

Intel® Solid State Drive Data Center S4500/S4600 Series

Product Specification

- Capacities:
 - S4500
 - 240GB, 480GB, 960GB, 1.92TB, 3.84TB, 7.68TB
 - S4600
 - 240GB, 480GB, 960GB, 1.92TB, 3.84TB
- Components
 - 3D NAND TLC Flash Memory
- Form Factor: 2.5-inch
- Random Read and Write IOPS^{1,2}
(Full LBA Range, using FIO* on Linux*, Queue Depth 32)
 - S4500
 - Random 4KB³ Reads: Up to 72,000 IOPS
 - Random 4KB Writes: Up to 33,000 IOPS
 - Random 8KB³ Reads: Up to 48,000 IOPS
 - Random 8KB Writes: Up to 21,000 IOPS
 - S4600
 - Random 4KB³ Reads: Up to 72,000 IOPS
 - Random 4KB Writes: Up to 65,000 IOPS
 - Random 8KB³ Reads: Up to 48,000 IOPS
 - Random 8KB Writes: Up to 40,000 IOPS
- Sequential Read and Write Performance¹
 - Sustained Sequential Read: Up to 500 MB/s⁴
 - Sustained Sequential Write: Up to 490 MB/s
- Endurance:
 - S4500: Up to 7.64 PBW⁵ (JESD219 workload)
 - S4600: Up to 10.84 PBW⁵ (JESD219 workload)
- Latency
 - Sequential Latency (Typ.) R/W : 36/36 µs
 - Random Latency (Typ.) R/W : 110/52 µs
- Quality of Service^{6,7}
 - Read/Write (Typ.): 300/800 µs (99.9%)
- Read/Write Performance Consistency^{7,8}
 - Up to 99%/90%
- Hardware-based AES-256 Encryption activated with ATA password
- Product Ecological Compliance
 - RoHS*
- Certifications and Declarations
 - UL*, CE*, RMC Mark*, BSMI*, KCC*, Microsoft* WHCK, VCCI*, SATA-IO*
- Compliance
 - SATA Revision 3.0; compatible with SATA 6Gb/s, 3Gb/s and 1.5Gb/s interface rates
 - ATA/ATAPI Command Set – 3 (ACS-3 Rev 5); includes SCT (Smart Command Transport) and device statistics log support
 - Enhanced SMART ATA feature set
 - Native Command Queuing (NCQ) command set
 - Data set management Trim command
- Power
 - 5V or 5V+12V SATA Supply Rail⁹
 - SATA Interface Power Management
 - OS-aware hot plug/removal
 - Enhanced power-loss data protection feature
 - S4500: Active/Idle: Up to 5.6 W/1.1 W (Typ.)^{7,10}
 - S4600: Active/Idle: Up to 5.0 W/1.0 W (Typ.)^{7,10}
- Weight:
 - 240GB, 480GB, 960GB: 63 grams ± 2 grams
 - 1.92TB, 3.84TB: 66 grams ± 2 grams
 - 7.68TB: TBD
- Temperature
 - Operating: 0° C to 70° C
 - Non-Operating¹¹: -55° C to 95° C
 - Temperature monitoring and logging
 - Thermal throttling supported
- Shock (operating and non-operating):
 - 1,000 G/0.5 ms
- Vibration
 - Operating: 2.17 G_{RMS} (5-700 Hz)
 - Non-Operating: 3.13 G_{RMS} (5-800 Hz)
- Reliability
 - Uncorrectable Bit Error Rate (UBER): 1 sector per 10¹⁷ bits read
 - Mean Time Between Failures (MTBF): 2 million hours
 - End-to-End data protection
 - Power Loss Protection
- Compatibility
 - Windows 7* and Windows 10*
 - Windows Server 2016*
 - Windows Server 2012* R2
 - Windows Server 2008* R2
 - VMWare* 6.0, 6.5
 - Red Hat* Enterprise Linux* 6.5, 6.7, 7.1 and 7.2
 - SUSE* Linux* Enterprise Server 11 SP4, 12 SP1
 - CentOS* 64bit 6.3, 6.5, and 7.0
 - Intel® SSD Data Center Tool

1. Performance values vary by capacity

2. Performance specifications apply to both compressible and incompressible data

3. 4KB = 4,096 bytes; 8KB = 8,192 bytes

4. MB/s = 1,000,000 bytes/second

5. 1PB = 10¹⁵ Bytes

6. Based on Random 4KB QD=1 workload, measured as the time taken for 99.9 percentile of commands to finish the round-trip from host to drive and back to host

7. Measurement taken once the workload has reached steady state but including all background activities required for normal operation and data reliability

8. Based on Random 4KB QD=32 workload, measured as the (IOPS in the 99.9th percentile slowest 1-second interval)/(average IOPS during the test)

9. If both 12V and 5V power supplies are present, defaults to 5V+ 12V power supplies. Does not support 12 volt only.

10. Based on 5V power supply

11. Contact your Intel representative for details on the non-operating temperature range.



Ordering Information

Contact your local Intel sales representative for ordering information.

Revision History

Revision	Description	Date
001	Initial release	July 2017

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase.

System Configuration for all performance testing: Intel® Xeon® CPU E5-2699 v4 @ 2.20GHz on Intel® S2600WT motherboard, Intel® C612 Chipset, BIOS Version SE5C610.86B.01.01.0019.101220160604 32GB DDR4, FIO version 2.18, CentOS 7.0, Kernel 4.8.6 (DAS patch)

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

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1 Overview

This document describes the specifications and capabilities of the Intel® Solid State Drive Data Center S4500 and S4600 Series (Intel® SSD DC S4500/S4600 Series).

Intel® SSD DC S4500/S4600 Series delivers great performance and Quality of Service combined with high reliability for Serial Advanced Technology Attachment (SATA)-based computers in a 2.5-inch form factor in capacities of 240GB, 480GB, 960GB, 1.92TB, 3.84TB and 7.68TB.

By combining Intel's 3D NAND TLC Flash Memory technology with SATA 6 GB/s interface support, DC S4500/S4600 Series delivers Sequential Read speeds of up to 500 MB/s and Sequential Write speeds of up to 490 MB/s. DC S4500/S4600 Series also delivers Random 4k Read speeds of up to 72,000 IOPS and Random 4K Write speeds of up to 65,000 IOPS, and Quality of Service of 0.3 ms for random 4KB reads measured at a queue depth of 1.

The industry-standard 2.5-inch form factor enables interchangeability with existing hard disk drives (HDDs) and native SATA HDD drop-in replacement with the enhanced performance, reliability, ruggedness, and power savings offered by an SSD.

Intel® SSD DC S4500/S4600 Series offers these key features:

- Standard/Medium Endurance Technology
- High I/O and throughput performance
- Consistent I/O latency
- Tested and Proven power-loss data protection with self-test
- Proven End-to-End data protection, Demonstrated 10^{-17} UBER
- Thermal throttling
- Temperature Sensor
- Inrush current management
- Low power
- High reliability
- Temperature monitor and logging
- <5% Performance Degradation over product life



1.1 Terminology

Table 1: Terms and Acronyms

Term	Definition
ATA	Advanced Technology Attachment
CRC	Cyclic Redundancy Check
DAS	Device Activity Signal
DMA	Direct Memory Access
ECC	Error Correction Code
EXT	Extended
FPDMA	First Party Direct Memory Access
GB	Gigabyte. Note: The total usable capacity of the SSD may be less than the total physical capacity because a small portion of the capacity is used for NAND flash management and maintenance purposes.
Gb	Gigabit
HDD	Hard Disk Drive
HET	High Endurance Technology
KB	Kilobyte
I/O	Input/Output
IOPS	Input/Output Operations Per Second
ISO	International Standards Organization
LBA	Logical Block Address
MB	Megabyte (1,000,000 bytes)
TLC	Tri-level Cell
MTBF	Mean Time Between Failures
NCQ	Native Command Queuing
NOP	No Operation
PB	Petabyte
PCB	Printed Circuit Board
PIO	Programmed Input/Output
RDT	Reliability Demonstration Test
RMS	Root Mean Square
SATA	Serial Advanced Technology Attachment
SCT	SMART Command Transport
SMART	Self-Monitoring, Analysis and Reporting Technology. This is an open standard for developing hard drives and software systems that automatically monitors the health of a drive and reports potential problems.
SSD	Solid State Drive
TB	Terabyte
TYP	Typical
UBER	Uncorrectable Bit Error Rate



2 Product Specifications

2.1 Capacity

Table 2: User Addressable Sectors (LBA)

Capacity	Unformatted Capacity (Total User Addressable Sectors in LBA Mode)	
	Intel® SSD DC S4500 Series	Intel® SSD DC S4600 Series
240GB	468,862,128	468,862,128
480GB	937,703,088	937,703,088
960GB	1,875,385,008	1,875,385,008
1.92TB	3,750,748,848	3,750,748,848
3.84TB	7,501,476,528	7,501,476,528
7.68TB	15,002,931,888	—

Notes:

1GB = 1,000,000,000 bytes; 1 sector = 512 bytes.

LBA count shown represents total user storage capacity and will remain the same throughout the life of the drive.

The total usable capacity of the SSD may be less than the total physical capacity because a small portion of the capacity is used for NAND flash management and maintenance purposes.



2.2 Performance

Table 3: Random Read/Write Input/Output Operations Per Second (IOPS)¹ – DC S4500 Series

Specification	Unit	Intel SSD DC S4500 Series					
		240GB	480GB	960GB	1.92TB	3.84TB	7.68TB ⁴
Random 4KB Read (up to) ²	IOPS	69000	72000	72000	72000	72000	TBD
Random 4KB Write (up to)	IOPS	16000	20000	30000	33000	33000	TBD
Random 8KB Read (up to) ³	IOPS	40000	48000	48000	48000	48000	TBD
Random 8KB Write (up to)	IOPS	8000	10000	15000	18000	21000	TBD
Random 4KB 70/30 Read/Write (up to) ²	IOPS	35000	39000	46000	50000	50000	TBD
Random 8KB 70/30 Read/Write (up to) ³	IOPS	18000	24000	28000	30000	30000	TBD

Notes:

1. Performance measured using FIO* on Linux* with Queue Depth 32. Measurements are performed on a full Logical Block Address (LBA) span of the drive. Performance with different Queue Depths will be provided upon request. See page 2 for performance testing and configuration details.
2. 4KB = 4,096 bytes
3. 8KB = 8,192 bytes
4. Available at a later date. Please contact your Intel sales team for the launch dates.

