Intel® Solid-State Drive DC S3500 Series (1.2TB and 1.6TB)

Product Specification Addendum

- Capacity:
  - 1.2TB and 1.6TB
- Components:
  - Intel® 20nm NAND Flash Memory
  - Multi-Level Cell (MLC)
- Form Factor: 2.5–inch[1]
- Read and Write IOPS[2,3] (Full LBA Range, IOMeter* Queue Depth 32)
  - Random 4 KB[4] Reads: Up to 65,000 IOPS
  - Random 4 KB Writes: Up to 15,500 IOPS
  - Random 8 KB[4] Reads: Up to 44,500 IOPS
  - Random 8 KB Writes: Up to 8,000 IOPS
- Bandwidth Performance[2]
  - Sustained Sequential Read: Up to 500 MB/s[5]
  - Sustained Sequential Write: Up to 460 MB/s[5]
- Latency (average sequential)
  - Read: 55 µs (TYP)
  - Write: 65 µs (TYP)
- Quality of Service[6,7]
  - Read/Write: 500 µs / 5 ms (99.9%)
- AES 256-bit Encryption
- Compliance
  - SATA Revision 3.0; compatible with SATA 6Gb/s, 3Gb/s and 1.5Gb/s interface rates
  - ATA8-ACS2; 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
- Compatibility
  - Windows 7*, Windows 8*, Windows 8.1*
  - Windows* Server 2012 R2*, Windows Server 2012*
  - Windows* Server 2008* Enterprise 32/64bit SP2
  - Windows* Server 2008* R2 SP1
  - Windows* Server 2003* Enterprise 64bit SP2
  - Red Hat* Enterprise Linux* 5.5, 5.6, 6.1, 6.3, 7.0
  - SUSE* Linux Enterprise Server 10*, 11 SP1CentOS* 64bit 5.7, 6.3
  - Intel® SSD Toolbox with Intel® SSD Optimizer
- Altitude[8]
  - Operating: -1,000 to 10,000 ft
  - Operating[9]: -10,000 to 15,000 ft
  - Non-operating: -1,000 to 40,000 ft
- Product Ecological Compliance
  - RoHS*
- Power Management
  - 2.5 inch: 5V or 5V +12V SATA Supply Rail[10]
  - SATA Interface Power Management
  - OS-aware hot plug/removal
  - Enhanced power-loss data protection
- Power[11]
  - Active: Up to 5.2 W (TYP)
  - Idle: 700 mW
- Weight
  - 94 grams ± 2 grams
- Temperature
  - Operating: 0° C to 70° C
  - Non-Operating[12]: -55° C to 95° C
  - Temperature monitoring and logging
  - Thermal throttling
- Shock (operating and non-operating):
  1,000 G/0.5 msec
- 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 $10^{\wedge 17}$ bits read
  - Mean Time Between Failures (MTBF):
    2 million hours
  - End-to-End data protection
- Endurance Rating[13]
  - 1.2TB: 660 TBW
  - 1.6TB: 880 TBW
- Certifications and Declarations
  - UL*, CE*, C-Tick*, BSMI*, KCC*, Microsoft WHCK*, VCCI*, SATA-IO

1. The 2.5 form factor is identical to the S3500 lower capacity models.
2. Performance values vary by capacity
3. Performance specifications apply to both compressible and incompressible data
4. 4KB = 4,096 bytes; 8KB = 8,192 bytes
5. MB/s = 1,000,000 bytes/second.
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. Altitude pressure is simulated in a test chamber; excludes soft error
9. Extended operation at a higher altitude might impact reliability.
10. If both 5V and 12V power supplies are present, will source power from both. 5V must be present
11. Based on 5V power supply only
12. Please contact your Intel representative for details on the non-operating temperature range
13. Based on JESD218 standard

Order Number: 331349-003US

Ordering Information

Contact your local Intel sales representative for ordering information.

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Revision History

Revision	Description	Date
001	Initial release.	November 2014
002	Updated description and value of word 106 in Appendix A's Returned Sector Data table.	January 2015
003	Added 3 new sections, i.e., Supported Command Sets, SMART Attributes and Certifications and Declarations to this document.	July 2015

Related Document

Title	Link
Intel® Solid-State Drive DC S3500 Series Product Specification	http://www.intel.com/content/dam/www/public/us/en/documents/product-specifications/ssd-dc-s3500-spec.pdf

1 Overview

This document is an addendum to the Intel® SSD DC S3500 Series and outlines the differences between the previously released products and the higher capacity 1.2TB and 1.6TB products.

