provide better visibility of outliers.



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create big file without verification headers.

Step 3: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.0 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.6 mS	PASS

Step 4: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 5: Sequential reads : PASS

Read big file several times using sequential reads.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 6: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 7: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 8: Random reads : PASS

Read fio big file several times using random reads.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 9: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 10: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS

Media and integrity errors shall be 0	0	**PASS**
Error count shall not increase	0	**PASS**
Static parameters, such as Model Number, shall not change	0	**PASS**
SMART counters, such as Data Written, shall not decrement	0	**PASS**

TEST 19: DATA COMPRESSION

VERIFICATIONS	29	
PASS	29	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 04, 2023 - 06:31:18.103	Mar 04, 2023 - 06:36:37.052	0:05:18.949

DESCRIPTION

This test attempts to determine if the drive implements data compression. Data compression is a feature that reduces the amount of data written to the NAND flash resulting in lower write latency, extended drive life, and reduced garbage collection overhead.

This test reports the average latency for 2 GiB of reads and writes with incompressible and compressible data. Drives with data compression should have lower latency for the compressible data pattern. The compressible data pattern is all 0s. The incompressible data pattern is a unique psuedo-random pattern every write. The read and writes are completed with a queue depth of 1, block size of 8 KiB for random addressing, and block size of 128 KiB for sequential addressing.

RESULTS

IO Latency vs Data Compressibility

IO PATTERN	COMPRESSIBLE	INCOMPRESSIBLE	DELTA	% DELTA
Random Write, 8 KiB, QD1	42.753 mS	42.489 mS	-0.264 mS	-0.6%
Random Read, 8 KiB, QD1	100.522 mS	103.220 mS	2.698 mS	2.6%
Sequential Write, 128 KiB, QD1	81.763 mS	85.776 mS	4.014 mS	4.7%
Sequential Read, 128 KiB, QD1	72.402 mS	71.867 mS	-0.535 mS	-0.7%

VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file without verification headers.

Step 3: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.5 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 4: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 5: Random data write 128K : PASS

Sequential Write, 128 KiB, QD1 with incompressible data.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 6: Random data read 128K : PASS

Sequential Read, 128 KiB, QD1 with incompressible data.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 7: Random data random write 8K : PASS

Random Write, 8 KiB, QD1 with incompressible data.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 8: Random data random read 8K : PASS

Random Read, 8 KiB, QD1 with incompressible data.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 9: Zero data write 128K : PASS

Sequential Write, 128 KiB, QD1 with compressible data.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 10: Zero data read 128K : PASS

Sequential Read, 128 KiB, QD1 with compressible data.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 11: Zero data random write 8K : PASS

Random Write, 8 KiB, QD1 with compressible data.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 12: Zero data random read 8K : PASS

Random Read, 8 KiB, QD1 with compressible data.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 13: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 14: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 20: SHORT BURST PERFORMANCE FULL DRIVE

VERIFICATIONS	31	
PASS	30	96.8%
FAIL	1	3.2%

STARTED	ENDED	DURATION
Mar 04, 2023 - 06:36:37.068	Mar 04, 2023 - 06:59:58.194	0:23:21.126

DESCRIPTION

This test is the same as Short Burst Performance test except the drive capacity is almost full at the start. Full drives may have lower performance than empty drives because of a lower number of erased blocks available for writes and a smaller dynamic cache.

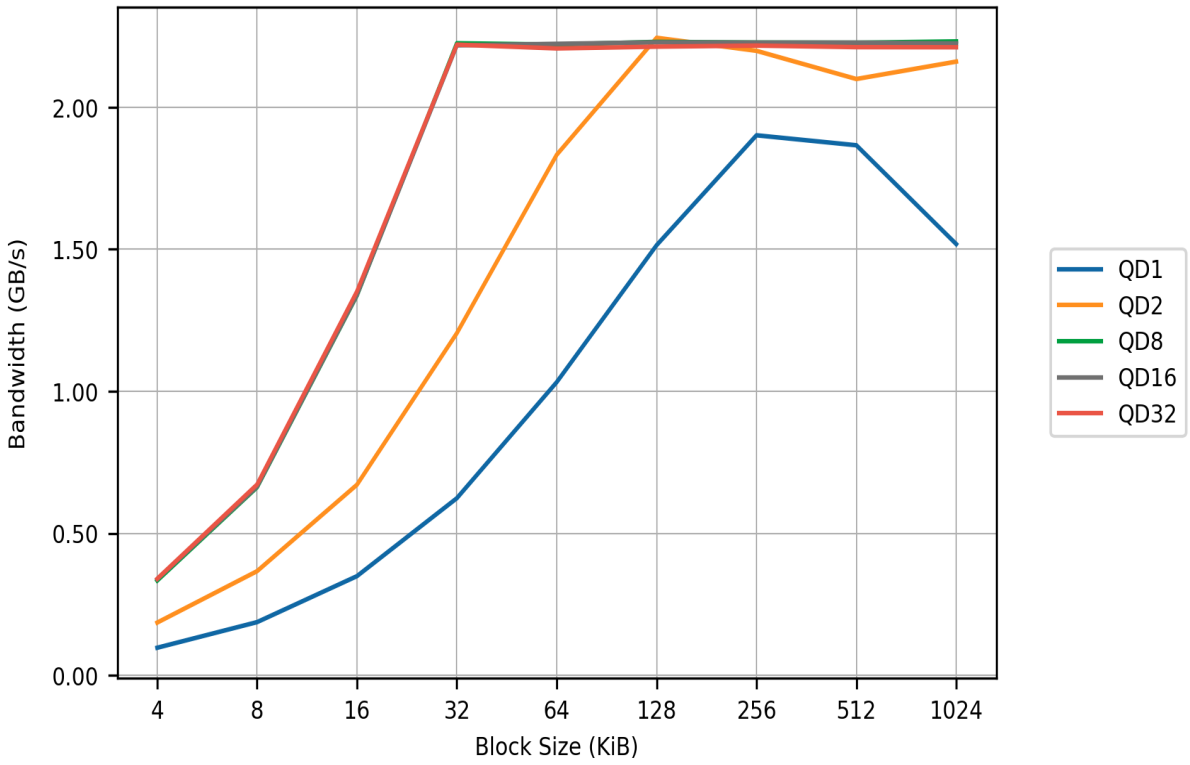
For additional details refer to the Short Burst Performance test.

RESULTS

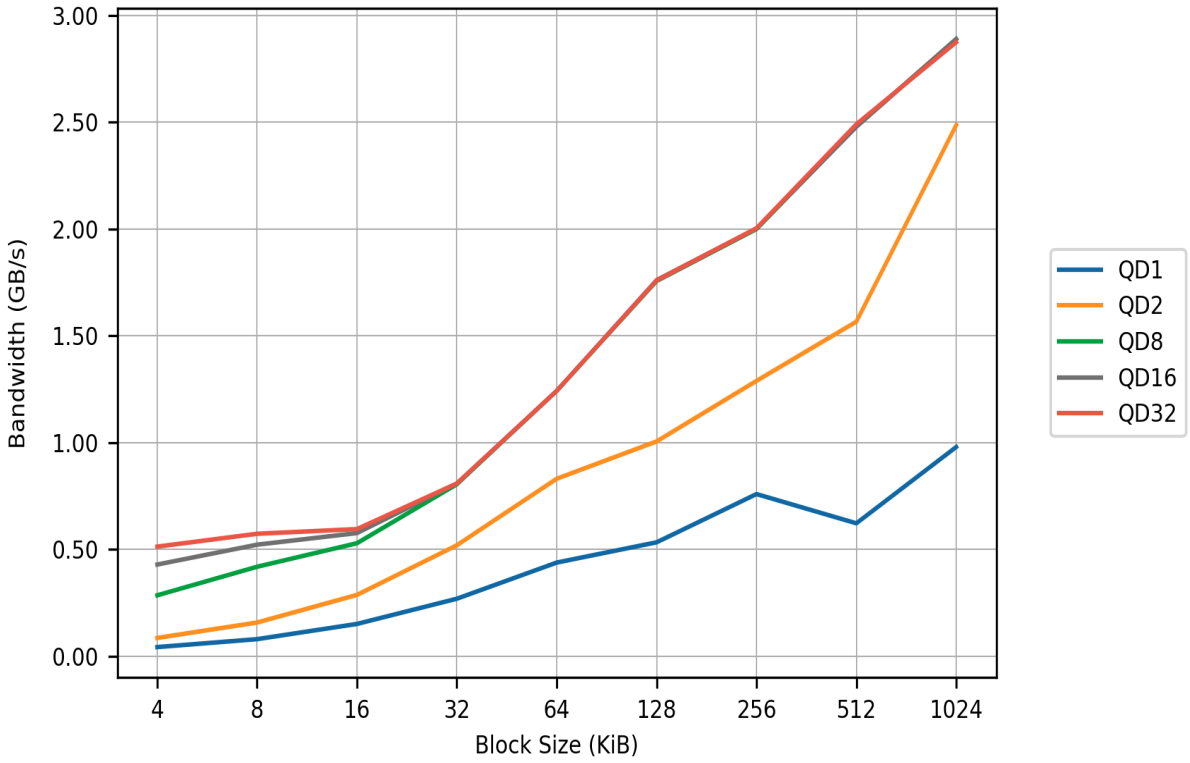
This table shows the bandwidth for several common datasheet and IO benchmark queue depths and block sizes.

IO PATTERN	IOPS	BANDWIDTH	LIMIT	RESULT
Sequential Write, QD32, 128KiB	16,950	2.222 GB/s	1.000 GB/s	PASS
Sequential Read, QD32, 128KiB	26,829	3.517 GB/s	1.000 GB/s	PASS
Random Write, QD1, 4KiB	23,706	0.097 GB/s	0.010 GB/s	PASS
Random Read, QD1, 4KiB	10,237	0.042 GB/s	0.010 GB/s	PASS
Random Write, QD32, 4KiB	82,997	0.340 GB/s	0.250 GB/s	PASS
Random Read, QD32, 4KiB	125,064	0.512 GB/s	0.250 GB/s	PASS

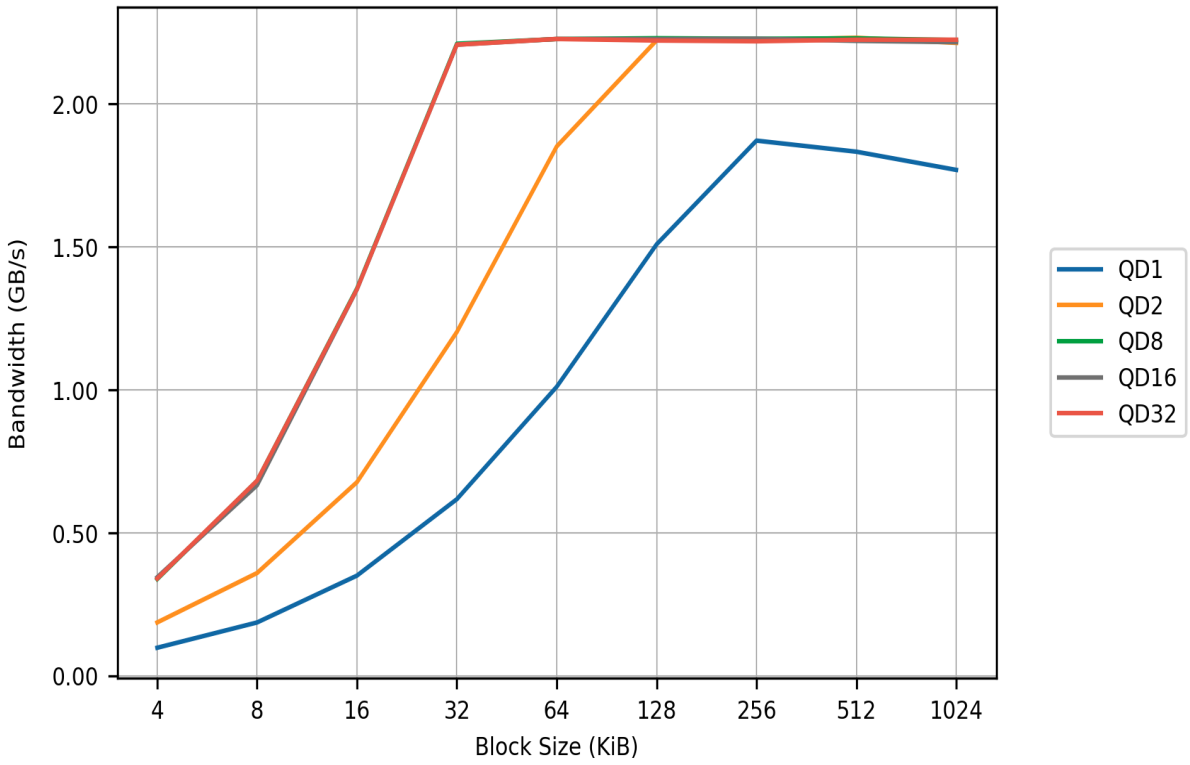
Random Write Bandwidth



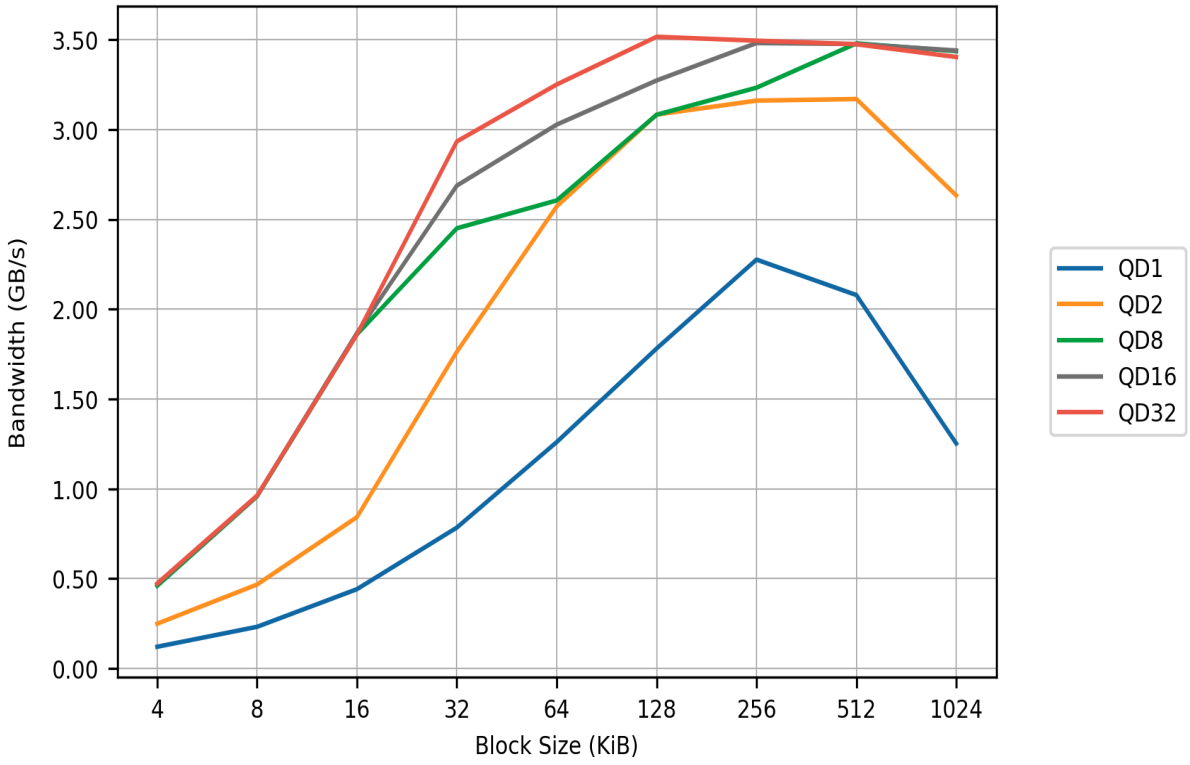
Random Read Bandwidth



Sequential Write Bandwidth



Sequential Read Bandwidth



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file without verification headers.