Table 4: Random Read/Write Input/Output Operations Per Second (IOPS)¹ – DC S4600 Series

Specification	Unit	Intel SSD DC S4600 Series				
		240GB	480GB	960GB	1.92TB	3.84TB ⁴
Random 4KB Read (up to) ²	IOPS	72000	72000	72000	72000	TBD
Random 4KB Write (up to)	IOPS	38000	60000	65000	65000	TBD
Random 8KB Read (up to) ³	IOPS	46000	48000	48000	48000	TBD
Random 8KB Write (up to)	IOPS	20000	32000	37000	40000	TBD
Random 4KB 70/30 Read/Write (up to) ²	IOPS	50000	60000	63000	65000	TBD
Random 8KB 70/30 Read/Write (up to) ³	IOPS	32000	39000	41000	42000	TBD

Notes:

1. Performance measured using FIO* on Linux* with Queue Depth 32. Measurements are performed on a full Logical Block Address (LBA) span of the drive. Performance with different Queue Depths will be provided upon request. See page 2 for performance testing and configuration details.
2. 4KB = 4,096 bytes
3. 8KB = 8,192 bytes
4. Available at a later date. Please contact your Intel sales team for the launch dates.

**Table 5: 2.5-Inch Random Read/Write IOPS Consistency¹ – DC S4500 Series**

Specification	Unit	Intel SSD DC S4500 Series					
		240GB	480GB	960GB	1.92TB	3.84TB	7.68TB ⁴
Random 4KB Read (up to) ²	%	99%	99%	99%	99%	99%	TBD
Random 4KB Write (up to)	%	90%	90%	90%	90%	90%	TBD
Random 8KB Read (up to) ³	%	99%	99%	99%	99%	99%	TBD
Random 8KB Write (up to)	%	85%	85%	85%	85%	85%	TBD

Notes:

1. Performance measured using FIO* on Linux* with Queue Depth 32. Measurements are performed on a full Logical Block Address (LBA) span of the drive. Performance with different Queue Depths will be provided upon request. See page 2 for performance testing and configuration details.
2. 4KB = 4,096 bytes
3. 8KB = 8,192 bytes
4. Available at a later date. Please contact your Intel sales team for the launch dates

Table 6: 2.5-Inch Random Read/Write IOPS Consistency¹ – DC S4600 Series

Specification	Unit	Intel SSD DC S4600 Series				
		240GB	480GB	960GB	1.92TB	3.84TB ⁴
Random 4KB Read (up to) ²	%	99%	99%	99%	99%	TBD
Random 4KB Write (up to)	%	90%	90%	90%	90%	TBD
Random 8KB Read (up to) ³	%	99%	99%	99%	99%	TBD
Random 8KB Write (up to)	%	90%	90%	90%	90%	TBD

Notes:

1. Performance measured using FIO* on Linux* with Queue Depth 32. Measurements are performed on a full Logical Block Address (LBA) span of the drive. Performance with different Queue Depths will be provided upon request. See page 2 for performance testing and configuration details.
2. 4KB = 4,096 bytes
3. 8KB = 8,192 bytes
4. Available at a later date. Please contact your Intel sales team for the launch dates

Table 7: Sequential Read and Write Bandwidth¹ – DC S4500 Series

Specification	Unit	Intel SSD DC S4500 Series					
		240GB	480GB	960GB	1.92TB	3.84TB	7.68TB ²
Sequential Read (SATA 6Gb/s) ¹	MB/s	500	500	500	500	500	TBD
Sequential Write (SATA 6Gb/s) ¹	MB/s	190	330	490	490	470	TBD

Note:

1. Performance measured using FIO* on Linux* with Queue Depth 32. Measurements are performed on a full Logical Block Address (LBA) span of the drive. Performance with different Queue Depths will be provided upon request. See page 2 for performance testing and configuration details.
2. Available at a later date. Please contact your Intel sales team for the launch dates.

**Table 8: Sequential Read and Write Bandwidth¹ – DC S4600 Series**

Specification	Unit	Intel SSD DC S4600 Series				
		240GB	480GB	960GB	1.92TB	3.84TB ²
Sequential Read (SATA 6Gb/s) ¹	MB/s	500	500	500	500	TBD
Sequential Write (SATA 6Gb/s) ¹	MB/s	260	480	490	480	TBD

Note:

1. Performance measured using FIO* on Linux* with Queue Depth 32. Measurements are performed on a full Logical Block Address (LBA) span of the drive. Performance with different Queue Depths will be provided upon request. See page 2 for performance testing and configuration details.
2. Available at a later date. Please contact your Intel sales team for the launch dates

Table 9: Latency (TYP)¹ – DC S4500 Series

Specification ²	Intel SSD DC S4500 Series					
	240GB	480GB	960GB	1.92TB	3.84TB	7.68TB ³
Read Sequential (μs)	36	36	36	36	36	TBD
Read Random (μs)	110	110	110	110	115	TBD
Write Sequential (μs)	36	36	36	36	36	TBD
Write Random (μs)	62	52	52	52	52	TBD

Note:

1. Latency measured using 4KB (4,096 bytes) transfer size with Queue Depth equal to 1 on a sequential and random workload.
2. See page 2 for performance testing and configuration details.
3. Available at a later date. Please contact your Intel sales team for the launch dates.

Table 10: Latency (TYP)¹ – DC S4600 Series

Specification ²	Intel SSD DC S4600 Series				
	240GB	480GB	960GB	1.92TB	3.84TB ³
Read Sequential (μs)	36	36	36	36	TBD
Read Random (μs)	110	110	110	110	TBD
Write Sequential (μs)	36	36	36	36	TBD
Write Random (μs)	52	52	52	52	TBD

Note:

1. Latency measured using 4KB (4,096 bytes) transfer size with Queue Depth equal to 1 on a sequential and random workload.
2. See page 2 for performance testing and configuration details.
3. Available at a later date. Please contact your Intel sales team for the launch dates.



Table 11: Quality of Service (QoS) – DC S4500 Series

Specification	Unit	Intel SSD DC S4500 Series					
		240GB	480GB	960GB	1.92TB	3.84TB	7.68TB ⁴
Quality of Service ^{1,2,3} (99.9%)							
Reads Queue Depth 1	ms	0.3	0.3	0.3	0.4	0.4	TBD
Reads Queue Depth 32	ms	2.0	2.0	2.0	1.2	1.2	TBD
Writes Queue Depth 1	ms	5.0	0.8	0.8	0.8	0.8	TBD
Writes Queue Depth 32	ms	12.0	8.0	8.0	8.0	5.0	TBD
Quality of Service ^{1,2,3} (99.9999%)							
Reads Queue Depth 1	ms	5.0	5.0	5.0	5.0	5.0	TBD
Reads Queue Depth 32	ms	6.0	6.0	6.0	6.0	6.0	TBD
Writes Queue Depth 1	ms	10.0	2.0	2.0	2.0	2.0	TBD
Writes Queue Depth 32	ms	20.0	15.0	15.0	15.0	15.0	TBD

Notes:

1. Device measured using FIO* on Linux*. Quality of Service measured using 4KB (4,096 bytes) transfer size on a random workload on a full Logical Block Address (LBA) span of the drive once the workload has reached steady state but including all background activities required for normal operation and data reliability. Runtime is 20 minutes.
2. Based on Random 4KB QD=1, 32 workloads, measured as the time taken for 99.9 (or 99.9999) percentile of commands to finish the round-trip from host to drive and back to host.
3. See page 2 for performance testing and configuration details.
4. Available at a later date. Please contact your Intel sales team for the launch dates.

Table 12: Quality of Service (QoS) – DC S4600 Series

Specification	Unit	Intel SSD DC S4600 Series				
		240GB	480GB	960GB	1.92TB	3.84TB ⁴
Quality of Service ^{1,2,3} (99.9%)						
Reads Queue Depth 1	ms	0.3	0.3	0.3	0.3	TBD
Reads Queue Depth 32	ms	1.2	1.0	1.0	1.0	TBD
Writes Queue Depth 1	ms	0.3	0.3	0.3	0.3	TBD
Writes Queue Depth 32	ms	5.0	4.0	2.0	2.0	TBD
Quality of Service ^{1,2,3} (99.9999%)						
Reads Queue Depth 1	ms	4.0	4.0	4.0	4.0	TBD
Reads Queue Depth 32	ms	6.0	6.0	5.0	5.0	TBD
Writes Queue Depth 1	ms	1.5	1.5	1.5	1.5	TBD
Writes Queue Depth 32	ms	10.0	7.0	7.0	7.0	TBD

Notes:

1. Device measured using FIO* on Linux*. Quality of Service measured using 4KB (4,096 bytes) transfer size on a random workload on a full Logical Block Address (LBA) span of the drive once the workload has reached steady state but including all background activities required for normal operation and data reliability. Runtime is 20 minutes.
2. Based on Random 4KB QD=1, 32 workloads, measured as the time taken for 99.9 (or 99.9999) percentile of commands to finish the round-trip from host to drive and back to host.
3. See page 2 for performance testing and configuration details.
4. Available at a later date. Please contact your Intel sales team for the launch dates.



Table 13: Power On to Ready – DC S4500 Series

Specification (in seconds)	Intel SSD DC S4500 Series					
	240GB	480GB	960GB	1.92TB	3.84TB	7.84TB ³
Planned Shutdown ¹ Typical	2.5	3.0	3.7	5.2	8.0	TBD
Unplanned Shutdown ² Typical	4.0	4.5	5.2	6.5	9.5	TBD

Notes:

1. Shutdown is preceded by STANDBY IMMEDIATE command.
2. Power On To Ready time assumes proper shutdown. Time varies if shutdown is not preceded by STANDBY IMMEDIATE command. For 95% of the time, the maximum time for power on to ready will be less than 15 seconds
3. Available at a later date. Please contact your Intel sales team for the launch dates.

Table 14: Power On to Ready – DC S4600 Series

Specification (in seconds)	Intel SSD DC S4600 Series				
	240GB	480GB	960GB	1.92TB	3.84TB ³
Planned Shutdown ¹ Typical	2.5	3.0	3.8	5.5	TBD
Unplanned Shutdown ² Typical	4.0	4.6	5.3	6.8	TBD

Notes:

1. Shutdown is preceded by STANDBY IMMEDIATE command.
2. Power On To Ready time assumes proper shutdown. Time varies if shutdown is not preceded by STANDBY IMMEDIATE command. For 95% of the time, the maximum time for power on to ready will be less than 15 seconds.
3. Available at a later date. Please contact your Intel sales team for the launch dates.