The Intel SSD DC S3500 Series delivers leading performance and Quality of Service combined with world-class reliability for Serial Advanced Technology Attachment (SATA)-based computers. These two new models extend the storage capacities of the existing Intel SSD DC S3500 Series.

By combining 20nm Intel® SSD NAND Flash Memory technology with SATA 6Gb/s interface support, the Intel SSD DC S3500 Series delivers sequential read speeds of up to 500 MB/s and sequential write speeds of up to 450 MB/s. Intel SSD DC S3500 Series delivers Quality of Service of 500 us for random 4KB reads measured at a queue depth of 1.

Intel SSD DC S3500 Series offers these key features:

- Standard Endurance Technology
- High I/O and throughput performance
- Consistent I/O latency
- Enhanced power-loss data protection
- End-to-End data protection
- Thermal throttling
- Temperature Sensor
- Inrush current management
- Low power
- High reliability
- Enhanced ruggedness
- Temperature monitor and logging
- Power loss protection capacitor self-test

The 2.5 form factor is identical to Intel SSD DC S3500 Series lower capacity models. For the full mechanical specifications, see the Intel® Solid-State Drive DC S3500 Series Product Specification.

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2 Product Specifications

2.1 Capacity

Table 1: User Addressable Sectors

Intel SSD DC S3500 Series	Unformatted Capacity (Total User Addressable Sectors in LBA Mode)
1.2TB[1]	2,344,225,968[2]
1.6TB[1]	3,125,627,568[2]

Notes:
1. 1TB = 1,000,000,000,000 (trillion) bytes; 1 sector = 512 bytes.
2. LBA count shown represents total user storage capacity and will remain the same throughout the life of the drive.

2.2 Performance

Table 2: Random Read/Write Input/Output Operations Per Second (IOPS)

Specification[1]	Unit	Intel SSD DC S3500 Series	
		1.2TB	1.6TB
Random 4KB Read (up to)[2]	IOPS	65,500	65,000
Random 4KB Write (up to)	IOPS	15,500	14,600
Random 8KB Read (up to)[3]	IOPS	44,500	44,000
Random 8KB Write (up to)	IOPS	8,000	7,500

Notes:
1. Performance measured using IOMeter* with Queue Depth 32. Measurements are performed on a full Logical Block Address (LBA) span of the drive.
2. 4KB = 4,096 bytes
3. 8KB = 8,192 bytes

Table 3: Random Read/Write IOPS Consistency

Specification1	Unit	Intel SSD DC S3500 Series	
		1.2TB	1.6TB
Random 4 KB Read (up to)[2]	%	90	90
Random 4 KB Write (up to)	%	80	80
Random 8 KB Read (up to)[3]	%	90	90
Random 8 KB Write (up to)	%	80	80

Notes:
1. Performance consistency measured using IOMeter* 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). Measurements are performed 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.
2. 4KB = 4,096 bytes
3. 8KB = 8,192 bytes

Table 4: Sequential Read and Write Bandwidth

Specification	Unit	Intel SSD DC S3500 Series	
		1.2TB	1.6TB
Sequential Read (SATA 6Gb/s)[1]	MB/s	500	500
Sequential Write (SATA 6Gb/s)[1]	MB/s	460	460

Note:
1. Performance measured using IOMeter* with 128 KB (131,072 bytes) of transfer size with Queue Depth 32.

Table 5: Latency

Specification	Intel SSD DC S3500 Series	
	1.2TB	1.6TB
Latency[1] (TYP)		
Read	50 µs	50 µs
Write	65 µs	65 µs
Power On to Ready[2]	6.0 s	7.0 s

Notes:
1. Device measured using IOMeter. Latency measured using 4KB (4,096 bytes) transfer size with Queue Depth equal to 1 on a sequential workload.
2. Power On To Ready time assumes proper shutdown. Time varies if shutdown is not preceded by STANDBY IMMEDIATE command.