Step 3: Full drive : PASS

Verify the drive is full.

REQUIREMENT	VALUE	RESULT
Disk free space must be less than 10%	4.2%	PASS

Step 4: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.6 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.8 mS	PASS

Step 5: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 6: Sequential Write : PASS

Measure performance of short burst of sequential writes.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 7: Sequential Read : PASS

Measure performance of short burst of sequential reads.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 8: Random Write : PASS

Measure performance of short burst of random writes.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 9: Random Read : PASS

Measure performance of short burst of random reads.

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS

Step 10: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 11: Verify performance : FAIL

Verify short burst performance.

REQUIREMENT	VALUE	RESULT
Short burst, random reads, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	0.042 GB/s	PASS
Short burst, random writes, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	0.097 GB/s	PASS
Short burst, sequential reads, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	3.517 GB/s	PASS
Short burst, sequential writes, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	2.222 GB/s	PASS
IO bandwidth behaved as expected across queue depth, block size, address type	REVIEW	FAIL

Step 12: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS

NVM Subsystem Unreliable shall be No	No	**PASS**
Media in read-only shall be No	No	**PASS**
Volatile memory backup fail shall be No	No	**PASS**
Media and integrity errors shall be 0	0	**PASS**
Error count shall not increase	0	**PASS**
Static parameters, such as Model Number, shall not change	0	**PASS**
SMART counters, such as Data Written, shall not decrement	0	**PASS**

TEST 21: LONG BURST PERFORMANCE FULL DRIVE

VERIFICATIONS	40	
PASS	38	95.0%
FAIL	2	5.0%

STARTED	ENDED	DURATION
Mar 04, 2023 - 06:59:58.210	Mar 04, 2023 - 09:51:05.100	2:51:06.890

DESCRIPTION

This test is the same as Long Burst Performance test except the drive capacity is 90% at the start. Full drives may have lower performance than empty drives because of a lower number of erased blocks available for writes and a smaller dynamic cache.

For additional details refer to the Long Burst Performance test.

RESULTS

This table shows the bandwidth for several common datasheet and IO benchmark queue depths and block sizes.

IO PATTERN	IOPS	BANDWIDTH	LIMIT	RESULT
Sequential Write, QD32, 128KiB	13,172	1.726 GB/s	1.000 GB/s	PASS
Sequential Read, QD32, 128KiB	17,252	2.261 GB/s	1.000 GB/s	PASS
Random Write, QD1, 4KiB	24,250	0.099 GB/s	0.100 GB/s	FAIL
Random Read, QD1, 4KiB	10,283	0.042 GB/s	0.010 GB/s	PASS

The table below provides the average and ending bandwidth. The ending bandwidth could be significantly lower if thermal throttling or excessive garbage collection occurs.

IO PATTERN	AVERAGE	FIRST SEC	FIRST 15 SEC	LAST 120 SEC
Random Write, QD1, 4KiB	0.099 GB/s	0.098 GB/s	0.099 GB/s	0.099 GB/s
Random Read, QD1, 4KiB	0.042 GB/s	0.041 GB/s	0.042 GB/s	0.042 GB/s
Sequential Write, QD32, 128KiB	1.727 GB/s	2.254 GB/s	2.261 GB/s	1.557 GB/s
Sequential Read, QD32, 128KiB	2.261 GB/s	3.478 GB/s	3.522 GB/s	1.976 GB/s

This table below reports the composite temperature during the IO burst. The expectation is the end and start temperatures should be within the delta limit. A higher temperature could indicate background operations are ongoing.

The table also includes the Throttle Time which is the sum for all throttle levels. Note that the units for throttle levels WCTEMP and CCTEMP is in minutes. Therefore, throttling for less than one minute may not be indicated for these levels.

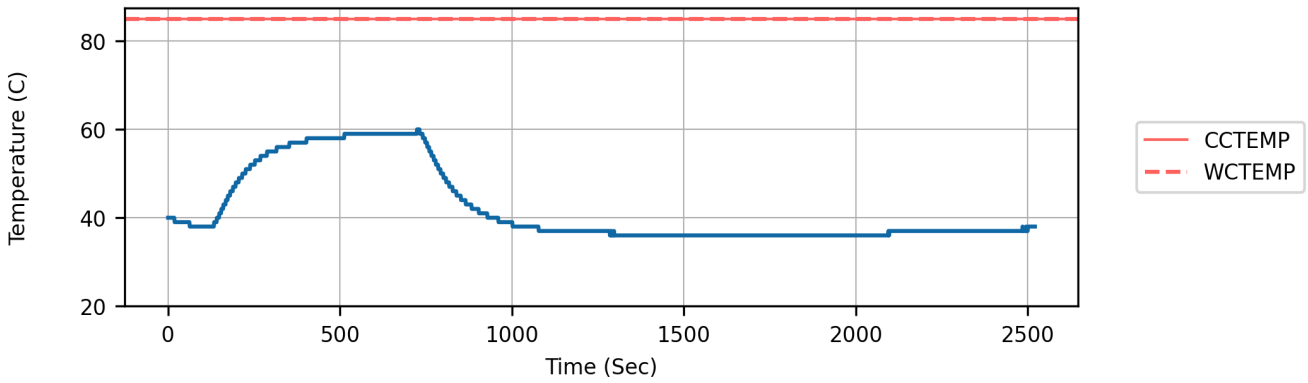
IO PATTERN	THROTTLE	MAX	START	END	DELTA	LIMIT
Random Write, QD1, 4KiB	0 sec	60 C	40	38	-2 C	5 C
Random Read, QD1, 4KiB	0 sec	61 C	38	40	2 C	5 C

Sequential Write, QD32, 128KiB	0 sec	83 C	40	42	2 C	5 C
Sequential Read, QD32, 128KiB	0 sec	83 C	42	39	-3 C	5 C

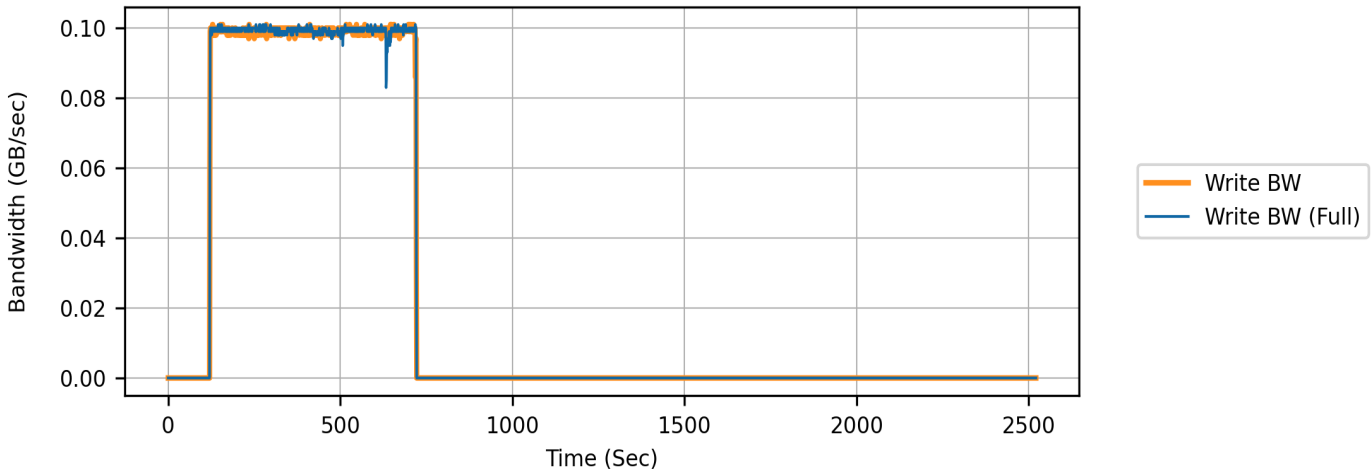
RANDOM WRITES

These plots are for writes using random addressing, block size of 4 KiB, and queue depth of 1.

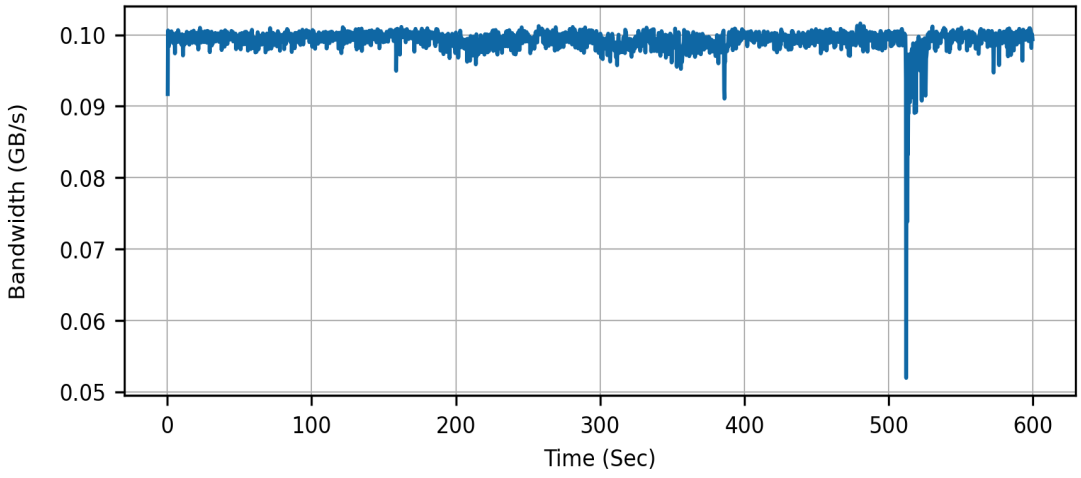
Temperature (Including Idle)



IO Write Bandwidth (Including Idle)



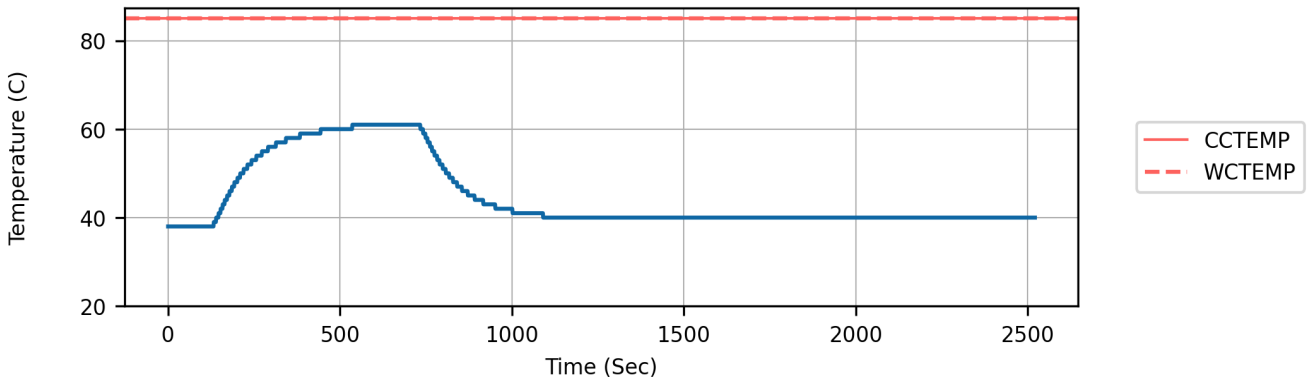
IO Write Bandwidth (Excluding Idle)



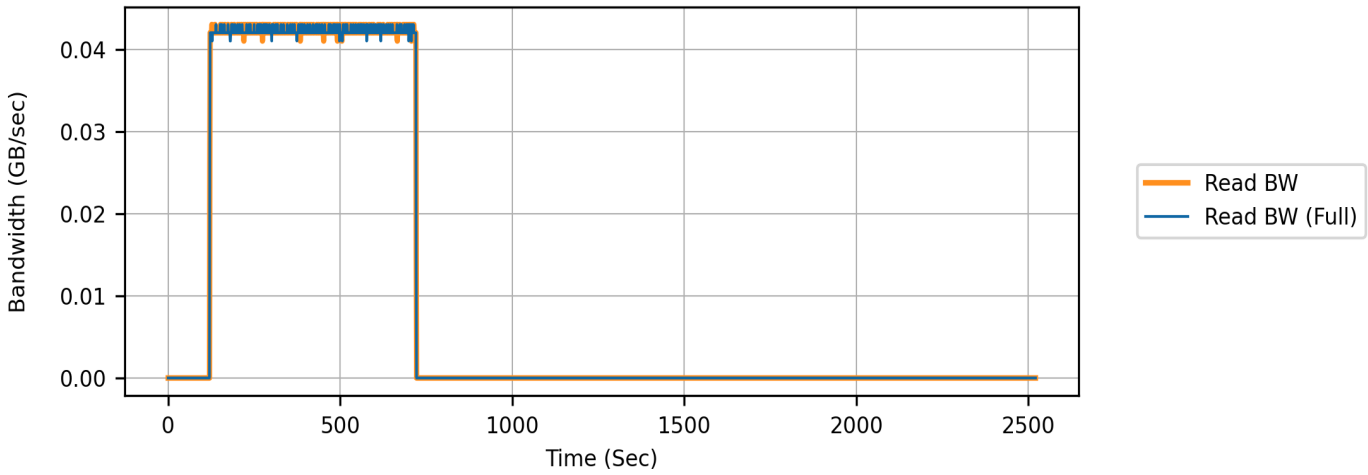
RANDOM READS

These plots are for reads using random addressing, block size of 4 KiB, and queue depth of 1.