2.3 Electrical Characteristics

Table 15: Operating Voltage

Electrical Characteristics	Intel SSD DC S4500/S4600 Series
5V Operating Characteristics: Operating Voltage range Rise time (Max/Min) Fall time (Min) ¹ Noise level Min Off time ² Inrush Current (Typical Peak) ³	5V (±5%) 1 s / 1 ms 5 kV/s 500 mV pp 10 Hz – 100 KHz 50 mV pp 100 KHz – 20 MHz 500 ms 1.5 A, < 1 s
12V Operating Characteristics: Operating Voltage range Rise time (Max/Min) Fall time (Min) ¹ Noise level Min Off time ² Inrush Current (Typical Peak) ³	12V (±10%) 1 s / 1 ms 12 kV/s 1000 mV pp 10 Hz – 100 KHz 100 mV pp 100 KHz – 20 MHz 500 ms 1.5 A, < 1 s

Notes:

1. Fall time must be equal or better than minimum to guarantee full functionality of enhanced power loss management.
2. The drive must be powered off for at least 500msec before powering on.
3. Measured from initial device power supply application.

Table 16: Power Consumption (5V Supply) – DC S4500 Series

Specification	Unit	Intel SSD DC S4500 Series					
		240GB	480GB	960GB	1.92TB	3.84TB	7.68TB ⁵
Active Write - RMS Average ¹	W	2.6	3.6	4.8	5.0	5.6	TBD
Active Write - Burst ²	W	5.9	6.7	8.5	9.7	10.8	TBD
Active Read - RMS Average ³	W	1.9	1.9	2	2	2.1	TBD
Active Read - Burst ⁴	W	5.4	5.6	5.6	6.2	5.5	TBD
Idle	W	0.9	0.9	1.0	1.0	1.1	TBD

Notes:

1. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Average Power is measured using Agilent Power Analyzer over a 100 ms sample period.
2. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Burst Power is measured using Agilent Power Analyzer over a 500 μ s sample period.
3. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) average power is measured using Agilent Power Analyzer over a 100 ms sample period.
4. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) burst power is measured using Agilent Power Analyzer over a 500 μ s sample period.
5. Available at a later date. Please contact your Intel sales team for the launch dates.

Table 17: Power Consumption (5V Supply) – DC S4600 Series

Specification	Unit	Intel SSD DC S4600 Series				
		240GB	480GB	960GB	1.92TB	3.84TB ⁵
Active Write - RMS Average ¹	W	3.1	4.5	4.8	4.9	TBD
Active Write - Burst ²	W	6.2	7.8	8.8	9.3	TBD
Active Read - RMS Average ³	W	2	1.9	2.0	2	TBD
Active Read - Burst ⁴	W	5.5	5.8	6.2	5.8	TBD
Idle	W	0.9	0.9	1.0	1.0	TBD

Notes:

1. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Average Power is measured using Agilent Power Analyzer over a 100 ms sample period.
2. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Burst Power is measured using Agilent Power Analyzer over a 500 μ s sample period.
3. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) average power is measured using Agilent Power Analyzer over a 100 ms sample period.
4. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) burst power is measured using Agilent Power Analyzer over a 500 μ s sample period.
5. Available at a later date. Please contact your Intel sales team for the launch dates.



Table 18: Power Consumption (5V + 12V Supply) – DC S4500 Series

Specification	Unit	Intel SSD DC S4500 Series											
		240GB		480GB		960GB		1.92TB		3.84TB		7.68TB ⁵	
		5V	12V	5V	12V	5V	12V	5V	12V	5V	12V	5V	12V
Active Write - RMS Average ¹	W	1.54	1.28	1.63	1.90	1.98	2.72	2.0	2.86	2.15	3.13	TBD	TBD
Active Write - Burst ²	W	4.97	1.63	5.14	2.55	5.06	3.81	5.55	4.45	5.65	5.42	TBD	TBD
Active Read - RMS Average ³	W	1.61	0.59	1.60	0.60	1.71	0.60	1.73	0.62	1.79	0.71	TBD	TBD
Active Read - Burst ⁴	W	4.80	1.02	4.93	1.06	4.89	1.24	4.92	1.17	4.79	1.52	TBD	TBD
Idle	W	0.85	0.40	0.85	0.40	0.92	0.40	0.92	0.40	0.95	0.40	TBD	TBD

Notes:

1. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Average Power is measured using Agilent Power Analyzer over a 100 ms sample period.
2. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Burst Power is measured using Agilent Power Analyzer over a 500 μ s sample period.
3. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) average power is measured using Agilent Power Analyzer over a 100 ms sample period.
4. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) burst power is measured using Agilent Power Analyzer over a 500 μ s sample period.
5. Available at a later date. Please contact your Intel sales team for the launch dates.

Table 19: Power Consumption (5V + 12V Supply) – DC S4600 Series

Specification	Unit	Intel SSD DC S4600 Series									
		240GB		480GB		960GB		1.92TB		3.84TB ⁵	
		5V	12V	5V	12V	5V	12V	5V	12V	5V	12V
Active Write - RMS Average ¹	W	1.76	1.64	1.83	2.61	1.95	2.79	2.0	2.86	TBD	TBD
Active Write - Burst ²	W	4.77	2.10	5.38	3.52	5.48	3.93	5.55	4.45	TBD	TBD
Active Read - RMS Average ³	W	1.74	0.63	1.62	0.57	1.68	0.60	1.73	0.62	TBD	TBD
Active Read - Burst ⁴	W	4.69	1.01	5.27	1.03	5.26	1.14	4.92	1.17	TBD	TBD
Idle	W	0.85	0.40	0.85	0.40	0.92	0.40	0.92	0.40	TBD	TBD

Notes:

1. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Average Power is measured using Agilent Power Analyzer over a 100 ms sample period.
2. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Burst Power is measured using Agilent Power Analyzer over a 500 μ s sample period.
3. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) average power is measured using Agilent Power Analyzer over a 100 ms sample period.
4. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) burst power is measured using Agilent Power Analyzer over a 500 μ s sample period.
5. Available at a later date. Please contact your Intel sales team for the launch dates.



2.4 Environmental Conditions

Table 20: Temperature, Shock, Vibration, Altitude

Temperature	Range
Case Temperature Operating Non-operating ¹	0 – 70° C -55 – 95° C
Temperature Gradient ² Operating Non-operating	30° C/hr (Typical) 30° C/hr (Typical)
Humidity Operating Non-operating	5 – 95 % 5 – 95 %
Shock and Vibration	Range
Shock ³ Operating Non-operating	1,000 G (Max) at 0.5 ms 1,000 G (Max) at 0.5 ms
Vibration ⁴ Operating Non-operating	2.17 GRMS (5-700 Hz) Max 3.13 GRMS (5-800 Hz) Max
Altitude ⁵	Range
Operating Non-operating	-1,000 to 10,000 ft -10,000 to 15,000 ft ⁶ -1,000 to 40,000 ft

Notes:

1. Contact your Intel representative for details on the non-operating temperature range.
2. Temperature gradient measured without condensation.
3. Shock specifications assume the SSD is mounted securely with the input vibration applied to the drive-mounting screws. Stimulus may be applied in the X, Y or Z axis. Shock specification is measured using Root Mean Squared (RMS) value.
4. Vibration specifications assume the SSD is mounted securely with the input vibration applied to the drive-mounting screws. Stimulus may be applied in the X, Y or Z axis. Vibration specification is measured using RMS value.
5. Altitude pressure is simulated in a test chamber; excludes soft error.
6. Extended operation at a higher altitude might impact reliability.



2.5 Thermal Specifications

Table 21: Airflow Requirements – DC S4500 Series

Airflow ¹ Definition	Unit	Ambient Temperature ³	Intel SSD DC S4500 Series					
			240GB	480GB	960GB	1.92TB	3.84TB	7.68TB ⁴
Approach Airflow ²	LFM	35° C	≤ 70	≤ 80	110	120	130	TBD
	LFM	55° C	≤ 300	≤ 400	850	850	850	TBD

Notes:

1. It is recommended that airflow should be towards the server, from the non-connector side to the connector side. Airflow is specified across the surface of the drive. Spacing between two SSDs is assumed to be 3mm.
2. The approach velocity of the airflow will be less than the airflow along the surface. Approach area of 1.35 ft² is assumed.
3. The workload used is 100% Sequential Write which has worst case power consumption and thermal condition.
4. Available at a later date. Please contact your Intel sales team for the launch dates.

Table 22: Airflow Requirements – DC S4600 Series

Airflow ¹ Definition	Unit	Ambient Temperature ³	Intel SSD DC S4600 Series				
			240GB	480GB	960GB	1.92TB	3.84TB ⁴
Approach Airflow ²	LFM	35° C	≤ 70	≤ 80	110	120	TBD
	LFM	55° C	≤ 300	≤ 400	850	850	TBD

Notes:

1. It is recommended that airflow should be towards the server, from the non-connector side to the connector side. Airflow is specified across the surface of the drive. Spacing between two SSDs is assumed to be 3mm.
2. The approach velocity of the airflow will be less than the airflow along the surface. Approach area of 1.35 ft² is assumed.
3. The workload used is 100% Sequential Write which has worst case power consumption and thermal condition.
4. Available at a later date. Please contact your Intel sales team for the launch dates.