Table 6: Quality of Service

Specification	Unit	Intel SSD DC S3500 Series			
		Queue Depth=1		Queue Depth=32	
		1.2TB	1.6TB	1.2TB	1.6TB
Quality of Service[1, 2] (99.9%)					
Reads	ms	0.5	0.5	5	5
Writes	ms	5	0.5	15	10
Quality of Service[1, 2] (99.9999%)					
Reads	ms	5	5	5	10
Writes	ms	15	10	20	20

Notes:
1. Device measured using IOMeter. 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.
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.

2.3 Electrical Characteristics

Table 7: Operating Voltage for 2.5-inch Form Factor

Electrical Characteristics	Intel SSD DC S3500 Series
	1.2TB/1.6TB
5 V Operating Characteristics:	
Operating Voltage range	5 V (±5%)
Rise time (Max/Min)	1 s / 1 ms
Fall time (Min)[2]	1 ms
Noise level	500 mV pp 10 Hz – 100 KHz 50 mV pp 100 KHz – 20 MHz
Min Off time[3]	500 ms
Inrush Current (Typical Peak) [1]	1.2 A, < 1 s
12 V Operating Characteristics:	
Operating Voltage range	12 V (±10%)
Rise time (Max/Min)	1 s / 1 ms
Fall time (Min)[2]	1 ms
Noise level	1000 mV pp 10 Hz – 100 KHz 100 mV pp 100 KHz – 20 MHz
Min Off time[3]	500 ms
Inrush Current (Typical Peak) [1]	1.2 A, < 1 s

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

Table 8: Power Consumption for 2.5-inch Form Factor (5V Supply)

Specification	Unit	Intel SSD DC S3500 Series	
		1.2TB	1.6TB
Active Write - RMS Average [1]	W	5.0	5.2
Active Write - RMS Burst [2]	W	6.9	7.2
Active Write - RMS MAX Burst [3]	W	8.7	8.7
Active Read - RMS Average [4]	W	2.5	2.5
Active Read – RMS Burst [5]	W	3.0	3.4
Active Read – RMS MAX Burst [6]	W	4.8	4.8
Idle	W	0.7	0.7

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 with PLI capacitor charge enabled.
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 µs sample period with PLI capacitor charge disabled.
3. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Max burst power is measured using Agilent Power Analyzer over a 500 us sample period with PLI capacitor charge enabled. Pulse is 0.25% of total time.
4. 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 with PLI capacitor charge enabled.
5. 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 µs sample period with PLI capacitor charge disabled.
6. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) Max Burst power is measured using Agilent Power Analyzer over a 500 us sample period with PLI capacitor charge enabled. Pulse is approximately 0.25% of total time.

Table 9: Power Consumption for 2.5-inch Form Factor (5V and 12V Supply)

Specification	Unit	Intel SSD DC S3500 Series			
		1.2TB		1.6TB	
		5V	12V	5V	12V
Active Write - RMS Average [1]	W	1.9	2.9	2.0	3.4
Active Write - RMS Burst [2]	W	2.5	5.5	2.6	6.0
Active Write - RMS MAX Burst [3]	W	4.3	5.7	4.2	6.0
Active Read - RMS Average [4]	W	1.3	0.01	1.3	0.01
Active Read - RMS Burst [5]	W	2.1	0.1	2.0	0.1
Active Read – RMS MAX Burst [6]	W	3.6	0.2	3.5	0.3
Idle	W	0.7	0.01	0.7	0.01

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 with PLI capacitor charge enabled.
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 µs sample period with PLI capacitor charge disabled.
3. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential writes. RMS (Root Mean Squared) Max burst power is measured using Agilent Power Analyzer over a 500 us sample period with PLI capacitor charge enabled. Pulse is 0.25% of total time.
4. 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 with PLI capacitor charge enabled.
5. 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 µs sample period with PLI capacitor charge disabled.
6. The workload equates 128 KB (131,072 bytes) Queue Depth equal to 32 sequential reads. RMS (Root Mean Squared) Max Burst power is measured using Agilent Power Analyzer over a 500 us sample period with PLI capacitor charge enabled. Pulse is approximately 0.25% of total time.

2.4 Environmental Conditions

Table 10: Temperature, Shock, Vibration for Intel SSD DC 3500 2.5-inch Form Factor

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 msec 1,000 G (Max) at 0.5 msec
Vibration[4] Operating Non-operating	 2.17 G_{RMS} (5-700 Hz) 3.13 G_{RMS} (5-800 Hz)

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.