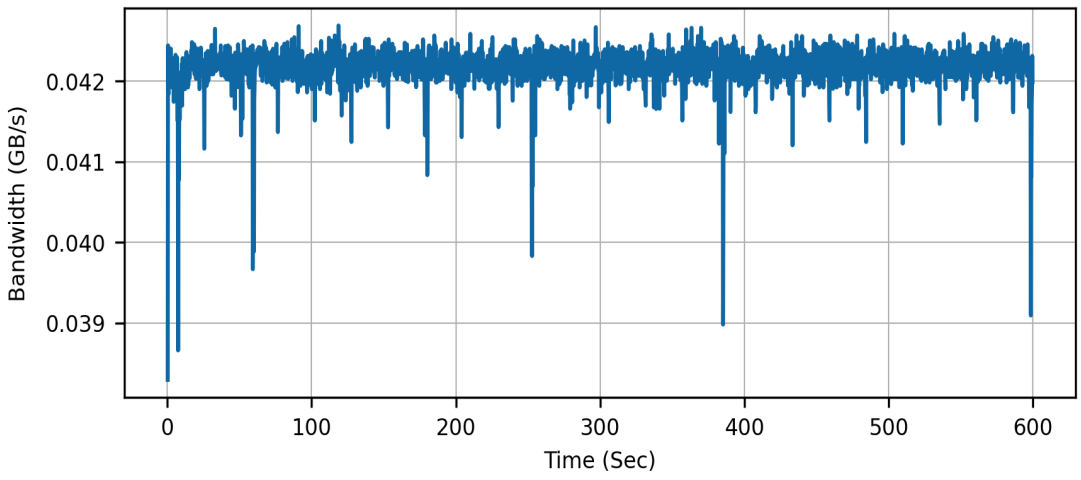
Temperature (Including Idle)



IO Read Bandwidth (Including Idle)



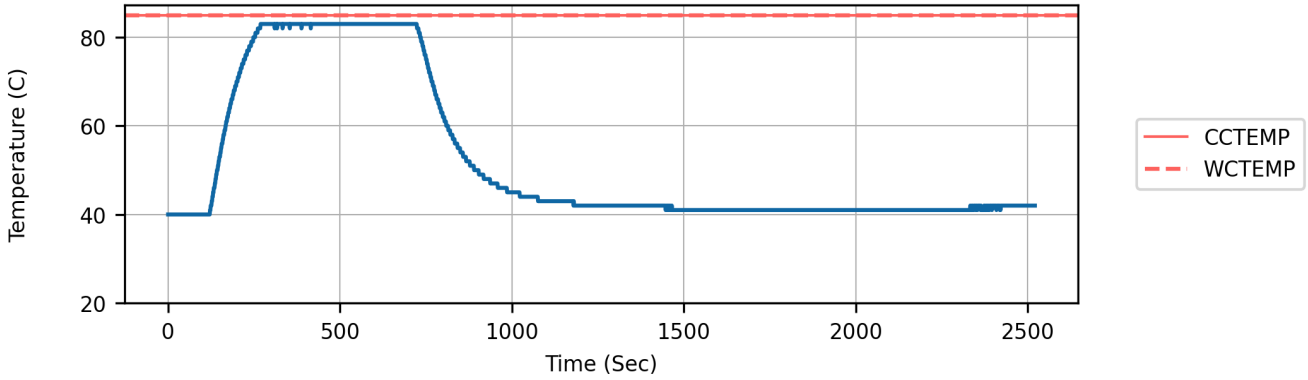
IO Read Bandwidth (Excluding Idle)



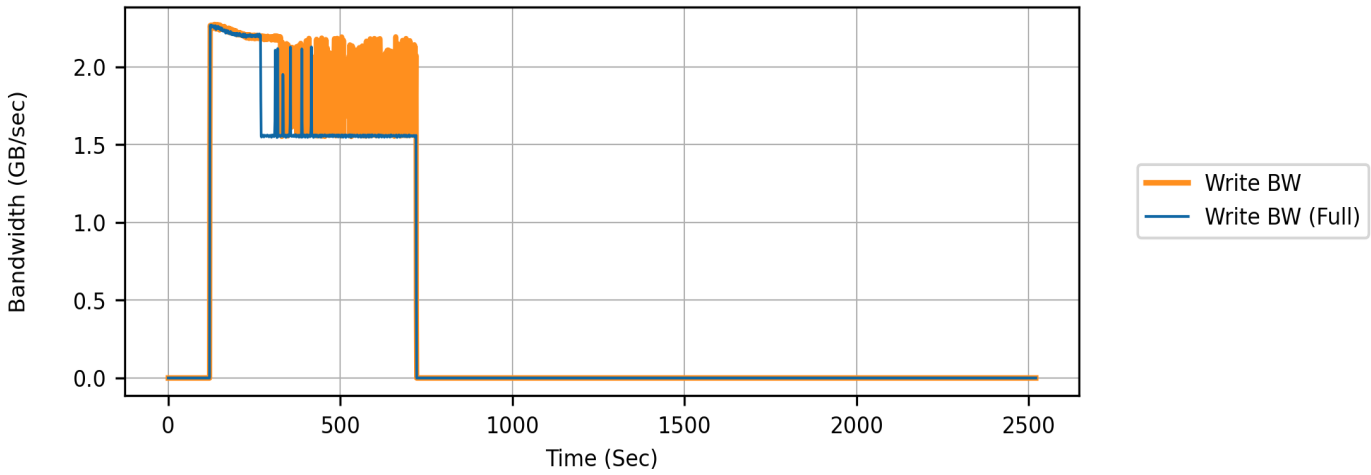
SEQUENTIAL WRITES

These plots are for writes using sequential addressing, block size of 128 KiB, and queue depth of 32.

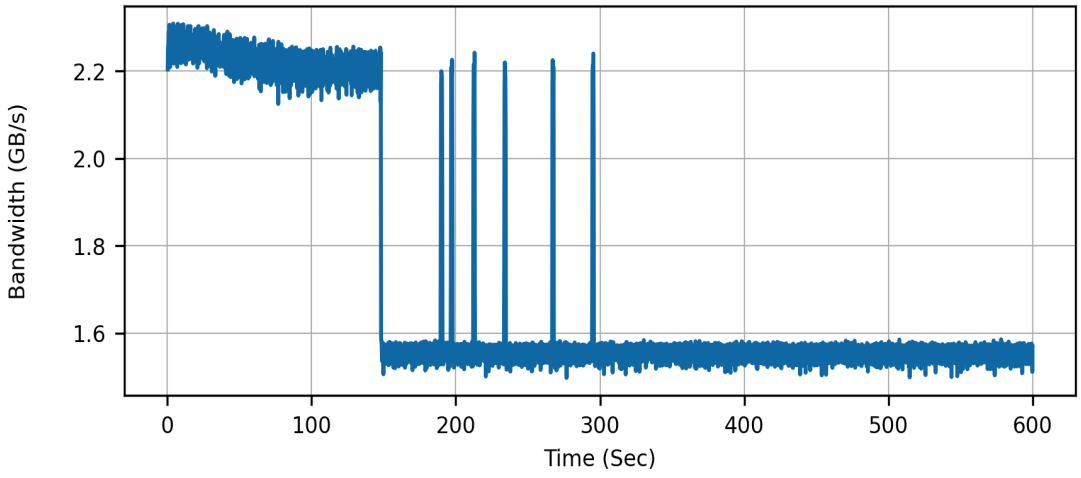
Temperature (Including Idle)



IO Write Bandwidth (Including Idle)



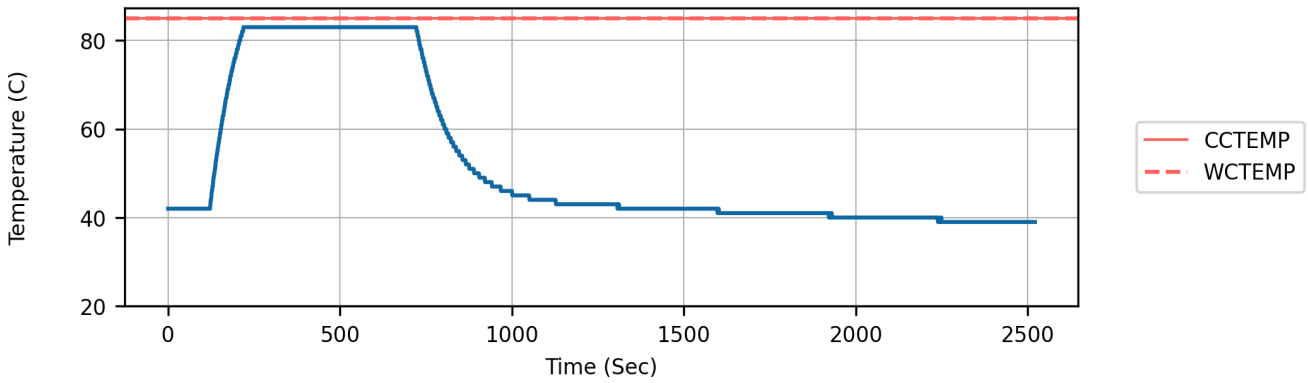
IO Write Bandwidth (Excluding Idle)



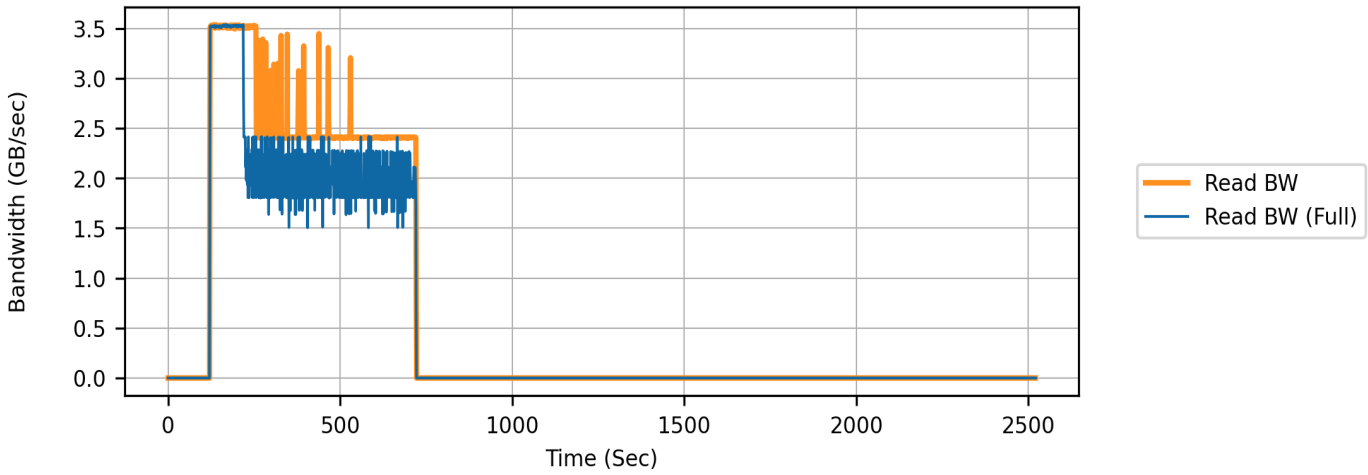
SEQUENTIAL READS

These plots are for reads using sequential addressing, block size of 128 KiB, and queue depth of 32.

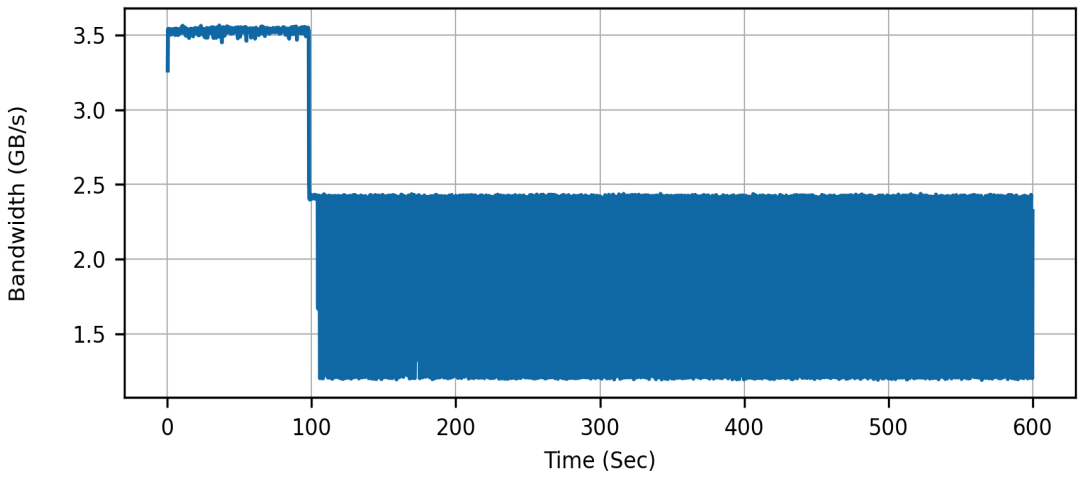
Temperature (Including Idle)



IO Read Bandwidth (Including Idle)



IO Read Bandwidth (Excluding Idle)



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Get or create small file without verification headers.