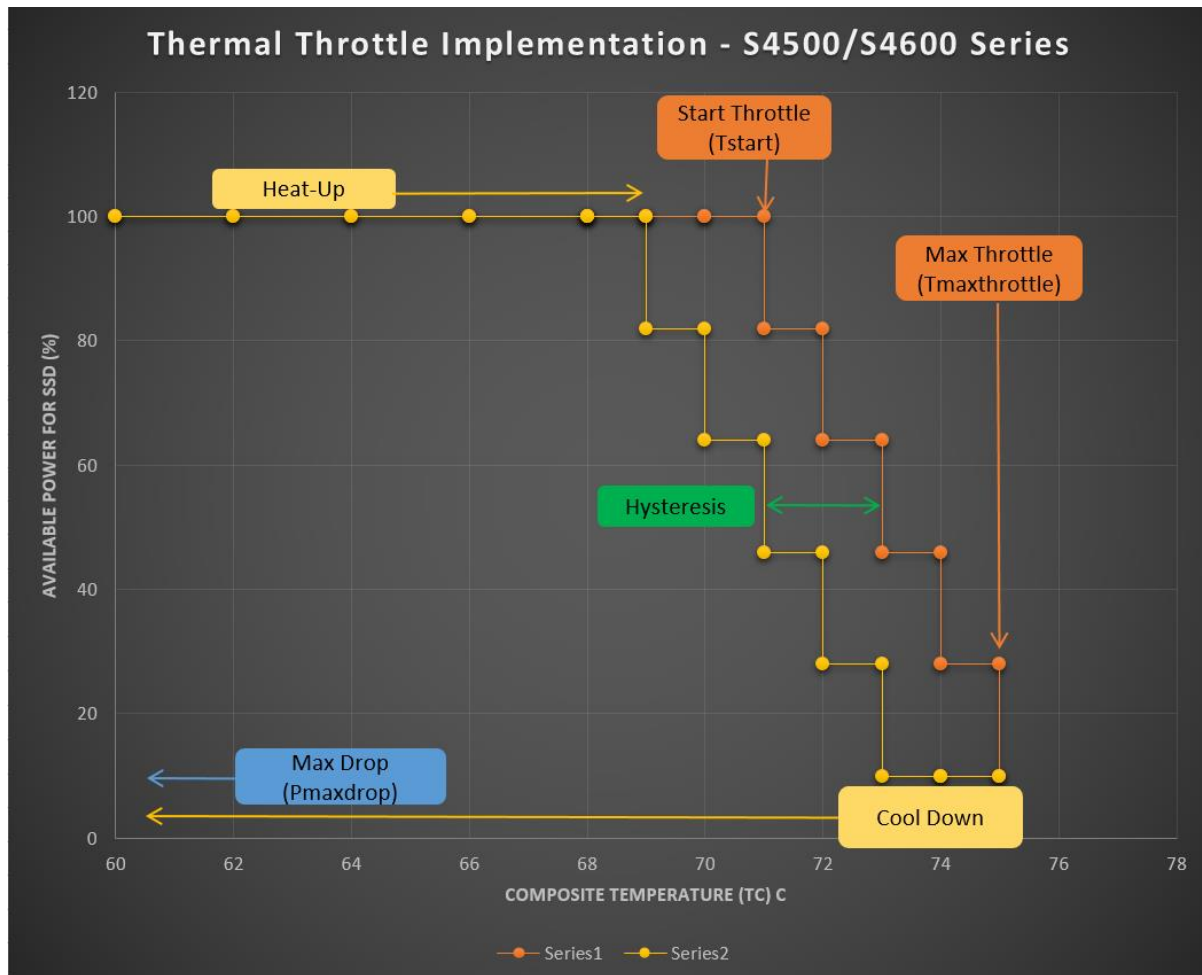
2.5.1 Thermal Throttling

Intel SSD DC S4500/S4600 Series will provide performance throttling during high temperature scenarios to mitigate thermal challenges. Thermal throttling works by moving the power ceiling in N number of linear steps as shown in Figure 1.

Key definitions for important parameters are:

- Tstart – throttling starts
- Tmax – max throttling is applied
- Pmaxdrop – maximum drop allowed determined by the internal setting
- Thysteresis – 2C comes into play during the cooling phase to prevent rapid oscillations between the throttle states. The temperature must hit the hysteresis level to return the power ceiling back to previous levels.

Figure 1: Thermal Throttling Behavior



Shown above is the Thermal throttling behavior for Intel SSD DC S4500/S4600 Series SSD, Pmaxdrop is 10%, Tstart is 71° C, Tmax_throttle is 75° C and N is 5.

The following table shows the Thermal throttle settings for Intel SSD DC S4500/S4600 Series across all SKUs.

Table 23: Intel SSD DC S4500/S4600 Series Thermal Throttle Settings

Capacities	Throttle Start	Throttle Max	Throttle Steps
All	71	75	5

2.5.2 Boundary Condition

To maintain SMART temperature BEh in the operating range, the following air flow conditions are provided as an estimate.

Figure 2 shows the operating domain curve measured for 240GB, 480GB, 960GB, 1.92TB, and 3.84TB. The curves show allowable air inlet temperature vs. Flow Velocity (LFM) to prevent throttling of the drive. Workload used to characterize the operating domain curve is 128K Sequential Writes, Queue Depth 32 after the drive reaches steady state.

For example: on a DC S4500 Series 240GB SSD for a LFM of 200, the maximum inlet air temperature should be maintained below 53° C to prevent the drive from throttling (power or performance reductions). This test data is obtained by characterizing drive temperature response in a wind tunnel with drives spaced 3mm apart, as shown in Figure 3 using a system configuration of Asus* X99 MB, Windows* 7, and IOMeter* v1.1.

Figure 2: DC S4500/S4600 Series Operating Domain Curves

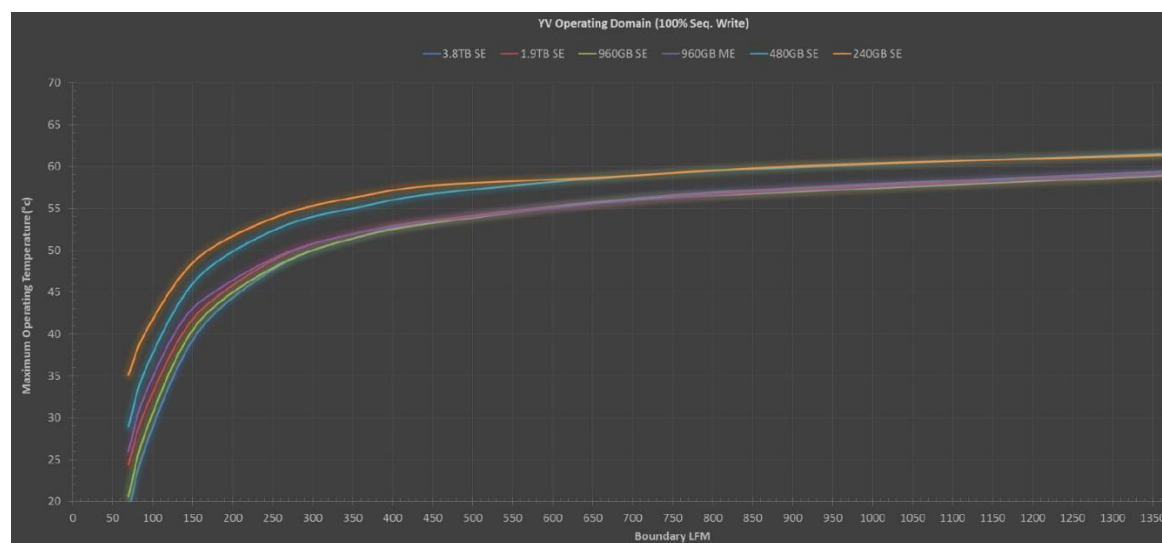
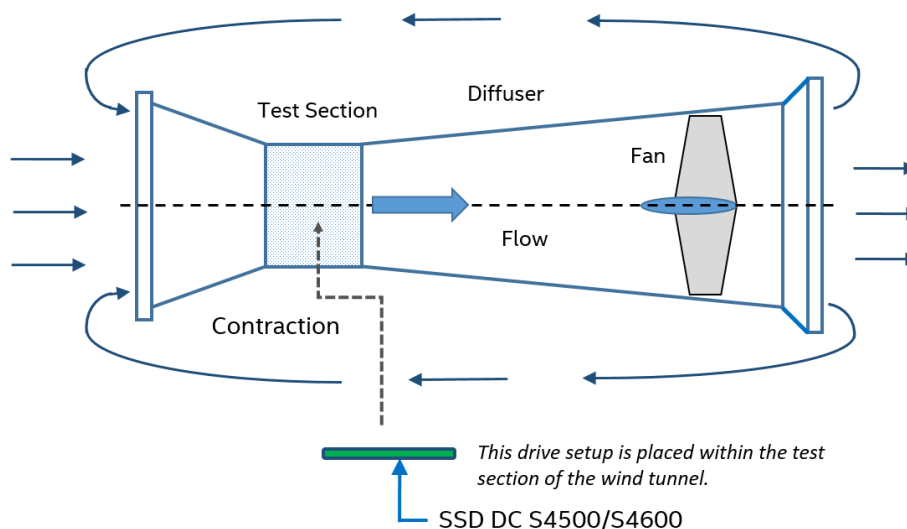


Figure 3: Open Return Wind Tunnel





2.6 Product Regulatory Compliance

Intel SSD DC S4500/S4600 Series meets or exceeds the regulatory or certification requirements listed in the following table:

Table 24: Product Regulatory Compliance Specifications

Title	Description	Region For Which Conformity Declared
TITLE 47-Telecommunications CHAPTER 1— FEDERAL COMMUNICATIONS COMMISSION PART 15 — RADIO FREQUENCY DEVICES ICES-003, Issue 4 Interference-Causing Equipment Standard Digital Apparatus	FCC Part 15B Class B CA/CSA-CEI/IEC CISPR 22:02. This is CISPR 22:1997 with Canadian Modifications	USA Canada
IEC 55024 Information Technology Equipment — Immunity characteristics— Limits and methods of measurement CISPR24:2010	EN-55024: 1998 and its amendments	European Union
IEC 55022 Information Technology Equipment — Radio disturbance Characteristics— Limits and methods of measurement CISPR24:2008 (Modified)	EN-55022: 2006 and its amendments	European Union
EN-60950-1 2 nd Edition	Information Technology Equipment — Safety — Part 1: General Requirements	USA/Canada
UL/CSA EN-60950-1 2 nd Edition	Information Technology Equipment — Safety — Part 1: General Requirements	USA/Canada



2.7 Reliability

Intel SSD DC S4500/S4600 Series meets or exceeds SSD endurance and data retention requirements as specified in the JESD218 standard. Reliability specifications are listed in the following table:

Table 25: Reliability Specifications

Parameter	Value
Uncorrectable Bit Error Rate (UBER) Uncorrectable bit error rate will not exceed one sector in the specified number of bits read. In the unlikely event of a non-recoverable read error, the SSD will report it as a read failure to the host; the sector in error is considered corrupt and is not returned to the host.	< 1 sector per 10^{17} bits read
Mean Time Between Failures (MTBF) Mean Time Between Failures is estimated based on Telcordia* methodology and demonstrated through Reliability Demonstration Test (RDT).	2 million hours
Power On/Off Cycles Power On/Off Cycles is defined as power being removed from the SSD, and then restored. Most host systems remove power from the SSD when entering suspend and hibernate as well as on a system shutdown.	24 per day
Insertion Cycles (2.5-inch form factor only) SATA/power cable insertion/removal cycles.	50 on SATA cable 500 on backplane
Data Retention The time period for retaining data in the NAND at maximum rated endurance.	3 months power-off retention once SSD reaches rated write endurance at 40° C

Table 26: Endurance Rating – DC S4500 Series

Capacities	JEDEC Workload			64K Sequential Write		
	Endurance ¹ (Petabyte Written)	DWPD (for 3 yrs.)	DWPD (for 5 yrs.)	Endurance ¹ (Petabyte Written)	DWPD (for 3 yrs.)	DWPD (for 5 yrs.)
240GB	0.62	2.37	1.42	1.64	6.25	3.75
480GB	0.90	1.71	1.03	3.00	5.70	3.42
960GB	1.86	1.76	1.06	5.94	5.64	3.39
1.92TB	3.27	1.76	1.06	11.62	5.52	3.31
3.84TB	7.64	1.82	1.09	22.53	5.35	3.21
7.68TB ²	TBD	TBD	TBD	TBD	TBD	TBD

Note:

1. Refer to JESD218 standard table 1 for UBER, FFR and other Enterprise SSD endurance verification requirements. Endurance verification acceptance criterion based on establishing <1E-16 at 60 confidence.
2. Available at a later date. Please contact your Intel sales team for the launch dates.



Table 27: Endurance Rating – DC S4600 Series

	JEDEC Workload			64K Sequential Write		
Capacities	Endurance ¹ (Petabyte Written)	DWPD (for 3 yrs.)	DWPD (for 5 yrs.)	Endurance ¹ (Petabyte Written)	DWPD (for 3 yrs.)	DWPD (for 5 yrs.)
240GB	1.40	5.32	3.19	2.19	8.34	5.01
480GB	2.95	5.60	3.36	4.37	8.30	4.98
960GB	5.25	5.00	3.00	8.11	7.71	4.63
1.92TB	10.84	5.15	3.09	16.16	7.68	4.61
3.84TB ²	TBD	TBD	TBD	TBD	TBD	TBD

Note:

1. Refer to JESD218 standard table 1 for UBER, FFR and other Enterprise SSD endurance verification requirements. Endurance verification acceptance criterion based on establishing <1E-16 at 60% confidence.
2. Available at a later date. Please contact your Intel sales team for the launch dates.

2.8 Temperature Sensor

The Intel SSD DC S4500/S4600 Series has multiple temperature sensors with an accuracy of +/-2° C over a range of -20° C to +80° C. However a **Composite Temperature** will be reported as the Drive Temperature. **Composite Temperature** is an artificial measurement that represents the minimum delta of any temperature monitored component to its unique warning limit, normalized to be a delta from 70° C.

$$\text{Temp}_{\text{Composite}} = 70 - \min(\text{Limit}_A - \text{CurTemp}_A, \text{Limit}_B - \text{CurTemp}_B, \text{Limit}_C - \text{CurTemp}_C, \dots, \text{Limit}_N - \text{CurTemp}_N)$$

Drive Composite Temperature can be monitored using SMART attribute: Drive Temperature (BEh). The thermal throttling of the drive is done based off composite temperature value. Worst case component temperature drives thermal throttling of the drive.

2.9 Power Loss Capacitor Test

The Intel SSD DC S4500/S4600 Series supports testing of the power loss capacitor, which can be monitored using the following SMART attribute: (175, AFh).

2.10 Hot Plug Support

Hot Plug insertion and removal is supported in the presence of a proper connector and appropriate operating system (OS), as described in the SATA 3.1 specification.

This product supports asynchronous signal recovery and issues an unsolicited COMINIT when first mated with a powered connector to guarantee reliable detection by a host system without hardware device detection.

User Data is protected from planned or unplanned power loss by the Enhanced Power Management technology on the Intel SSD DC S4500/S4600 Series.

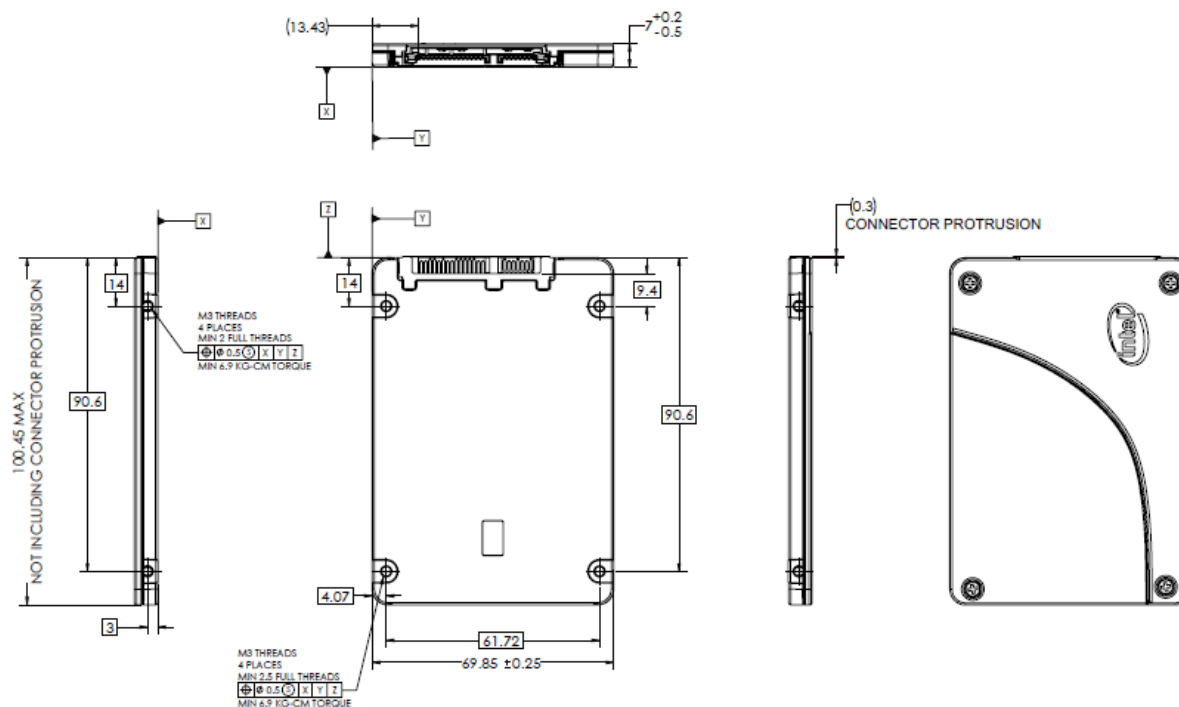
2.11 Hardware Based AES-XTS 256-bit Encryption Activated with ATA Password

The Intel SSD DC S4500/S4600 Series supports hardware based full drive encryption and protects all user data at rest with AES-256 bit encryption. Access to user data on the drive can be authenticated at power-on using BIOS or ATA Security Feature Set.

3 Mechanical Information

Figure 4 shows the physical package information for the Intel SSD DC S4500/S4600 Series in the 2.5 inch form factors. All dimensions are in millimeters.

Figure 4: Intel SSD DC S4500/S4600 Series 2.5-inch Dimensions

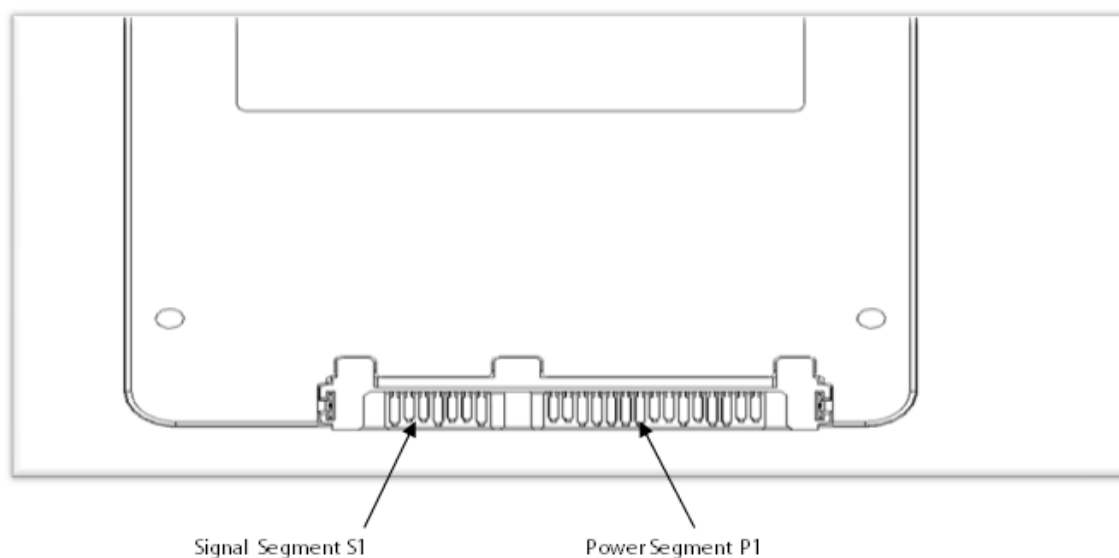


8

4 Pin and Signal Descriptions

4.1 2.5-inch Form Factor Pin Locations

Figure 5: Layout of 2.5-inch Form Factor Signal and Power Segment Pins



Note: 2.5-inch connector supports built in latching capability.

4.2 Connector Pin Signal Definitions

Table 28: Serial ATA Connector Pin Signal Definitions—2.5-inch Form Factors

Pin	Function	Definition
S1	Ground	1 st mate
S2	A+	Differential signal pair A
S3	A-	
S4	Ground	1 st mate
S5	B-	Differential signal pair B
S6	B+	
S7	Ground	1 st mate

Note: Key and spacing separate signal and power segments.