2.5 Product Regulatory Compliance

Intel SSD DC S3500 Series meets or exceeds the regulatory or certification requirements listed in the following table:

Table 11: Product Regulatory Compliance Specifications

Title	Description	Region For Which Conformity Declared
TITLE 47-Telecommunications CHAPTER 1— FEDERAL COMMUNMICATIONS COMMISSION PART 15 — RADIO FREQUENCY DEVICES	FCC Part 15B Class B	USA
ICES*-003, Issue 4 Interference-Causing Equipment Standard Digital Apparatus	CA/CSA-CEI/IEC CISPR 22-10 (Ref. CISPR 22:2008).	Canada
IEC* 55024 Information Technology Equipment — Immunity characteristics— Limits and methods of measurement CISPR24:2010	EN-55024: 2010 and its amendments	European Union
IEC* 55022 Information Technology Equipment — Radio disturbance Characteristics— Limits and methods of measurement CISPR22:2008 (Modified)	EN-55022: 2010 and its amendments	European Union
EN-60950-1 2nd Edition	Information Technology Equipment — Safety — Part 1: General Requirements	USA/Canada
UL/CSA EN-60950-1 2nd Edition	Information Technology Equipment — Safety — Part 1: General Requirements	USA/Canada

2.6 Reliability

Intel SSD DC S3500 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 12: 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 1017 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 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
Endurance Rating1 The number of drive writes such that the SSD meets the requirements according to the JESD2182 standard and JESD219 workload	1.2TB: Up to 660 TBW 1.6: Up to 880 TBW

Note:

1. Refer to JESD218 standard table 1 for UBER, FFR and other Enterprise SSD endurance verification requirements. UBER design and majority of life target is 1E-17. Endurance verification acceptance criterion based on establishing <1E-16 at 60 confidence.

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3 Supported Command Sets

The Intel SSD DC S3500 Series HD supports all mandatory ATA (Advanced Technology Attachment) commands defined in the ATA8-ACS specification described in this section.

3.1 ATA General Feature Command Set

The Intel SSD DC S3500 Series HD 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 S3500 Series HD 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 MODE[1]
- WRITE MULTIPLE
- FLUSH CACHE
- READ BUFFFER
- WRITE BUFFER
- NOP
- DOWNLOAD MICROCODE
- WRITE UNCORRECTABLE EXT

1. The only multiple supported will be multiple 1

3.2 Power Management Command Set

The Intel SSD DC S3500 Series HD supports the Power Management command set, which consists of:

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

3.3 Security Mode Feature Set

The Intel SSD DC S3500 Series HD 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

3.4 SMART Command Set

The Intel SSD DC S3500 Series HD 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

3.4.1 Attributes

Table 13 lists the SMART attributes supported by the Intel SSD DC S3500 Series HD and the corresponding status flags and threshold settings.

Table 13: 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
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)

ID	Attribute	Status Flags						Threshold
		SP	EC	ER	PE	OC	PW	
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)
AEh	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 <= result <= 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 *Raw value*: reports number of LBA tag mismatches in end-to-end data protection path. *Normalized value*: always 100.	1	1	0	0	1	1	90
BBh	Uncorrectable Error Count The raw value shows the count of errors that could not be recovered using Error Correction Code (ECC). *Normalized value*: always 100.	1	1	0	0	1	0	0 (none)
BEh	Temperature - Airflow Temperature (Case) Reports the SSD case temperature. Raw value suggests 100 - case temperature in C degrees.	1	0	0	0	1	0	0 (none)
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)
C2h	Temperature - Device Internal Temperature Reports internal temperature of the SSD. Temperature reading is the value direct from the printed circuit board (PCB) sensor without offset.	1	0	0	0	1	0	0 (none)

ID	Attribute	Status Flags						Threshold
		SP	EC	ER	PE	OC	PW	
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	0	0	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)
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	1	1	0	0	1	0	0 (none)

ID	Attribute	Status Flags						Threshold
		SP	EC	ER	PE	OC	PW	
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 14: 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

3.4.2 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. The raw value tracks the percentage up to 2 decimal precision points. 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 232 = 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.

3.4.3 SMART Logs

The Intel SSD DC S3500 Series HD implements the following Log Addresses: 00h, 02h, 03h, 06h, and 07h.