Step 3: Full drive : PASS

Verify the drive is full.

REQUIREMENT	VALUE	RESULT
Disk free space must be less than 10%	4.2%	PASS

Step 4: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.5 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 5: Random write : PASS

Start reading NVMe information for random write, size=4096, depth=1

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur running IO	0	PASS
Long burst end temperature shall be within 5C of start temperature	2C	PASS

Step 6: Random read : PASS

Start reading NVMe information for random read, size=4096, depth=1

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS

Error count shall not increase	0	PASS
No errors shall occur running IO	0	PASS
Long burst end temperature shall be within 5C of start temperature	2C	PASS

Step 7: Sequential write : PASS

Start reading NVMe information for sequential write, size=131072, depth=32

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur running IO	0	PASS
Long burst end temperature shall be within 5C of start temperature	2C	PASS

Step 8: Sequential read : PASS

Start reading NVMe information for sequential read, size=131072, depth=32

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur running IO	0	PASS
Long burst end temperature shall be within 5C of start temperature	3C	PASS

Step 9: Verify performance : FAIL

Verify long burst performance.

REQUIREMENT	VALUE	RESULT
Long burst, random reads, 4KiB, QD1 bandwidth shall be greater than 0.01 GB/s	0.042 GB/s	PASS
Long burst, random writes, 4KiB, QD1 bandwidth shall be greater than 0.1 GB/s	0.099 GB/s	FAIL
Long burst, sequential reads, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	2.261 GB/s	PASS
Long burst, sequential writes, 128KiB, QD32 bandwidth shall be greater than 1.0 GB/s	1.726 GB/s	PASS
IO bandwidth behaved as expected across queue depth, block size, address type	REVIEW	FAIL

Step 10: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS

Media in read-only shall be No	No	**PASS**
Volatile memory backup fail shall be No	No	**PASS**
Media and integrity errors shall be 0	0	**PASS**
Error count shall not increase	0	**PASS**
Static parameters, such as Model Number, shall not change	0	**PASS**
SMART counters, such as Data Written, shall not decrement	0	**PASS**

TEST 22: HIGH BANDWIDTH STRESS

VERIFICATIONS	23	
PASS	23	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 04, 2023 - 09:51:05.115	Mar 04, 2023 - 09:57:17.091	0:06:11.976

DESCRIPTION

This test verifies drive reliability running high bandwidth IO stress. High bandwidth stress maximizes the amount of data during reads and writes to stress specific drive subsystems. The high bandwidth is achieved with a 50/50 mix of sequential reads and writes, block size of 128 KiB, and queue depth of 32.

Drive reliability is defined as completing all reads and writes without error or data corruption. Data verification is performed on all reads and writes to ensure no data corruption.

RESULTS

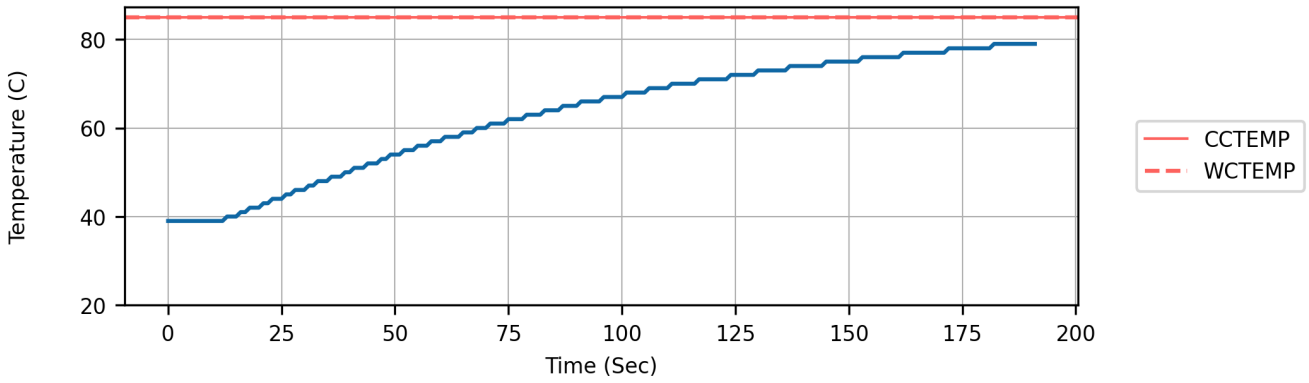
Verify the temperatures and thermal throttling time, if any, in this table are within the expected range.

STRESS TIME	THROTTLE TIME	MIN TEMP	MAX TEMP
3.00 min	0 sec	39 C	79 C

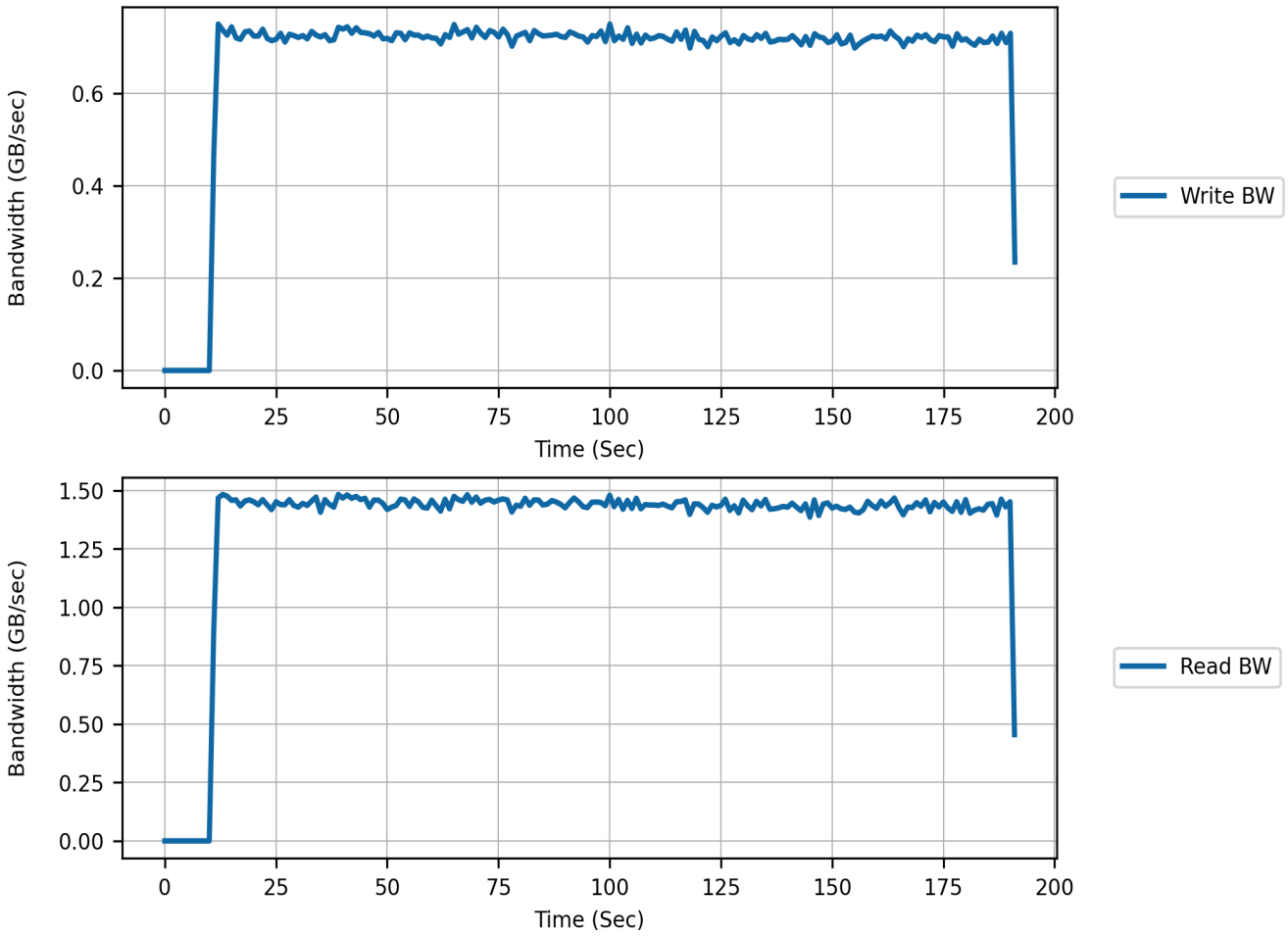
Verify the aggregate bandwidth is within expected range.

DATA WRITTEN	WRITE BANDWIDTH	DATA READ	READ BANDWIDTH
130.0 GB	0.730 GB/s	259.4 GB	1.441 GB/s

This temperature plot includes idle time before and after the IO stress. In this plot, verify the temperature behaves as expected. For details see Analyze temperature and bandwidth plots with nvmecmd [5]



The plots below shows the read and write bandwidth during the test including the idle time before and after the IO stress. In these plots, verify the bandwidth behaves as expected. For details see Analyze temperature and bandwidth plots with nvmecmd [5]



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Use big file if exists, else get or create a small file.

Step 3: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT

Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.5 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 4: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 5: IO stress : PASS

Run high bandwidth IO stress with fio

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 6: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 7: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 23: HIGH IOPS STRESS

VERIFICATIONS	23	
PASS	23	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 04, 2023 - 09:57:17.091	Mar 04, 2023 - 10:03:29.163	0:06:12.072

DESCRIPTION

This test verifies drive reliability running high IOPS IO stress. The high IOPS maximizes the amount of IOs to stress specific drive subsystems. The high IOPS is achieved with a 50/50 mix of random reads and writes, block size of 4 KiB, and queue depth of 8.

Drive reliability is defined as completing all reads and writes without error or data corruption. Data verification is performed on all reads and writes to ensure no data corruption.

RESULTS

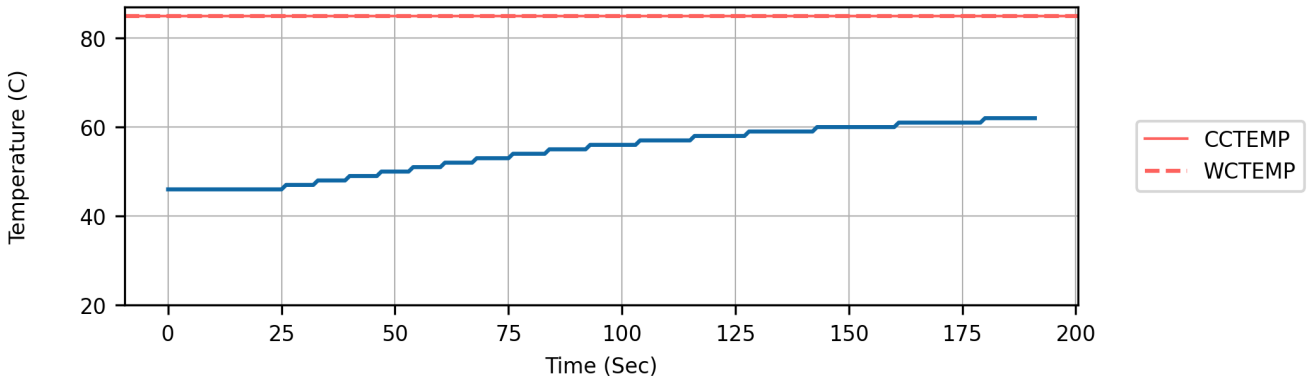
Verify the temperatures and thermal throttling time, if any, in this table are within the expected range.

STRESS TIME	THROTTLE TIME	MIN TEMP	MAX TEMP
180 sec	0 sec	46 C	62 C

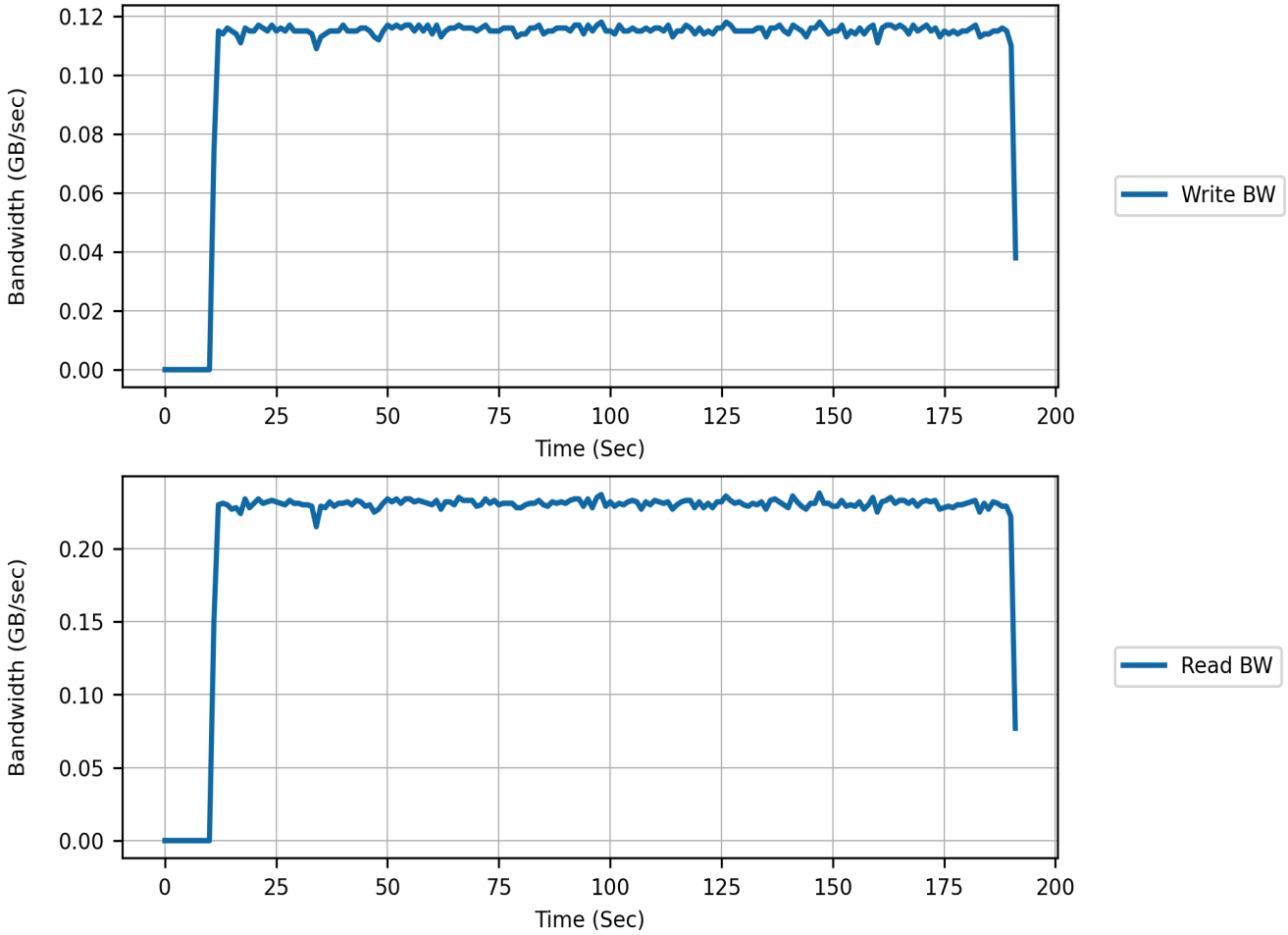
This table lists the amount of IOs during the IO stress.