4.3 Power Pin Signal Definitions

Table 29: Serial ATA Power Pin Definitions—2.5-inch Form Factors

Pin ¹	Function	Definition	Mating Order
P1 ²	Not connected	(3.3V Power)	--
P2 ²	Not connected	(3.3V Power)	--
P3 ²	Not connected	(3.3V Power; pre-charge)	2 nd Mate
P4 ^{3,4}	Ground	Ground	1 st Mate
P5 ³	Ground	Ground	1 st Mate
P6 ³	Ground	Ground	1 st Mate
P7 ^{3,5}	V ₅	5V Power	1 st Mate
P8 ^{3,5}	V ₅	5V Power	2 nd Mate
P9 ^{3,5}	V ₅	5V Power	2 nd Mate
P10 ³	Ground	Ground	1 st Mate
P11 ⁶	DAS/DSS	Device Activity Signal/Device Staggered Spin-up	2 nd Mate
P12 ^{3,4}	Ground	Ground	1 st Mate
P13 ⁷	V ₁₂	12V Power	1 st Mate
P14 ⁷	V ₁₂	12V Power	2 nd Mate
P15 ⁷	V ₁₂	12V Power	2 nd Mate

Notes:

1. All pins are in a single row, with a 1.27 mm (0.050-inch) pitch.
2. Pins P1, P2 and P3 are connected together, although they are not connected internally to the device. The host may put 3.3V on these pins.
3. The mating sequence is:
 - ground pins P4-P6, P10, P12 and the 5V power pin P7
 - signal pins and the rest of the 5V power pins P8-P9
4. Ground connectors P4 and P12 may contact before the other 1st mate pins in both the power and signal connectors to discharge ESD in a suitably configured backplane connector.
5. Power pins P7, P8, and P9 are internally connected to one another within the device.
6. The host may ground P11 if it is not used for Device Activity Signal (DAS).
7. Pins P13, P14 and P15 are internally connected to one another within the device. The host may put 12V on these pins.



5 Supported Command Sets

The Intel SSD DC S4500/S4600 Series supports all mandatory ATA (Advanced Technology Attachment) commands defined in the ATA8-ACS3 REV5F specification described in this section.

5.1 ATA General Feature Command Set

The Intel SSD DC S4500/S4600 Series supports the ATA General Feature command set (non- PACKET), which consists of:

- EXECUTE DEVICE DIAGNOSTIC
- SET FEATURES
- IDENTIFY DEVICE

Note: See Appendix A, "IDENTIFY DEVICE Command Data" for details on the sector data returned after issuing an IDENTIFY DEVICE command.

The Intel SSD DC S4500/S4600 Series also supports the following optional commands:

- READ DMA
- WRITE DMA
- READ SECTOR(S)
- READ VERIFY SECTOR(S)
- READ MULTIPLE
- SEEK
- SET FEATURES
- WRITE SECTOR(S)
- SET MULTIPLE MODE¹
- WRITE MULTIPLE
- FLUSH CACHE
- READ BUFFER
- WRITE BUFFER
- NOP
- DOWNLOAD MICROCODE
- WRITE UNCORRECTABLE EXT

1. The only multiple supported will be multiple 1

5.2 Power Management Command Set

The Intel SSD DC S4500/S4600 Series supports the Power Management command set, which consists of:

- CHECK POWER MODE
- IDLE
- IDLE IMMEDIATE
- SLEEP
- STANDBY
- STANDBY IMMEDIATE



5.3 Security Mode Feature Set

The Intel SSD DC S4500/S4600 Series supports the Security Mode command set, which consists of:

- SECURITY SET PASSWORD
- SECURITY UNLOCK
- SECURITY ERASE PREPARE
- SECURITY ERASE UNIT
- SECURITY FREEZE LOCK
- SECURITY DISABLE PASSWORD

5.4 SMART Command Set

The Intel SSD DC S4500/S4600 Series supports the SMART command set, which consists of:

- SMART READ DATA
- SMART READ ATTRIBUTE THRESHOLDS
- SMART ENABLE/DISABLE ATTRIBUTE AUTOSAVE
- SMART SAVE ATTRIBUTE VALUES
- SMART EXECUTE OFF-LINE IMMEDIATE
- SMART READ LOG SECTOR
- SMART WRITE LOG SECTOR
- SMART ENABLE OPERATIONS
- SMART DISABLE OPERATIONS
- SMART RETURN STATUS
- SMART ENABLE/DISABLE AUTOMATIC OFFLINE

5.4.1 Attributes

The following table lists the SMART attributes supported by the Intel SSD DC S4500/S4600 Series and the corresponding status flags and threshold settings.

Table 30: SMART Attributes

ID	Attribute	Status Flags						Threshold
		SP	EC	ER	PE	OC	PW	
05h	Re-allocated Sector Count The raw value of this attribute shows the number of retired blocks since leaving the factory (grown defect count).	1	1	0	0	1	0	0 (none)
09h	Power-On Hours Count The raw value reports power-on time, cumulative over the life of the SSD, integer number in hour time units.	1	1	0	0	1	0	0 (none)
0Ch	Power Cycle Count The raw value of this attribute reports the cumulative number of power cycle events over the life of the device.	1	1	0	0	1	0	0 (none)
AAh	Available Reserved Space (See Attribute E8)	1	1	0	0	1	1	10



ID	Attribute	Status Flags						Threshold
		SP	EC	ER	PE	OC	PW	
ABh	Program Fail Count The raw value of this attribute shows total count of program fails and the normalized value, beginning at 100, shows the percent remaining of allowable program fails.	1	1	0	0	1	0	0 (none)
ACh	Erase Fail Count The raw value of this attribute shows total count of erase fails and the normalized value, beginning at 100, shows the percent remaining of allowable erase fails.	1	1	0	0	1	0	0 (none)
AEnh	Unexpected Power Loss Also known as "Power-off Retract Count" per magnetic-drive terminology. Reports number of unclean shutdowns, cumulative over the life of the SSD. An "unclean shutdown" is the removal of power without STANDBY IMMEDIATE as the last command (regardless of PLI activity using capacitor power).	1	1	0	0	1	0	0 (none)
AFh	Power Loss Protection Failure Last test result as microseconds to discharge cap, saturates at max value. Also logs minutes since last test and lifetime number of tests. Bytes 0-1: Last test result as microseconds to discharge cap, saturates at max value. Test result expected in range $25 \leq \text{result} \leq 5000000$, lower indicates specific error code Bytes 2-3: Minutes since last test, saturates at max value. Bytes 4-5: Lifetime number of tests, not incremented on power cycle, saturates at max value.	1	1	0	0	1	1	10
B7h	SATA Downshift Count The count of the number of times SATA interface selected lower signaling rate due to error.	1	1	0	0	1	0	0 (none)
B8h	End-to-End Error Detection Count <i>Raw value:</i> reports number of LBA tag mismatches in end-to-end data protection path. <i>Normalized value:</i> always 100.	1	1	0	0	1	1	90
BBh	Uncorrectable Error Count <i>Raw value:</i> shows the count of errors that could not be recovered using Error Correction Code (ECC). <i>Normalized value:</i> always 100.	1	1	0	0	1	0	0 (none)
BEh	Drive Temperature Reports the SSD drive temperature. Raw value suggests 100 - drive temperature in C degrees.	1	0	0	0	1	0	0 (none)



ID	Attribute	Status Flags						Threshold
		SP	EC	ER	PE	OC	PW	
C0h	Power-Off Retract Count (Unsafe Shutdown Count) The raw value of this attribute reports the cumulative number of unsafe (unclean) shutdown events over the life of the device. An unsafe shutdown occurs whenever the device is powered off without STANDBYIMMEDIATE being the last command.	1	1	0	0	1	0	0 (none)
C5h	Pending Sector Count Number of current unrecoverable read errors that will be re-allocated on next write.	0	1	0	0	1	0	0 (none)
C7h	CRC Error Count The total number of encountered SATA interface cyclic redundancy check (CRC) errors.	1	1	1	1	1	0	0 (none)
E1h	Host Writes The raw value of this attribute reports the total number of sectors written by the host system. The raw value is increased by 1 for every 65,536 sectors (32MB) written by the host.	1	1	0	0	1	0	0 (none)
E2h	Timed Workload Media Wear Measures the wear seen by the SSD (since reset of the workload timer, attribute E4h), as a percentage of the maximum rated cycles.	1	1	0	0	1	0	0 (none)
E3h	Timed Workload Host Read/Write Ratio Shows the percentage of I/O operations that are read operations (since reset of the workload timer, attribute E4h).	1	1	0	0	1	0	0 (none)
E4h	Timed Workload Timer Measures the elapsed time (number of minutes since starting this workload timer).	1	1	0	0	1	0	0 (none)
E8h	Available Reserved Space This attribute reports the number of reserve blocks remaining. The normalized value begins at 100 (64h), which corresponds to 100 percent availability of the reserved space. The threshold value for this attribute is 10 percent availability.	1	1	0	0	1	1	10
E9h	Media Wearout Indicator This attribute reports the number of cycles the NAND media has undergone. The normalized value declines linearly from 100 to 1 as the average erase cycle count increases from 0 to the maximum rated cycles. Once the normalized value reaches 1, the number will not decrease, although it is likely that significant additional wear can be put on the device.	1	1	0	0	1	0	0 (none)



ID	Attribute	Status Flags						Threshold
		SP	EC	ER	PE	OC	PW	
EAh	Thermal Throttle Status Reports Percent Throttle Status and Count of events Byte 0 = Throttling status. Decimal value 0 = No Throttle Applied, 100 = 100% throttling applied. Intermediate percentages are supported. A value larger than 100d is invalid. Bytes 1-4 = Throttling event count. 32 bit counter indicates the number of times thermal throttle has activated. Value is preserved over power cycles. Byte 5 = Reserved Normalized value: always 100.	1	1	0	0	1	0	0 (none)
F1h	Total LBAs Written The raw value of this attribute reports the total number of sectors written by the host system. The raw value is increased by 1 for every 65,536 sectors (32MB) written by the host.	1	1	0	0	1	0	0 (none)
F2h	Total LBAs Read The raw value of this attribute reports the total number of sectors read by the host system. The raw value is increased by 1 for every 65,536 sectors (32MB) read by the host.	1	1	0	0	1	0	0 (none)
F3h	Total Bytes Written The raw value of this attribute reports the total number of sectors written to the NAND media. This includes NAND writes triggered by host writes, defrag, background data refresh and wear level relocation writes etc. The raw value is increased by 1 for every 65,536 sectors (32MB) writes to the NAND media. Upon NAND write, new value returned once per minute.	1	1	0	0	1	0	0 (none)

Table 31: SMART Attribute Status Flags

Status Flag	Description	Value = 0	Value = 1
SP	Self-preserving attribute	Not a self-preserving attribute	Self-preserving attribute
EC	Event count attribute	Not an event count attribute	Event count attribute
ER	Error rate attribute	Not an error rate attribute	Error rate attribute
PE	Performance attribute	Not a performance attribute	Performance attribute
OC	Online collection attribute	Collected only during offline activity	Collected during both offline and online activity
PW	Pre-fail warranty attribute	Advisory	Pre-fail

5.4.2 Timed Workload Endurance Indicators

Timed Workload Media Wear Indicator — ID E2h

This attribute tracks the drive wear seen by the device during the last wear timer loop, as a percentage of the maximum rated cycles. This value should be divided by 1024 to get the percentage.

For example: if the raw value is 4455, the percentage is $4455/1024 = 4.35\%$. The raw value is held at FFFFh until the wear timer (attribute E4h) reaches 60 (minutes) after a SMART EXECUTE OFFLINE IMMEDIATE (B0h/D4h) subcommand 40h to the SSD. The normalized value is always set to 100 and should be ignored.

Timed Workload Host Reads Percentage — ID E3h

This attribute shows the percentage of I/O operations that are read operations during the last workload timer loop. The raw value tracks this percentage and is held at FFFFh until the workload timer (attribute E4h) reaches 60 (minutes). The normalized value is always set to 100 and should be ignored.

Workload Timer — ID E4h

This attribute is used to measure the time elapsed during the current workload. The attribute is reset when a SMART EXECUTE OFFLINE IMMEDIATE (D4h) subcommand 40h is issued to the drive. The raw value tracks the time in minutes and has a maximum value of $2^{32} = 4,294,967,296$ minutes (8,171 years). The normalized value is always set to 100 and should be ignored.

User Notes

- Sending a SMART EXECUTE OFFLINE IMMEDIATE (B0h/D4h) subcommand 40h to the SSD resets and starts all three attributes (Media Wear Indicator, Attribute E2h, Host Reads Percentage, Attribute E3h, and the Workload timer, Attribute E4h) to FFFFh.
- The Attribute raw values are held at FFFFh until the Workload timer (Attribute E4h) reaches a total of 60 (minutes) of power on time. After 60 minutes, the Timed Workload data is made available.
- After the Workload timer (E4h) reaches 60 (minutes), the Timed Workload data is saved every minute so only 59 seconds of data is lost if power is removed without receiving ATA STANDBY IMMEDIATE. Accumulated data is not reset due to power loss.
- Upon power up, the attributes hold a snapshot of their last saved values for 59 seconds and live data is available after 60 seconds, once the initial one hour interval is completed.

Example Use Cases

The Timed Workload Endurance attributes described in this section are intended to be used to measure the amount of media wear that the drive is subjected to during a timed workload.

Ideally, the system that the drive is being used in should be capable of issuing SMART commands. Otherwise, provisions have been provided to allow the media wear attributes to be persistent so the drive can be moved to a SMART capable system to read out the drive wear attribute values.

Use Case 1 – With a System Capable of SMART Commands

1. On a SMART capable system, issue the SMART EXECUTE OFF-LINE IMMEDIATE (D4h) sub-command 40h to reset the drive wear attributes.
2. Run the workload to be evaluated for at least 60 minutes. Otherwise the drive wear attributes will not be available.
3. Read out the drive wear attributes with the SMART READ DATA (D0h) command.



Use Case 2 – With a System Not Capable of SMART Commands

1. On a SMART capable system, issue the SMART EXECUTE OFF-LINE IMMEDIATE (D4h) sub-command 40h to reset the drive wear attributes.
2. Move the drive to the system where the workload will be measured (and not capable of SMART commands).
3. Run the workload to be evaluated for at least 60 minutes. Otherwise the drive wear attributes will not be available.
4. Do a clean system power down by issuing the ATA STANDBY IMMEDIATE command prior to shutting down the system. This will store all the drive wear SMART attributes to persistent memory within the drive.
5. Move the drive to a SMART capable system.
6. Read out the drive wear attributes with the SMART READ DATA (D0h) command within 59 seconds after power-up.

Example Calculation of Drive Wear

The following is an example of how the drive wear attributes can be used to evaluate the impact of a given workload. The Host Writes SMART attribute (E1h) can also be used to calculate the amount of data written by the host during the workload by reading this attribute before and after running the workload. This example assumes that the steps shown in “Example Use Cases” on page 18 were followed to obtain the following attribute values:

- Timed Workload Media Wear (E2h) has a raw value of 16. Therefore, the percentage wear = $16/1024 = 0.016\%$.
- Timed Workload Host Read/Write Ratio (E3h) has a normalized value of 80, indicating that 80% of operations were reads.
- Workload Timer (E4h) has a raw value of 500. Therefore the workload ran for 500 minutes.
- Host Writes Count (E1h) had a raw value of 100,000 prior to running the workload and a value of 130,000 at the end of the workload. Therefore, the number of sectors written by the host during the workload was $30,000 * 65,535 = 1,966,050,000$ sectors or $1,966,050,000 * 512/1,000,000,000 = 1,007$ GB.

The following conclusions can be made for this example case:

The workload took 500 minutes to complete with 80% reads and 20% writes. A total of 1,007 GB of data was written to the device, which increased the media wear in the drive by 0.016%. At this point in time, this workload is causing a wear rate of 0.016% for every 500 minutes, or 0.00192%/hour.

5.4.3 SMART Logs

The Intel SSD DC S4500/S4600 Series implements the following Log Addresses: 00h, 02h, 03h, 06h, and 07h.

The DC S4500/S4600 Series implements host vendor specific logs (addresses 80h-9Fh) as read and write scratchpads, where the default value is zero (0). Intel SSD DC S4500/S4600 does not write any specific values to these logs unless directed by the host through the appropriate commands.

The DC S4500/S4600 Series also implements a device vendor specific log at address A9h as a read-only log area with a default value of zero (0). Besides that, the DC S4500/S4600 Series also implements log address B8h (if the drive is in disable logical mode, log address B8h will have a failure code). Finally, the DC S4500/S4600 Series also implements log at addresses B9h and BAh (both of them are Intel error logs, and read only for customers).



5.5 Device Statistics

In addition to the SMART attribute structure, statistics pertaining to the operation and health of the Intel SSD DC S4500/S4600 Series can be reported to the host on request through the Device Statistics log as defined in the ATA specification.

The Device Statistics log is a read-only GPL/SMART log located at read log address 0x04 and is accessible using READ LOG EXT, READ LOG DMA EXT or SMART READ LOG commands.

The following table lists the Device Statistics supported by the Intel SSD DC S4500/S4600 Series.

Table 32: Device Statistics

Page	Offset	Description	Equivalent SMART attribute (if applicable)
0x00	--	List of Supported Pages	--
0x01 – General Statistics	0x08	Power Cycle Count	0Ch
	0x10	Power-On Hours	09h
	0x18	Logical Sectors Written	E1h
	0x20	Num Write Commands – incremented by one for every host write	--
	0x28	Logical Sectors Read	F2h
	0x30	Num Read Commands – incremented by one for every host read	--
0x04 – General Error Statistics	0x08	Num Reported Uncorrectable Errors	BBh
	0x10	Num Resets Between Command Acceptance and Completion	--
0x05 – Temperature Statistics	0x00	Device Statistics Information Header	--
	0x08	Current Temperature	--
	0x10	Average Short Term Temperature	--
	0x18	Average Long Term Temperature	--
	0x20	Highest Temperature	--
	0x28	Lowest Temperature	--
	0x30	Highest Average Short Term Temperature	--
	0x38	Lowest Average Short Term Temperature	--
	0x40	Highest Average Long Term Temperature	--
	0x48	Lowest Average Long Term Temperature	--
	0x50	Time in Over-Temperature	--
	0x58	Specified Maximum Operating Temperature	--
	0x60	Time in Under-Temperature	--
	0x68	Specified Minimum Operating Temperature	--
0x06 – Transport Statistics	0x08	Number of Hardware Resets	--
	0x10	Number of ASR Events	--
	0x18	Number of Interface CRC Errors	--
0x07 – Solid State Device Statistics	0x08	Percentage Used Endurance Indicator	E9h Note: This device statistic counts from 1 to 150



5.6 SMART Command Transport (SCT)

With SMART Command Transport (SCT), a host can send commands and data to an SSD and receive status and data from an SSD using standard write/read commands to manipulate two SMART Logs:

- Log Address E0h ("SCT Command/Status") — used to send commands and retrieve status
- Log Address E1h ("SCT Data Transfer") — used to transport data

Intel SSD DC S4500/S4600 supports the following standard SCT actions:

- Write Same — DC S4500/S4600 Series implements this action code as described in the ATA specification.
- Error Recovery Control — DC S4500/S4600 Series accepts this action code and will store and return error-recovery time limit values.
- Feature Control - DC S4500/S4600 Series supports feature code 0001h (write cache) feature code 0002h (write cache reordering), and feature code 0003h (time interval for temperature logging). It also supports D000h (Power Safe Write Cache capacitor test interval), D001h (read/write power governor mode), D002h (read thermal governor mode), D003h (read power governor burst power), and D004h (read power governor average power).
- Data table command - DC S4500/S4600 Series supports data table command as specified in ATA8-ACS3 REV5. This will read out temperature logging information in table ID 0002h.
- Read Status Support - DC S4500/S4600 Series supports read status log
- By using SCT command 0xD801 with State=0, Option=1, ID Word 106 can be changed from 0x6003 to 0x4000 (4KB physical sector size to 512B physical sector size support change).