DATA WRITTEN	WRITE IOPS	DATA READ	READ IOPS
20.8 GB	28.1 K	41.5 GB	56.3 K

This temperature plot includes idle time before and after the IO stress. Review the plot and verify the temperature behaves as expected. For details see Analyze temperature and bandwidth plots with nvmecmd [5]



The plots below shows the read and write bandwidth during the test including the idle time before and after the IO stress. Review the plots and verify the bandwidth behaves as expected. For details see Analyze temperature and bandwidth plots with nvmecmd [5].



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Use big file if exists, else get or create a small file.

Step 3: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.4 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.6 mS	PASS

Step 4: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 5: IO stress : PASS

Run high IOPS stress with fio

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 6: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 7: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 24: BURST STRESS

VERIFICATIONS	23	
PASS	23	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 04, 2023 - 10:03:29.178	Mar 04, 2023 - 10:12:26.223	0:08:57.045

DESCRIPTION

This test verifies drive reliability running short bursts of IO stress. The short bursts of reads and writes are followed by an idle period. This stresses the power management subsystem by constantly transitioning power states. A variety of burst lengths, idle times, queue depths, and block sizes are run with a 50/50 mix of reads and writes.

Drive reliability is defined as completing all reads and writes without error or data corruption. Data verification is performed on all reads and writes to ensure no data corruption.

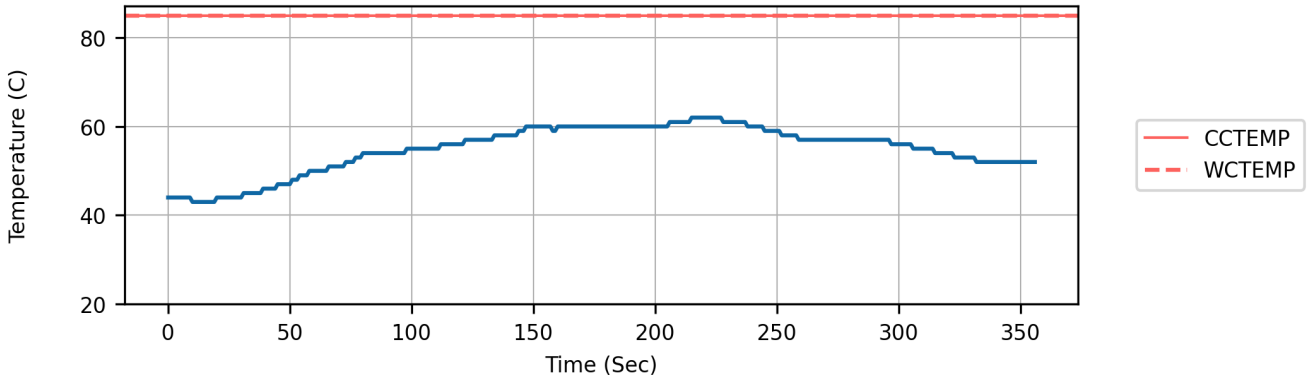
RESULTS

The below bursts were completed. Each burst runs 5 seconds and consists of an idle time followed by read/write of size blocks.

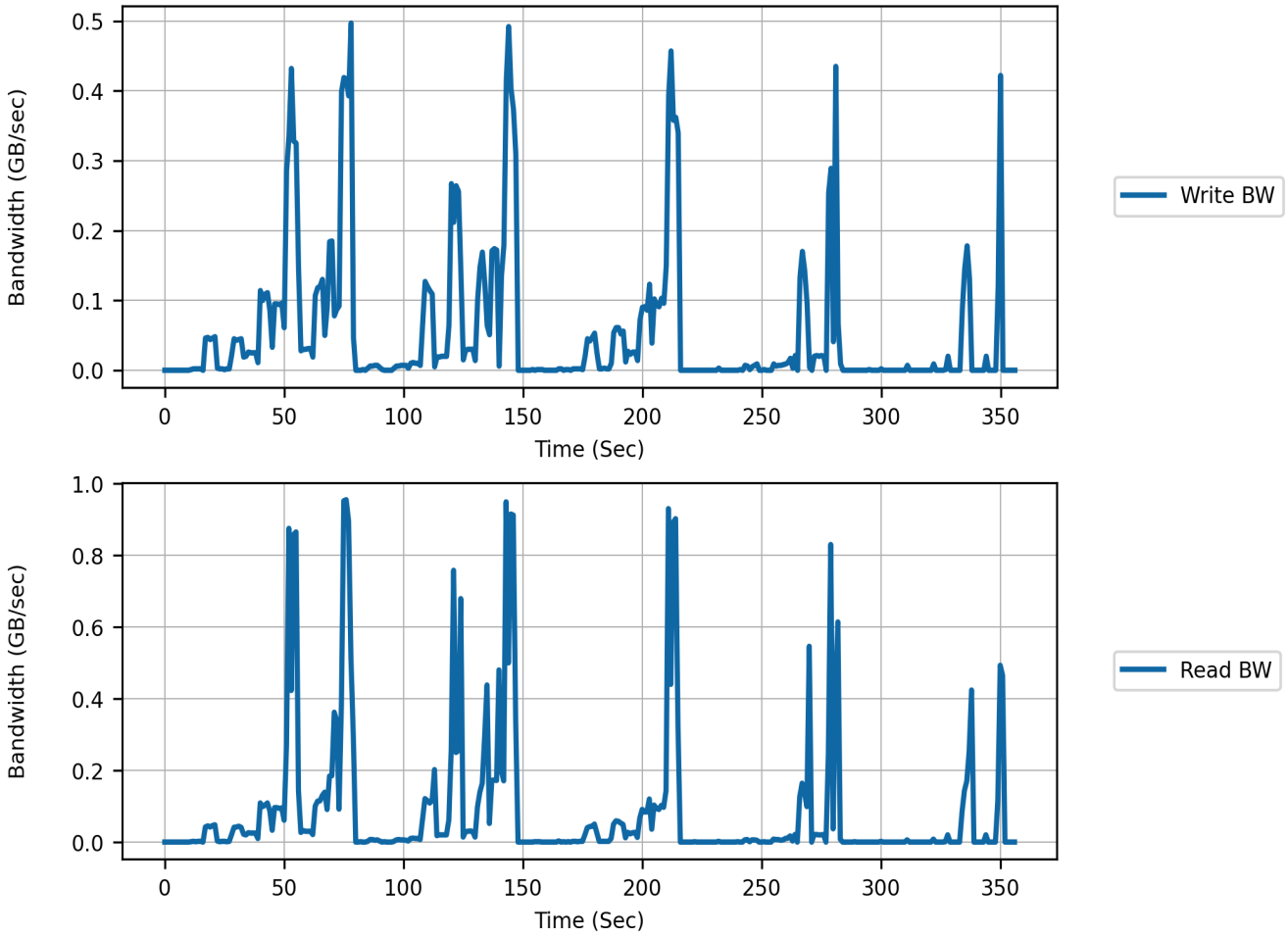
BURST	IDLE TIME	DEPTH	# BLOCKS	BLOCK SIZE
0	1000 mS	1	[1, 100, 10000]	4096
1	1000 mS	1	[1, 100, 10000]	131072
2	1000 mS	32	[1, 100, 10000]	4096
3	1000 mS	32	[1, 100, 10000]	131072
4	1000 mS	1	[1, 100, 10000]	4096
5	1000 mS	1	[1, 100, 10000]	131072
6	1000 mS	32	[1, 100, 10000]	4096
7	1000 mS	32	[1, 100, 10000]	131072
8	1000 mS	1	[1, 100, 10000]	4096
9	1000 mS	1	[1, 100, 10000]	131072
10	1000 mS	32	[1, 100, 10000]	4096
11	1000 mS	32	[1, 100, 10000]	131072
12	10000 mS	1	[1, 100, 10000]	4096
13	10000 mS	1	[1, 100, 10000]	131072
14	10000 mS	32	[1, 100, 10000]	4096
15	10000 mS	32	[1, 100, 10000]	131072
16	10000 mS	1	[1, 100, 10000]	4096
17	10000 mS	1	[1, 100, 10000]	131072
18	10000 mS	32	[1, 100, 10000]	4096
19	10000 mS	32	[1, 100, 10000]	131072

20	10000 mS	1	[1, 100, 10000]	4096
21	10000 mS	1	[1, 100, 10000]	131072
22	10000 mS	32	[1, 100, 10000]	4096
23	10000 mS	32	[1, 100, 10000]	131072
24	100000 mS	1	[1, 100, 10000]	4096
25	100000 mS	1	[1, 100, 10000]	131072
26	100000 mS	32	[1, 100, 10000]	4096
27	100000 mS	32	[1, 100, 10000]	131072
28	100000 mS	1	[1, 100, 10000]	4096
29	100000 mS	1	[1, 100, 10000]	131072
30	100000 mS	32	[1, 100, 10000]	4096
31	100000 mS	32	[1, 100, 10000]	131072
32	100000 mS	1	[1, 100, 10000]	4096
33	100000 mS	1	[1, 100, 10000]	131072
34	100000 mS	32	[1, 100, 10000]	4096
35	100000 mS	32	[1, 100, 10000]	131072
36	1000000 mS	1	[1, 100, 10000]	4096
37	1000000 mS	1	[1, 100, 10000]	131072
38	1000000 mS	32	[1, 100, 10000]	4096
39	1000000 mS	32	[1, 100, 10000]	131072
40	1000000 mS	1	[1, 100, 10000]	4096
41	1000000 mS	1	[1, 100, 10000]	131072
42	1000000 mS	32	[1, 100, 10000]	4096
43	1000000 mS	32	[1, 100, 10000]	131072
44	1000000 mS	1	[1, 100, 10000]	4096
45	1000000 mS	1	[1, 100, 10000]	131072
46	1000000 mS	32	[1, 100, 10000]	4096
47	1000000 mS	32	[1, 100, 10000]	131072
48	5000000 mS	1	[1, 100, 10000]	4096
49	5000000 mS	1	[1, 100, 10000]	131072
50	5000000 mS	32	[1, 100, 10000]	4096
51	5000000 mS	32	[1, 100, 10000]	131072
52	5000000 mS	1	[1, 100, 10000]	4096
53	5000000 mS	1	[1, 100, 10000]	131072
54	5000000 mS	32	[1, 100, 10000]	4096
55	5000000 mS	32	[1, 100, 10000]	131072
56	5000000 mS	1	[1, 100, 10000]	4096
57	5000000 mS	1	[1, 100, 10000]	131072
58	5000000 mS	32	[1, 100, 10000]	4096
59	5000000 mS	32	[1, 100, 10000]	131072

This temperature plot includes a 10 second idle time before and after the IO stress. Review the plot and verify the temperature behaves as expected. For details see Analyze temperature and bandwidth plots with nvmecmd [5]



The plots below shows the read and write bandwidth during the test including the idle time before and after the IO stress. Review the plots and verify the bandwidth behaves as expected. For details see Analyze temperature and bandwidth plots with nvmecmd [5]



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Use big file if exists, else get or create a small file.

Step 3: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.4 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.6 mS	PASS

Step 4: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 5: IO stress : PASS

Run bursts of IO stress with fio

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 6: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 7: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 25: TEMPERATURE CYCLE STRESS

PASS

VERIFICATIONS	25	
PASS	25	100.0%
FAIL	0	0.0%

STARTED	ENDED	DURATION
Mar 04, 2023 - 10:12:26.239	Mar 04, 2023 - 10:27:39.266	0:15:13.027

DESCRIPTION

This test runs IO stress that alternates between periods of high bandwidth reads and idle. This pattern causes the drive's composite temperature to alternate between low and high temperatures. The drive heats up during the IO reads and cools down during the idle time. The thermal expansion and contraction exerts mechanical stress on the drive.

The IO stress is 100% reads with queue depth 32 and block size 128 KiB.

This test is not meant to replace standard component qualification tests such as JESD22-A104 or system environmental tests such as 4-corners.