5.7 Data Set Management Command Set

Intel SSD DC S4500/S4600 Series supports the Data Set Management command set Trim attribute, which consists of:

- DATA SET MANAGEMENT

5.8 Accessible Max Address Configuration Command Set

Intel SSD DC S4500/S4600 Series supports the Accessible Max Address Configuration Command set, which consists of:

- GET NATIVE MAX ADDRESS EXT
- SET ACCESSIBLE MAX ADDRESS EXT
- FREEZE ACCESSIBLE MAX ADDRESS EXT



5.9 48-Bit Address Command Set

Intel SSD DC S4500/S4600 Series supports the 48-bit Address command set, which consists of:

- FLUSH CACHE EXT
- READ DMA EXT
- READ NATIVE MAX ADDRESS EXT
- READ SECTOR(S) EXT
- READ VERIFY SECTOR(S) EXT
- SET MAX ADDRESS EXT
- WRITE DMA EXT
- WRITE MULTIPLE EXT
- WRITE SECTOR(S) EXT
- WRITE MULTIPLE FUA EXT
- WRITE DMA FUA EXT

5.10 General Purpose Log Command Set

Intel SSD DC S4500/S4600 Series supports the General Purpose Log command set, which consists of:

- READ LOG EXT
- WRITE LOG EXT

5.11 Native Command Queuing

Intel SSD DC S4500/S4600 Series supports the Native Command Queuing (NCQ) command set, which includes:

- READ FPDMA QUEUED
- WRITE FPDMA QUEUED

Note: With a maximum Queue Depth set to 32.

5.12 Software Settings Preservation

Intel SSD DC S4500/S4600 Series supports the SET FEATURES parameter to enable/disable the preservation of software settings.



6 Certifications and Declarations

The following table describes the Device Certifications supported by the Intel SSD DC S4500/S4600 Series.

Table 33: Device Certifications and Declarations

Certification	Description
CE Compliant	Low Voltage DIRECTIVE 2006/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006, and EMC Directive 2004/108/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 December 2004.
UL Recognized	Underwriters Laboratories, Inc. Bi-National Component Recognition; UL 60950-1, 2nd Edition, 2007-03-27 (Information Technology Equipment - Safety - Part 1: General Requirements) CSA C22.2 No. 60950-1-07, 2nd Edition, 2007-03 (Information Technology Equipment - Safety - Part 1: General Requirements)
C-Tick Compliant	Compliance with the Australia/New Zealand Standard AS/NZS3548 and Electromagnetic Compatibility (EMC) Framework requirements of the Australian Communication Authority (ACA).
BSMI Compliant	Compliance to the Taiwan EMC standard CNS 13438: Information technology equipment - Radio disturbance Characteristics - limits and methods of measurement, as amended on June 1, 2006, is harmonized with CISPR 22: 2005.04.
KCC	Compliance with paragraph 1 of Article 11 of the Electromagnetic Compatibility Control Regulation and meets the Electromagnetic Compatibility (EMC) Framework requirements of the Radio Research Laboratory (RRL) Ministry of Information and Communication Republic of Korea.
VCCI	Voluntary Control Council for Interface to cope with disturbance problems caused by personal computers or facsimile.
RoHS Compliant	Restriction of Hazardous Substance Directive
WEEE	Directive on Waste Electrical and Electronic Equipment



7 References

The following table identifies the standards information referenced in this document.

Table 34: Standards References

Date	Title	Location
October 2013	ACS-3-ATA/ATAPI Command Set 3 Specification	http://www.t13.org/
July 2011	Serial ATA Revision 3.1	http://www.sata-io.org/
July 2012	Solid-State Drive (SSD) Requirements and Endurance Test Method (JESD219)	http://www.jedec.org/standards-documents/results/jesd219
Sept 2010	Solid-State Drive (SSD) Requirements and Endurance Test Method (JESD218)	http://www.jedec.org/standards-documents/docs/jesd218/
June 2009	RoHS	http://qdms.intel.com/ Click <i>Search MDDS Database</i> and search for material description datasheet
Dec 2008	VCCI	http://www.vcci.jp/vcci_e/
May 2006	SFF-8223, 2.5-inch Drive w/Serial Attachment Connector	http://www.sffcommittee.org/
May 2005	SFF-8201, 2.5-inch drive form factor	http://www.sffcommittee.org/
1995	ENV 50204 (Radiated electromagnetic field from digital radio telephones)	http://www.dbicorporation.com/radimmun.htm/
1995 1996 1995 1995 1997 1994	International Electrotechnical Commission EN 61000 4-2 (Electrostatic discharge immunity test) 4-3 (Radiated, radio-frequency, electromagnetic field immunity test) 4-4 (Electrical fast transient/burst immunity test) 4-5 (Surge immunity test) 4-6 (Immunity to conducted disturbances, induced by radio-frequency fields) 4-11 (Voltage Variations, voltage dips, short interruptions and voltage variations immunity tests)	http://www.iec.ch/

Appendix A: IDENTIFY DEVICE Command Data

Table 35: Returned Sector Data

Word	F = Fixed V = Variable X = Both	Default Value	Description
0	X	0040h	General configuration bit-significant information
1	X	3FFFh	Obsolete - Number of logical cylinders (16,383)
2	V	C837h	Specific configuration
3	X	0010h	Obsolete - Number of logical heads (16)
4-5	X	0h	Retired
6	X	003Fh	Obsolete - Number of logical sectors per logical track (63)
7-8	V	0h	Reserved for assignment by the CompactFlash* Association (CFA)
9	X	0h	Retired
10-19	F	varies	Serial number (20 ASCII characters)
20-21	X	0h	Retired
22	X	0h	Obsolete
23-26	F	varies	Firmware revision (8 ASCII characters)
27-46	F	varies	Model number (Intel® Solid-State Drive)
47	F	8001h	7:0—Maximum number of sectors transferred per interrupt on multiple commands
48	F	4000h	Trusted Computing Feature Set
49	F	2F00h	Capabilities
50	F	4000h	Capabilities
51-52	X	0h	Obsolete
53	F	0006h	Words 88 and 70:64 valid
54-58	X	00FBFh	Obsolete
59	F	FD01h	Number of sectors transferred per interrupt on multiple commands
60-61	V	240GB: 0FFFFFFFh 480GB: 0FFFFFFFh 960GB: 0FFFFFFFh 1920GB: 0FFFFFFFh 3840GB: 0FFFFFFFh 7680GB: 0FFFFFFFh	Total number of user-addressable sector for 28-bit commands
62	X	0h	Obsolete
63	X	0007h	Multi-word DMA modes supported/selected
64	F	0003h	PIO modes supported
65	F	0078h	Minimum multiword DMA transfer cycle time per word
66	F	0078h	Manufacturer's recommended multiword DMA transfer cycle time
67	F	0078h	Minimum PIO transfer cycle time without flow control
68	F	0078h	Minimum PIO transfer cycle time with IORDY flow control
69	F	403Ch	Additional Supported
70	F	0000h	Reserved
71-74	F	0h	Reserved for IDENTIFY PACKET DEVICE command
75	F	001Fh	Queue depth
76	F	850Eh	Serial ATA capabilities
77	F	0006h	Reserved for future Serial ATA definition
78	F	0040h	Serial ATA features supported



Word	F = Fixed V = Variable X = Both	Default Value	Description
79	V	0040h	Serial ATA features enabled
80	F	07FCh	Major version number
81	F	006Dh	Minor version number
82	F	706Bh	Command set supported
83	F	7401h	Command sets supported
84	F	6163h	Command set/feature supported extension
85	X	7069h	Command set/feature enabled
86	X	B401h	Command set/feature enabled
87	X	6163h	Command set/feature default
88	X	407Fh	Ultra DMA Modes
89	F	0002h	Time required for security erase unit completion
90	F	0002h	Time required for enhanced security erase completion
91	V	0h	Current advanced power management value
92	V	FFFEh	Master Password Revision Code
93	X	0h	Hardware reset result: the contents of bits (12:0) of this word shall change only during the execution of a hardware reset
94	V	0h	Vendor's recommended and actual acoustic management value
95	F	0h	Stream minimum request size
96	V	0h	Streaming transfer time - DMA
97	V	0h	Streaming access latency - DMA and PIO
98-99	F	0h	Streaming performance granularity
100-103	V	240GB: 1BF244B0h 480GB: 37E436B0h 960GB: 6FC81AB0h 1920GB: 8BBA0CB0h 3840GB: BA4D4AB0h 7680GB: 37E3E92B0h	Maximum user LBA for 48-bit address feature set
104	V	0h	Streaming transfer time - PIO
105	V	0004h	Maximum number of 512-byte blocks of LBA Range Entries per DATA SET MANAGEMENT command
106	F	6003h	Physical sector size / logical sector size – User Changeable by SCT command to report 512B
107	F	0h	Inter-seek delay for ISO-7779 acoustic testing in microseconds
108-111	F	varies	Unique ID
112-115	F	0h	Reserved for worldwide name extension to 128 bits
116	V	0h	Reserved for technical report
117-118	F	0h	Words per logical sector
119	F	415Ch	Supported settings
120	X	411Ch	Command set/feature enabled/supported
121-126	F	0h	Reserved
127	X	0h	Removable Media Status Notification feature set support
128	X	0029h	Security status
129-159	V	0h	Vendor-specific
160	X	0h	CompactFlash Association (CFA) power mode 1
161-167	X	0h	Reserved for assignment by the CFA
168	X	0003h	Device Nominal Form Factor
169	X	0001h	Data set management Trim attribute support



Word	F = Fixed V = Variable X = Both	Default Value	Description
170-175	F	0h	Reserved for assignment by the CFA
176-205	V	Varies	Current media serial number
206	X	003Dh	SCT Command Transport
207-208	F	0000h	Reserved
209	X	4000h	Alignment of logical blocks within a physical block
210-211	V	0000h	Write-Read-Verify Sector Count Mode 3 (DWord)
212-213	F	0000h	Write-Read-Verify Sector Count Mode 2 (DWord)
214-216	X	0000h	Obsolete
217	F	0001h	Nominal media rotation rate
218	V	0000h	Reserved
219	F	0000h	Obsolete
220	V	0000h	Reserved
221	X	0000h	Reserved
222	F	10FFh	Transport major version number
223	F	0000h	Transport minor version number
224-233	F	0000h	Reserved
234	F	0001h	Minimum number of 512-byte data blocks per DOWNLOAD MICROCODE command for mode 03h
235	F	FFFFh	Maximum number of 512-byte data blocks per DOWNLOAD MICROCODE command for mode 03h
236-254	X	0000h	Reserved
255	V	Varies	Integrity word

Notes:

F = Fixed. The content of the word is fixed and does not change. For removable media devices, these values may change when media is removed or changed.

V = Variable. The state of at least one bit in a word is variable and may change depending on the state of the device or the commands executed by the device.

X = F or V. The content of the word may be fixed or variable.