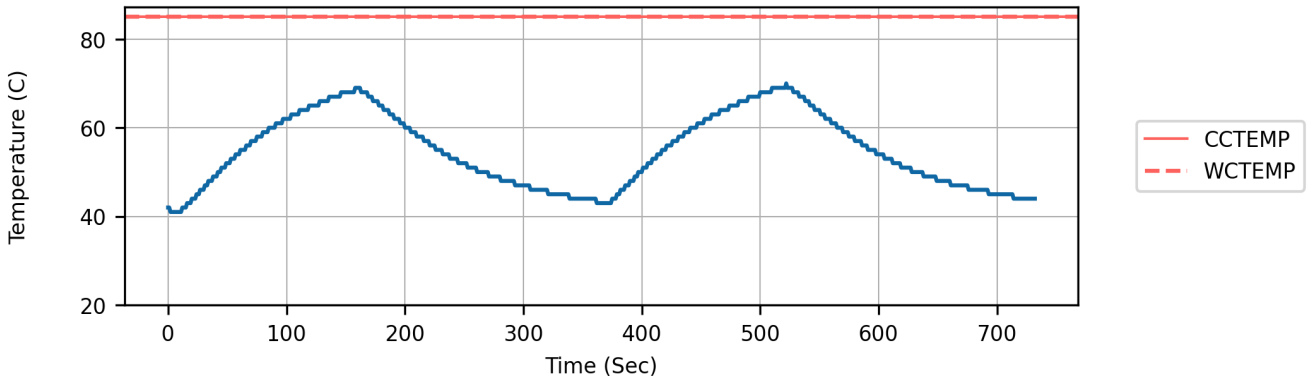
RESULTS

In this table, the Stress Time and Idle Time are for each cycle but the minimum and maximum temperatures are for all cycles.

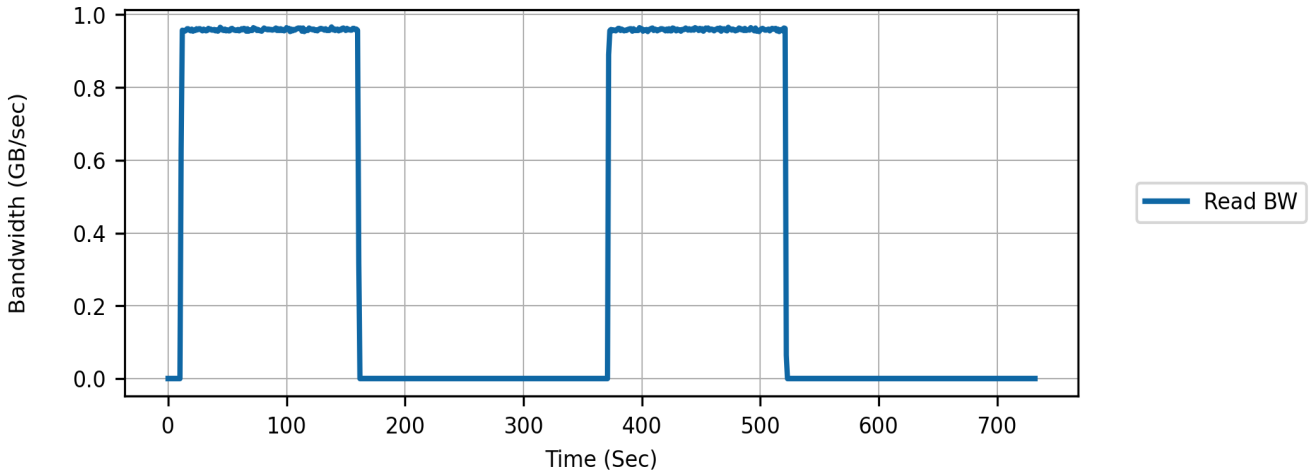
STRESS TIME	IDLE TIME	NUMBER CYCLES	MIN TEMP	MAX TEMP
150 sec	210 sec	2	41 C	70 C

Temperature and IO Bandwidth

Review this temperature plot to verify the temperature behaves as expected. For details see Analyze temperature and bandwidth plots with nvmecmd [5]



Review this bandwidth plot to verify the read bandwidth behaves as expected. For details see Analyze temperature and bandwidth plots with nvmecmd [5].



VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Test start info : PASS

Read test start info and verify drive not in error state.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Step 2: Get fio file : PASS

Use big file if exists, else get or create a small file.

Step 3: Idle wait : PASS

Wait for idle temperature and garbage collection

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Admin Command average latency shall be less than 50 mS	7.5 mS	PASS
Admin Command maximum latency shall be less than 500 mS	8.7 mS	PASS

Step 4: Sample info : PASS

Start sampling SMART and power state info every 1.0 seconds.

Step 5: IO stress : PASS

Run bursts of IO reads to cycle temperature

REQUIREMENT	VALUE	RESULT
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS
No errors shall occur running IO	0	PASS
No data corruption shall occur running IO	0	PASS

Step 6: Verify samples : PASS

Stop sampling and verify no sample errors

REQUIREMENT	VALUE	RESULT
SMART counters, such as Data Written, shall not decrement	0	PASS
Error count shall not increase	0	PASS
No errors shall occur reading information samples	PASS	PASS

Step 7: Test end info : PASS

Read test end info and verify no errors or unexpected changes occurred during test.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS
Error count shall not increase	0	PASS
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS

TEST 26: SUITE END INFO

VERIFICATIONS	14	
PASS	13	92.9%
FAIL	1	7.1%

STARTED	ENDED	DURATION
Mar 04, 2023 - 10:27:39.281	Mar 04, 2023 - 10:27:39.646	0:00:00.365

DESCRIPTION

This test reads the NVMe drive information at the end of the test suite and verifies the drive is healthy, not worn out, and no unexpected changes occurred during the test suite.

The test verifies the following unexpected changes do not occur. Static parameters, such as Model and Serial Number, must not change. SMART counters, such as Power-On Hours, must not decrement. Error parameters, such as media and data integrity errors, must not increase. The change in Power On Hours must match the host computer time change.

For additional details see Read and compare NVMe information with nvmecmd [4].

RESULTS

The host reported a time difference of 12:45:06.736 and the change in Power On Hours was 6 .

A total of 268 static parameters were verified with 2 unexpected changes. A total of 24 counter parameters were verified not to decrement.

VERIFICATIONS

This section lists the test steps and requirement verifications.

Step 1: Read info : PASS

Read NVMe information using nvmecmd.

REQUIREMENT	VALUE	RESULT
Admin commands shall pass	Pass	PASS

Step 2: Verify info : PASS

Verify drive is healthy and not worn out.

REQUIREMENT	VALUE	RESULT
Available Spare shall be greater than 10 %	100 %	PASS
NVM Subsystem Unreliable shall be No	No	PASS
Media in read-only shall be No	No	PASS
Volatile memory backup fail shall be No	No	PASS
Media and integrity errors shall be 0	0	PASS

Time operating at or above the critical temperature shall be 0	0 min	PASS
Percent throttled shall be less than 1%	0.0%	PASS
Percentage Used shall be less than 90%	48%	PASS
Prior self-test failures shall be 0	0	PASS

Step 3: Verify changes : FAIL

Verify no unexpected changes from starting info.

REQUIREMENT	VALUE	RESULT
Static parameters, such as Model Number, shall not change	0	PASS
SMART counters, such as Data Written, shall not decrement	0	PASS
Power On Hour change shall be within 1 hour of host time change	6.75 hrs	FAIL
Error count shall not increase	0	PASS

NVME PARAMETERS

TITLE	DESCRIPTION	VALUE
128-bit Host Identifier	Controller support for 128-bit Host Identifier, from CTRATT	Not Supported
Abort Command Limit (ACL)	Maximum number of concurrently executing Abort commands supported by the controller	8
Admin Vendor Specific command handling	Admin Vendor Specific Commands use standard format or vendor specific format, from AVSCC	Not Vendor Specific
Aggregation Threshold (THR)	Feature 08h: Recommended minimum number of completion queue entries to aggregate per interrupt vector before signaling an interrupt to the host	1
Aggregation Time (TIME)	Feature 08h: Recommended maximum time that a controller may delay an interrupt due to interrupt coalescing	No Delay
Arbitration Burst (AB)	Feature 01h: Number of commands that may be executed at one time from a particular Submission Queue as power of 2 (2^n)	2 (2^2=4)
Associated Function Type	Controller associated with SR-IOV virtual function or PCI function type from CMIC	PCI
Asynchronous Event Request Limit (AERL)	Maximum number of concurrently outstanding Asynchronous Event Request commands supported by the controller	4
Atomic Write Unit Normal (AWUN)	Size of write in logical blocks guaranteed to be written atomically across all namespaces with any supported namespace format during normal operation	1024
Atomic Write Unit Power Fail (AWUPF)	Size of write in logical blocks guaranteed to be written atomically across all namespaces with any supported namespace format during a power fail or error condition	1
Autonomous Power State Transition	Autonomous Power State Transition support, from APSTA	Supported
Autonomous Power State Transition Enable (APSTE)	Feature 0Ch: Autonomous power state transitions. Also see APSTA	Disabled
Available Space Below Threshold	Critical Warning: Available spare space has fallen below the threshold	No
Available Spare	Normalized percentage (0 to 100%) of the remaining spare capacity available	100 %
Available Spare Threshold	Available spare threshold indicated as a normalized percentage (0 to 100%)	10 %
Block Erase Sanitize	Controller support for block sanitize, from SANICAP	Not Supported
Commands Supported and Effects Log Page	Controller support for log page attribute Commands Supported and Effects Log Page, from LPA	Supported

Compare NVM Command	Controller support for the Compare NVM command, from ONCS	Supported
Compare and Write Fused Operation	Controller support for the Compare and Write fused operation, from FUSES	Not Supported
Composite Temperature	Current composite temperature of the controller and namespace(s) associated with that controller	36 C
Composite Temperature Over Threshold	Feature 04h: Composite Temperature over threshold limit	85 C
Composite Temperature Under Threshold	Feature 04h: Composite Temperature under threshold limit	-273 C
Controller Busy Time	Time the controller is busy with I/O commands	14,985 Min
Controller ID (CNTLID)	NVM subsystem unique controller identifier associated with the controller	4
Controller Vendor	Controller vendor from PCI lookup: https://pcisig.com/membership/member-companies	Samsung
Critical Composite Temperature Threshold (CCTEMP)	Temperature that indicates a critical overheating condition (e.g. possible data loss, device shutdown, extreme throttling, or permanent damage)	85 C
Critical Composite Temperature Time	Time controller is operational and Composite Temperature is greater than the Critical Composite Temperature Threshold	0 Min
Crypto Erase	Crypto erase supported as part of secure erase, from FNA	Supported
Crypto Erase Sanitize	Controller support for crypto sanitize, from SANICAP	Not Supported
Current Number Of Self-Tests	Current number of self tests reported in log page 6	20
Current Power State (PS)	Feature 02h: Current power state of the controller	0
Current Self-Test Completion	Percentage of the device self-test operation that is complete	0
Current Self-Test Operation	Status of the current device self-test operation	No Test In Progress
Data Read	Data Read in GB calculated from Data Units Read	559,672.625 GB
Data Units Read	Number of 512,000 byte data units read from the controller; does not include metadata	1,093,110,596
Data Units Written	Number of 512,000 byte data units written to the controller; does not include metadata	514,855,885
Data Written	Data Written in GB calculated from Data Units Written	263,606.213 GB
Data Written TB	Data Written in TB calculated from Data Units Written	263.6 TB
Dataset Management NVM Command	Controller support for the Dataset Management NVM command, from ONCS	Supported

Deallocated or Unwritten Logical Block Error Enable (DULBE)	Feature 05h: Deallocated or Unwritten Logical Block error enabled for the namespace	Disabled
Device Self-test Command	Controller support for Device Self-test Command, from OACS	Supported
Directive Send and Directive Receive Commands	Controller support for Directive Send and Directive Receive Commands, from OACS	Not Supported
Disable Normal (DN)	Feature 0Ah: Host specifies AWUN and NAWUN are not required and controller shall only honor AWUPF and NAWUPF	Not Supported
Doorbell Buffer Config Command	Controller support for Doorbell Buffer Config Command, from OACS	Not Supported
Driver	OS driver information	Microsoft, 10.0.22621.755, 6/20/2006, stornvme.inf
Error Log Page Entries (ELPE)	Maximum number of Error Information log entries stored by the controller	64
Extended Data for Get Log Page	Controller support for log page attribute Extended Data for Get Log Page, from LPA	Not Supported
Extended Device Self-test Time (EDSTT)	Nominal time in minutes to complete extended device self-test when in power state 0	35 Min
FRU Globally Unique Identifier (FGUID)	Globally unique identifier for the Field Replaceable Unit (FRU)	000000-00000000000000000000000000
Firmware Activation Notices	Controller support for asynchronous events Firmware Activation Notices, from OAES	Not Supported
Firmware Activation Without Reset	Controller support for firmware activation without a reset, from FRMW	Supported
Firmware Active Slot	Firmware slot that loaded the active firmware, from AFI	1
Firmware Commit and Image Download Commands	Controller support for Firmware Commit and Image Download Commands, from OACS	Supported
Firmware Pending Slot	Firmware slot to be activated at the next controller reset, from AFI	Not Reported
Firmware Revision (FR)	Currently active firmware revision	2B2QEXM7
Firmware Slot 1 Read Status	Firmware slot 1 read only or read/write, from FRMW	Read/Write
Firmware Slot 1 Revision	Revision of firmware in this slot, see Firmware Revision for Slot # (FRS#)	2B2QEXM7
Firmware Slot 2 Revision	Revision of firmware in this slot, see Firmware Revision for Slot # (FRS#)	

Firmware Slot 3 Revision	Revision of firmware in this slot, see Firmware Revision for Slot # (FRS#)	
Firmware Slots	Number of firmware slots supported by controller, from FRMW	3
Firmware Update Granularity (FWUG)	Minimum granularity and alignment of the data provided in the Firmware Image Download command	Not Reported
Format All Namespaces	Format (excluding secure erase) applies to all namespaces in an NVM subsystem, from FNA	Supported
Format NVM Command	Controller support for Format NVM Command, from OACS	Supported
High Priority Weight (HPW)	Feature 01h: Number of commands that may be executed from the high priority service class in each arbitration round	1
Highest Version Detected	Highest NVMe version detected based on supported features	1.3.0
Host Controlled Thermal Management (HCTMA)	Controller support for host controlled thermal management	Supported
Host Memory Buffer Minimum Size (HMMIN)	Minimum size that the host is requested to allocate for the Host Memory Buffer feature in 4KiB units	Not Supported
Host Memory Buffer Preferred Size (HMPRE)	Preferred size that the host is requested to allocate for the Host Memory Buffer feature in 4KiB units	Not Supported
Host Power Source	Current host power source, battery or AC	AC
Host Read Commands	Number of read commands completed by the controller	15,324,862,955
Host Timestamp	Host number of milliseconds since midnight, 01-Jan-1970, UTC	1,677,908,552,850 mS
Host Timestamp Decoded	Host date and time	2023-03-03 21:42:32.850
Host Write Commands	Number of write commands completed by the controller	10,380,832,046
IEEE OUI Identifier (IEEE)	Organization Unique Identifier (OUI) for the controller vendor: http://standards-oui.ieee.org/oui/oui.txt	00-25-38
Keep Alive Support (KAS)	Granularity of the Keep Alive Timer	Not Supported
Low Priority Weight (LPW)	Feature 01h: Number of commands that may be executed from the low priority service class in each arbitration round	1
Maximum Completion Queue Entry Size	Maximum Completion Queue entry size when using the NVM Command Set in bytes reported as a power of two (2^n), from CQES	4 (2^4=16)
Maximum Data Transfer Size (MDTS)	Maximum data transfer size between host and controller in units of minimum memory page size as a power of two (2^n)	9 (2^9=512)

Maximum Outstanding Commands (MAXCMD)	Maximum number of commands that the controller processes at one time for a particular queue	Not Supported
Maximum Submission Queue Entry Size	Maximum Submission Queue entry size when using the NVM Command Set in bytes reported as a power of two (2^n), from SQES	6 (2^6=64)
Maximum Thermal Management Temperature (MXTMT)	Maximum temperature host may request in the Thermal Management Temperature 1 and 2 fields of Set Features command	85 C
Maximum Time for Firmware Activation (MTFA)	Maximum time the controller temporarily stops processing commands to activate the firmware image	Undefined
Media and Data Integrity Errors	Number of occurrences where the controller detected an unrecovered data integrity error	0
Media in Read-only	Critical Warning: Media has been placed in read only mode	No
Medium Priority Weight (MPW)	Feature 01h: Number of commands that may be executed from the medium priority service class in each arbitration round	1
Minimum Thermal Management Temperature (MNTMT)	Minimum temperature host may request in the Thermal Management Temperature 1 and 2 fields of Set Features command	83 C
Minutes Throttled	Number of minutes operating above the lowest temperature throttle limit	0.0 Min
Model	Model number with whitespace trimmed	Samsung SSD 970 EVO Plus 250GB
Model No Spaces	Model number trimmed and spaces replaced	Samsung_SSD_970_EVO_Plus_250GB
Model Number (MN)	Model number for the NVM subsystem assigned by the vendor	Samsung SSD 970 EVO Plus 250GB
NVM Subsystem Controllers	Single or multiple controllers contained in NVM subsystem from CMIC	Single
NVM Subsystem NVMe Qualified Name (SUBNQN)	The NVM Subsystem NVMe Qualified Name	
NVM Subsystem PCIe Ports	Single or multiple PCIE ports contained in NVM subsystem from CMIC	Single
NVM Subsystem Unreliable	Critical Warning: Reliability degraded due to significant media or internal errors	No
NVME MI Send/Receive Commands	Controller support for NVME MI Send/Receive Commands, from OACS	Not Supported
Namespace 1 Active LBA Format	Index of LBA format that namespace is formatted with, from FLBAS	0

Namespace 1 Atomic Boundary Offset (NABO)	The LBA on this namespace where the first atomic boundary starts	0
Namespace 1 Atomic Boundary Size Normal (NABSN)	Atomic boundary size in logical blocks for this namespace for the NAWUN value	No boundaries
Namespace 1 Atomic Boundary Size Power Fail (NABSPF)	Atomic boundary size for this namespace specific to the Namespace Atomic Write Unit Power Fail value	No boundaries
Namespace 1 Atomic Compare & Write Unit (NACWU)	Namespace specific size of the write operation in logical blocks guaranteed to be written atomically for a Compare and Write fused command	Same as ACWU
Namespace 1 Atomic Write Unit Normal (NAWUN)	Namespace specific size of the write operation in logical blocks guaranteed to be written atomically during normal operation	Same as AWUN
Namespace 1 Atomic Write Unit Power Fail (NAWUPF)	Namespace specific size of the write operation in logical blocks guaranteed to be written atomically during a power fail or error condition	Same as AWUPF
Namespace 1 Atomic Writes	If supported NAWUN, NAWUPF, and NACWU used instead of AWUN, AWUPF, and ACWU fields, from NSFEAT	Not Supported
Namespace 1 Capacity (NCAP)	The maximum number of logical blocks that may be allocated in the namespace	488,397,168
Namespace 1 Deallocate Bit in Write Zeros	Controller support for the Deallocate bit in the Write Zeros command for this namespace, from DLFEAT	Not Supported
Namespace 1 Deallocate Guard Field	Guard field for deallocated logical blocks that contain protection information is set to the CRC for the value read from the deallocated logical block, from DLFEAT	Not Supported
Namespace 1 Deallocate Logical Block Value	Values read from a deallocated logical block and its metadata, from DLFEAT	Not Reported
Namespace 1 Exclusive Access All Registrants Reservation	Namespace supports the Exclusive Access - All Registrants reservation type, from RESCAP	Not Supported
Namespace 1 Exclusive Access Registrants Only Reservation	Namespace supports the Exclusive Access - Registrants Only reservation type, from RESCAP	Not Supported
Namespace 1 Exclusive Access Reservation	Namespace supports the Exclusive Access reservation type, from RESCAP	Not Supported
Namespace 1 Extended Data LBA	If supported metadata is transferred at the end of the data LBA, creating an extended data LBA, from FLBAS	Not Supported

Namespace 1 Format Percent Complete	Percentage of the Format NVM command that remains to be completed, from FPI	0
Namespace 1 Format Progress Indicator	Namespace supports the Format Progress Indicator, from FPI	Supported
Namespace 1 Globally Unique Identifier (NGUID)	128-bit value that is globally unique and assigned to the namespace	00000000000000000-000000-00000000
Namespace 1 IEEE Extended Unique Identifier (EUI64)	64-bit IEEE Extended Unique Identifier (EUI-64) that is globally unique and assigned to the namespace	002538-570140ad8d
Namespace 1 Ignore Existing Key Specification	Ignore Existing Key is used as defined in revision 1.2.1 or 1.3+ of NVMe specification, from RESCAP	1.2.1 or earlier
Namespace 1 LBA 0 Data Size (LBADS)	LBA data size in power of two (2^n)	9 (2^9=512) *
Namespace 1 LBA 0 Relative Performance (RP)	Relative performance of this LBA format relative to other LBA formats	Best Performance *
Namespace 1 Logical Block Error	Controller support for the Deallocated or Unwritten Logical Block error for this namespace, from NSFEAT	Not Supported
Namespace 1 Metadata Transfer Buffer	Metadata transferred as part of a separate buffer that is specified in the Metadata Pointer, from MC	Not Supported
Namespace 1 Metadata Transfer Extended LBA	Metadata being transferred as part of an extended data LBA, from MC	Not Supported
Namespace 1 NGUID/EUID Not Reused	If supported non-zero NGUID and EUI64 fields for this namespace are never reused by the controller, from NSFEAT	Not Supported
Namespace 1 NVM Capacity (NVMCAP)	Total size of the NVM allocated to this namespace in bytes	250,059,350,016
Namespace 1 Number of LBA Formats (NLBAF)	Number of supported LBA data size and metadata size combinations supported by the namespace	1
Namespace 1 Optimal IO Boundary (NOIOB)	Optimal IO boundary in logical blocks for this namespace	Not Reported
Namespace 1 Persist Through Power Loss	Namespace supports the Persist Through Power Loss capability, from RESCAP	Not Supported
Namespace 1 Protection First	Namespace supports protection information transferred as first eight bytes of metadata, from DPC	Not Supported

Namespace 1 Protection Information Enabled	Type of Protection Information enabled, if any, from DPS	Disabled
Namespace 1 Protection Information First	Protection information, if enabled, is transferred as the first eight bytes of metadata, from DPS	Last 8 Bytes
Namespace 1 Protection Last	Namespace supports protection information transferred as the last eight bytes of metadata, from DPC	Not Supported
Namespace 1 Protection Type 1	Namespace supports Protection Information Type 1, from DPC	Not Supported
Namespace 1 Protection Type 2	Namespace supports Protection Information Type 2, from DPC	Not Supported
Namespace 1 Protection Type 3	Namespace supports Protection Information Type 3, from DPC	Not Supported
Namespace 1 Shared	Namespace may be attached to two or more controllers in the NVM subsystem concurrently (i.e., may be a shared namespace), from NMIC	Not Supported
Namespace 1 Size	Total calculated size of the namespace in GB	250 GB
Namespace 1 Size in GiB	Total calculated size of the namespace in GiB (1024*1024*1024)	232.9 GiB
Namespace 1 Size in LBA (NSZE)	Total size of this namespace in logical blocks	488,397,168
Namespace 1 Thin Provisioning	If supported the Namespace Capacity reported may be less than the Namespace Size, from NSFEAT	Not Supported
Namespace 1 Utilization (NUSE)	Current number of logical blocks allocated in the namespace	4,394,240
Namespace 1 Write Exclusive All Registrants Reservation	Namespace supports the Write Exclusive - All Registrants reservation type, from RESCAP	Not Supported
Namespace 1 Write Exclusive Registrants Only Reservation	Namespace supports the Write Exclusive - Registrants Only reservation type, from RESCAP	Not Supported
Namespace 1 Write Exclusive Reservation	Namespace supports the Write Exclusive reservation type, from RESCAP	Not Supported
Namespace Attribute Notices	Controller support for asynchronous events Namespace Activation Notices, from OAES	Not Supported
Namespace Management and Attachment Commands	Controller support for Namespace Management and Attachment Commands, from OACS	Not Supported
Non-Operational Power State Permissive Mode	Controller support for temporary exceeding power in non-operational power state for background operation, from CTRATT	Not Supported

Number Of Failed Self-Tests	Number of self tests that failed in log page 6	0
Number of Error Information Log Entries	Number of Error Information log entries over the life of the controller	1,235
Number of Namespaces (NN)	Number of valid namespaces present for the controller	1
Number of Power States Support (NPSS)	Number of NVM Express power states supported by the controller	5
OS Location	Drive location reported by the Operating System	\\.\PHYSICALDRIVE2
One Self-Test	Support for one device self-test at a time per system or per controller, from DSTO	Per Controller
Overwrite Sanitize	Controller support for overwrite sanitize, from SANICAP	Not Supported
PCI Bandwidth	Bandwidth in GT/s, product of speed and width	32.0 GT/s
PCI Device ID	PCI device identifier assigned for the device	0xA808
PCI Location	PCI bus address in the system	Bus 2, device 0, function 0
PCI Rated Bandwidth	Bandwidth in GT/s device is rated for, product of speed and width	32.0 GT/s
PCI Rated Speed	Maximum PCI bus speed the device is rated for	Gen3 8.0GT/s
PCI Rated Width	Maximum PCI bus width the device is rated for	x4
PCI Speed	Current PCI bus speed	Gen3 8.0GT/s
PCI Subsystem Vendor ID (SSVID)	Company vendor identifier assigned by PCI SIG for the subsystem	0x144D
PCI Vendor ID (VID)	Company vendor identifier assigned by PCI SIG for the controller	0x144D
PCI Width	Current PCI bus width in lanes	x4
PCIe Management Endpoint (PCIEME)	NVME MI: NVM Subsystem contains a Management Endpoint on a PCIe port	Not Supported
Percent Throttled	Total time throttled as a percent of Power On Hours	0.0 %
Percentage Used	Vendor specific estimate of the percentage life used, can exceed 100%	48 %
Persistent Event Log	Controller support for log page attribute Persistent Event Log, from LPA	Not Supported
Power Cycles	Number of power cycles	273
Power On Hours	Number of power on hours	754
Power State 0 Active Power (ACTP)	Largest average power over 10 seconds in this power state with workload from Active Power Workload (APW)	Not Reported
Power State 0 Active Power Workload (APW)	Workload used to calculate maximum power for the active power state	No workload

Power State 0 Entry Latency (ENLAT)	Maximum entry latency in microseconds associated with entering this power state	Not Reported
Power State 0 Exit Latency (EXLAT)	Maximum exit latency in microseconds associated with exiting this power state	Not Reported
Power State 0 Idle Power (IDLP)	Typical power consumed over 30 seconds in this power state when idle	Not Reported
Power State 0 Idle Time Prior to Transition (ITPT)	Feature 0Ch: Idle time that occurs in this power state prior to transitioning to the Idle Transition Power State in milliseconds	60 mS
Power State 0 Idle Transition Power State (ITPS)	Feature 0Ch: Power state to autonomously transition to after exceeding Idle Time Prior to Transition (ITPT)	3
Power State 0 Maximum Power (MP)	Maximum power consumed in this power state	7.8 Watts
Power State 0 Non-Operational State (NOPS)	Controller does not process I/O commands in a Non-Operational State	False
Power State 0 Relative Read Latency (RRL)	Relative read latency associated with this power state	0
Power State 0 Relative Read Throughput (RRT)	Relative read throughput associated with this power state	0
Power State 0 Relative Write Latency (RWL)	Relative write latency associated with this power state	0
Power State 0 Relative Write Throughput (RWT)	Relative write throughput associated with this power state	0
Power State 1 Active Power (ACTP)	Largest average power over 10 seconds in this power state with workload from Active Power Workload (APW)	Not Reported
Power State 1 Active Power Workload (APW)	Workload used to calculate maximum power for the active power state	No workload
Power State 1 Entry Latency (ENLAT)	Maximum entry latency in microseconds associated with entering this power state	Not Reported
Power State 1 Exit Latency (EXLAT)	Maximum exit latency in microseconds associated with exiting this power state	Not Reported
Power State 1 Idle Power (IDLP)	Typical power consumed over 30 seconds in this power state when idle	Not Reported
Power State 1 Idle Time Prior to Transition (ITPT)	Feature 0Ch: Idle time that occurs in this power state prior to transitioning to the Idle Transition Power State in milliseconds	60 mS

Power State 1 Idle Transition Power State (ITPS)	Feature 0Ch: Power state to autonomously transition to after exceeding Idle Time Prior to Transition (ITPT)	3
Power State 1 Maximum Power (MP)	Maximum power consumed in this power state	6 Watts
Power State 1 Non-Operational State (NOPS)	Controller does not process I/O commands in a Non-Operational State	False
Power State 1 Relative Read Latency (RRL)	Relative read latency associated with this power state	1
Power State 1 Relative Read Throughput (RRT)	Relative read throughput associated with this power state	1
Power State 1 Relative Write Latency (RWL)	Relative write latency associated with this power state	1
Power State 1 Relative Write Throughput (RWT)	Relative write throughput associated with this power state	1
Power State 2 Active Power (ACTP)	Largest average power over 10 seconds in this power state with workload from Active Power Workload (APW)	Not Reported
Power State 2 Active Power Workload (APW)	Workload used to calculate maximum power for the active power state	No workload
Power State 2 Entry Latency (ENLAT)	Maximum entry latency in microseconds associated with entering this power state	Not Reported
Power State 2 Exit Latency (EXLAT)	Maximum exit latency in microseconds associated with exiting this power state	Not Reported
Power State 2 Idle Power (IDLP)	Typical power consumed over 30 seconds in this power state when idle	Not Reported
Power State 2 Idle Time Prior to Transition (ITPT)	Feature 0Ch: Idle time that occurs in this power state prior to transitioning to the Idle Transition Power State in milliseconds	60 mS
Power State 2 Idle Transition Power State (ITPS)	Feature 0Ch: Power state to autonomously transition to after exceeding Idle Time Prior to Transition (ITPT)	3
Power State 2 Maximum Power (MP)	Maximum power consumed in this power state	3.4 Watts
Power State 2 Non-Operational State (NOPS)	Controller does not process I/O commands in a Non-Operational State	False

Power State 2 Relative Read Latency (RRL)	Relative read latency associated with this power state	2
Power State 2 Relative Read Throughput (RRT)	Relative read throughput associated with this power state	2
Power State 2 Relative Write Latency (RWL)	Relative write latency associated with this power state	2
Power State 2 Relative Write Throughput (RWT)	Relative write throughput associated with this power state	2
Power State 3 Active Power (ACTP)	Largest average power over 10 seconds in this power state with workload from Active Power Workload (APW)	Not Reported
Power State 3 Active Power Workload (APW)	Workload used to calculate maximum power for the active power state	No workload
Power State 3 Entry Latency (ENLAT)	Maximum entry latency in microseconds associated with entering this power state	210 uS (0.000 sec)
Power State 3 Exit Latency (EXLAT)	Maximum exit latency in microseconds associated with exiting this power state	1,200 uS (0.001 sec)
Power State 3 Idle Power (IDLP)	Typical power consumed over 30 seconds in this power state when idle	Not Reported
Power State 3 Idle Time Prior to Transition (ITPT)	Feature 0Ch: Idle time that occurs in this power state prior to transitioning to the Idle Transition Power State in milliseconds	9,940 mS
Power State 3 Idle Transition Power State (ITPS)	Feature 0Ch: Power state to autonomously transition to after exceeding Idle Time Prior to Transition (ITPT)	4
Power State 3 Maximum Power (MP)	Maximum power consumed in this power state	0.07 Watts
Power State 3 Non-Operational State (NOPS)	Controller does not process I/O commands in a Non-Operational State	True
Power State 3 Relative Read Latency (RRL)	Relative read latency associated with this power state	3
Power State 3 Relative Read Throughput (RRT)	Relative read throughput associated with this power state	3
Power State 3 Relative Write Latency (RWL)	Relative write latency associated with this power state	3

Power State 3 Relative Write Throughput (RWT)	Relative write throughput associated with this power state	3
Power State 4 Active Power (ACTP)	Largest average power over 10 seconds in this power state with workload from Active Power Workload (APW)	Not Reported
Power State 4 Active Power Workload (APW)	Workload used to calculate maximum power for the active power state	No workload
Power State 4 Entry Latency (ENLAT)	Maximum entry latency in microseconds associated with entering this power state	2,000 uS (0.002 sec)
Power State 4 Exit Latency (EXLAT)	Maximum exit latency in microseconds associated with exiting this power state	8,000 uS (0.008 sec)
Power State 4 Idle Power (IDLP)	Typical power consumed over 30 seconds in this power state when idle	Not Reported
Power State 4 Idle Time Prior to Transition (ITPT)	Feature 0Ch: Idle time that occurs in this power state prior to transitioning to the Idle Transition Power State in milliseconds	Disabled
Power State 4 Maximum Power (MP)	Maximum power consumed in this power state	0.01 Watts
Power State 4 Non-Operational State (NOPS)	Controller does not process I/O commands in a Non-Operational State	True
Power State 4 Relative Read Latency (RRL)	Relative read latency associated with this power state	4
Power State 4 Relative Read Throughput (RRT)	Relative read throughput associated with this power state	4
Power State 4 Relative Write Latency (RWL)	Relative write latency associated with this power state	4
Power State 4 Relative Write Throughput (RWT)	Relative write throughput associated with this power state	4
RTD3 Entry Latency (RTD3E)	Typical latency to enter Runtime D3 in microseconds	8,000,000 uS (8.000 sec)
RTD3 Resume Latency (RTD3R)	Typical latency resuming from Runtime D3 in microseconds	200,000 uS (0.200 sec)
Recommended Arbitration Burst (RAB)	Recommended number of commands that may be executed at one time from a particular Submission Queue as a power of two (2^n)	2 (2^2=4)
Replay Protected Memory Blocks (RPMBS)	Replay Protected Memory Blocks store data to a specific memory area in an authenticated and replay protected manner	Not Supported

Required Completion Queue Entry Size	Required Completion Queue entry size when using the NVM Command Set in bytes reported as a power of two (2^n), from CQES	4 (2^4=16)
Required Submission Queue Entry Size	Required Submission Queue entry size when using the NVM Command Set in bytes reported as a power of two (2^n), from SQES	6 (2^6=64)
Reservations	Controller support for reservations, from ONCS	Not Supported
Root PCI Device ID	PCI device identifier assigned for the root device	0xA32C
Root PCI Location	PCI bus address for the root device	Bus 0, device 27, function 4
Root PCI Vendor ID	PCI vendor identifier assigned for the root device	0x8086
SGL support in NVM command	SGL support for the NVM Command Set	Not Supported
SMART Critical Warning Notices Enable	Feature 0Bh: Asynchronous event notifications sent to host for SMART Critical Warnings	0x1F
SMART/Health Log Page per Namespace	Controller support for log page attribute SMART/Health Log Page per Namespace, from LPA	Supported
SMBus Management Endpoint (SMBUSME)	NVME MI: NVM Subsystem contains a Management Endpoint on an SMBus/I2C port	Not Supported
Save/Select Fields in Features Command	Controller support for Save and Select Fields in Features Command, from ONCS	Supported
Seconds Throttled	Number of seconds operating above the lowest temperature throttle limit	0
Secure Erase All Namespaces	Secure erase applies to all namespaces in an NVM subsystem, from FNA	Not Supported
Security Send and Security Receive Command	Controller support for Security Send and Security Receive Command, from OACS	Supported
Serial Number (SN)	Serial number for the NVM subsystem assigned by the vendor	S59BNS0N708295J
Size	Total calculated size in bytes	250059350016 Bytes
Size in GB	Total calculated size in GB (1000*1000*1000)	250.1 GB
Size in GiB	Total calculated size in GiB (1024*1024*1024)	232.9 GiB
Size in TB	Total calculated size in TB (1000*1000*1000*1000)	0.3 TB
Subsystem Vendor	Subsystem vendor from PCI lookup: https://pcisig.com/membership/member-companies	Samsung
Supported Admin Commands	Number of Admin commands supported in Log Page 5	16
Supported IO Commands	Number of IO commands supported in Log Page 5	7

Telemetry Log Notices	Controller support for log page attribute Telemetry Log Notices, from LPA	Not Supported
Temperature Over/Under Threshold	Critical Warning: A temperature is over or under a temperature threshold	No
Temperature Sensor 1	Current temperature reported by the temperature sensor	36 C
Temperature Sensor 1 Over Threshold	Feature 04h: Temperature Sensor over threshold limit	65,262 C
Temperature Sensor 1 Under Threshold	Feature 04h: Temperature Sensor under threshold limit	-273 C
Temperature Sensor 2	Current temperature reported by the temperature sensor	37 C
Temperature Sensor 2 Over Threshold	Feature 04h: Temperature Sensor over threshold limit	65,262 C
Temperature Sensor 2 Under Threshold	Feature 04h: Temperature Sensor under threshold limit	-273 C
Thermal Management Temperature 1 (TMT1)	Feature 10h: Temperature the controller transitions to lower active power states or other vendor specific actions while minimizing the impact on performance	Disabled
Thermal Management Temperature 1 Count	Number of times the controller transitioned to lower power active power states or performed vendor specific thermal management actions while minimizing the impact on performance	0
Thermal Management Temperature 1 Time	Number of seconds controller had transitioned to lower power active power states or performed vendor specific thermal management actions while minimizing the impact on performance	0 Sec
Thermal Management Temperature 2 (TMT2)	Feature 10h: Temperature the controller transitions to lower active power states or other vendor specific actions regardless of the impact on performance	Disabled
Thermal Management Temperature 2 Count	Number of times the controller transitioned to lower power active power states or performed vendor specific thermal management actions regardless of the impact on performance	0
Thermal Management Temperature 2 Time	Number of seconds controller had transitioned to lower power active power states or performed vendor specific thermal management actions regardless of the impact on performance	0 Sec
Time Limited Error Recovery (TLER)	Feature 05h: Limited retry timeout value	No Timeout
Timestamp	Feature 0Eh: Number of milliseconds since controller reset or host value (midnight, 01-Jan-1970, UTC)	1,677,902,741,943 mS

Timestamp Decoded	Feature 0Eh: Either date or time since controller reset depending on timestamp origin	2023-03-03 20:05:41.943
Timestamp Feature	Controller support for Timestamp in Features Command, from ONCS	Supported
Timestamp Origin	Feature 0Eh: Timestamp is time from controller reset or host programmed value	Host Programmed
Timestamp Stopped	Feature 0Eh: Timestamp may have stopped counting in some conditions (e.g. non-operational power states)	True
Total Errors	Total number of error entries in Log Page 1	7
Unique Description	Unique combination of model, size, and location	NVMe 2 [2:0:0] - Samsung SSD 970 EVO Plus 250GB
Unsafe Shutdowns	Number of unsafe shutdowns	38
Vendor Specific Command Configuration	NVM Vendor Specific Commands use vendor specific or other format defined in NVMe specification, from NVSCC	Not Vendor Specific
Version (VER)	NVMe version: https://nvmexpress.org/developers/nvme-specification/	1.3.0
Virtualization Mgt Command	Controller support for Virtualization Mgt Command, from OACS	Not Supported
Volatile Memory Backup Failed	Critical Warning: Volatile memory backup device, if present, has failed	No
Volatile Write Cache (VWC)	Presence of a volatile write cache, from VWC	Supported
Volatile Write Cache Enable (WCE)	Feature 06h: Volatile write cache enable	Enabled
Warning Composite Temperature Threshold (WCTEMP)	Temperature that indicates an overheating condition where controller operation continues	85 C
Warning Composite Temperature Time	Time controller is operational and Composite Temperature is greater than or equal to Warning Composite Temperature Threshold and less than the Critical Composite Temperature Threshold	0 Min
Windows Power ASPM (AC)	Windows OS Power Setting for PCIe ASPM when host on AC power	Disabled
Windows Power ASPM (DC)	Windows OS Power Setting for PCIe ASPM when host on battery power	Attempt L1
Windows Power NOPPME (AC)	Windows OS power setting for NOPPME when host on AC power	Not Supported
Windows Power NOPPME (DC)	Windows OS power setting for NOPPME when host on battery power	Not Supported
Windows Power NVMe Latency 1 (AC)	Windows OS Power Setting. After timeout 1, change to lowest power state with entry+exit latency less than this when host on AC power	50 mS

Windows Power NVMe Latency 1 (DC)	Windows OS Power Setting. After timeout 1, change to lowest power state with entry+exit latency less than this when host on battery power	5 mS
Windows Power NVMe Latency 2 (AC)	Windows OS Power Setting. After timeout 2, change to lowest power state with entry+exit latency less than this when host on AC power	100 mS
Windows Power NVMe Latency 2 (DC)	Windows OS Power Setting. After timeout 2, change to lowest power state with entry+exit latency less than this when host on battery power	100 mS
Windows Power NVMe Timeout 1 (AC)	Windows OS Power Setting. Timeout to transition NVMe to first lower power state when host on AC power	100 mS
Windows Power NVMe Timeout 1 (DC)	Windows OS Power Setting. Timeout to transition NVMe to first lower power state when host on battery power	100 mS
Windows Power NVMe Timeout 2 (AC)	Windows OS Power Setting. Timeout to transition NVMe to second lower power state when host on AC power	800 mS
Windows Power NVMe Timeout 2 (DC)	Windows OS Power Setting. Timeout to transition NVMe to second lower power state when host on battery power	1000 mS
Windows Power Plan	Name of active Windows OS Power Plan	HP Optimized (recommended)
Workload Hint (WH)	Feature 02h: Type of workload expected for a given power state	0
Write Uncorrectable NVM Command	Controller support for the Write Uncorrectable NVM command, from ONCS	Supported
Write Zeroes NVM Command	Controller support for the Write Zeroes NVM command, from ONCS	Supported
Data Used	Percent of TBW used	175.737475333333
TBW	Specification for Terabytes Written	150
Warranty Used	Percent of Warranty Used	5.16438356164383 5
Warranty Hours	Warranty In Hours	14600
Warranty Years	Warranty In Years	5
Namespace 1 Active LBA Size	Size in bytes of the active LBA for Namespace 1	512

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