The DC S3500 Series HD implements host vendor specific logs (addresses 80h-9Fh) as read and write scratchpads, where the default value is zero (0). Intel® SSD DC S3510 does not write any specific values to these logs unless directed by the host through the appropriate commands.

The DC S3500 Series HD 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 S3500 Series HD also implements log address B8h (if the drive is in disable logical mode, log address B8h will have the word error code for *BAD_CTX). Finally the DC S3500 Series HD also implements log at addresses B9h and BAh (both of them are Intel error logs, and read only for customers).

3.5 Device Statistics

In addition to the SMART attribute structure, statistics pertaining to the operation and health of the Intel SSD DC S3500 Series HD 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.

Table 20 lists the Device Statistics supported by the Intel SSD DC S3500 Series HD.

Table 15: Serial ATA Power Pin Definitions—2.5-inch Form Factors

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

3.6 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 S3510 supports the following standard SCT actions:

- Write Same — DC S3500 Series HD implements this action code as described in the ATA specification.
- Error Recovery Control — DC S3500 Series HD accepts this action code, and will store and return error-recovery time limit values.
- Feature Control - DC S3500 Series HD 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 S3500 Series HD supports data table command as specified in ATA8-ACS2. This will read out temperature logging information in table ID 0002h.
- Read Status Support - DC S3510 supports read status log
- By using SCT command 0xD801with 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).

3.7 Data Set Management Command Set

Intel SSD DC S3500 Series HD supports the Data Set Management command set Trim attribute, which consists of:

- `DATA SET MANAGEMENT`

3.8 Host Protected Area Command Set

Intel SSD DC S3500 Series HD supports the Host Protected Area command set, which consists of:

- `READ NATIVE MAX ADDRESS`
- `SET MAX ADDRESS`
- `READ NATIVE MAX ADDRESS EXT`
- `SET MAX ADDRESS EXT`

Intel SSD DC S3500 Series HD also supports the following optional commands:

- `SET MAX SET PASSWORD`
- `SET MAX LOCK`
- `SET MAX FREEZE LOCK`
- `SET MAX UNLOCK`

3.9 48-Bit Address Command Set

Intel SSD DC S3500 Series HD 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

3.10 General Purpose Log Command Set

Intel SSD DC S3500 Series HD supports the General Purpose Log command set, which consists of:

- READ LOG EXT
- WRITE LOG EXT

3.11 Native Command Queuing

Intel SSD DC S3500 Series HD 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.

3.12 Software Settings Preservation

Intel SSD DC S3500 Series HD supports the SET FEATURES parameter to enable/disable the preservation of software settings.

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4 Certifications and Declarations

Table 21 describes the Device Certifications supported by the Intel SSD DC S3500 Series HD .

Table 16: 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

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Appendix A: IDENTIFY DEVICE Command Data

Table 17: 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	0007h	Words 88 and 70:64 valid
54	X	3FFFh	Obsolete - Number of logical cylinders (16,383)
55	X	0010h	Obsolete - Number of logical heads (16)
56	X	003Fh	Obsolete - Number of logical sectors per logical track (63)
57-58	X	FC1000FBh	Obsolete
59	F	B101	Number of sectors transferred per interrupt on multiple commands
60-61	V	1200GB: 0FFFFFFFh 1600GB: 0FFFFFFFh	Total number of user-addressable sector
62	X	10000h	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	4030h	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

Word	F = Fixed V = Variable X = Both	Default Value	Description
77	F	0006h	Reserved for future Serial ATA definition
78	F	0040h	Serial ATA features supported
79	V	0040h	Serial ATA features enabled
80	F	03FCh	Major version number
81	F	0110h	Minor version number
82	F	746Bh	Command set supported
83	F	7501h	Command sets supported
84	F	6163h	Command set/feature supported extension
85	X	7469h	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	0FFFEh	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	1200GB: 8BBA0CB0h 1600GB: BA4D4AB0h	Maximum user LBA for 48-bit address feature set
104	V	0h	Streaming transfer time - PIO
105	V	0006h	Maximum number of 512-byte blocks of LBA Range Entries per DATA SET MANAGEMENT command
106	F	6003h	Physical sector size / logical sector size
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	405Ch	Supported settings
120	X	401Ch	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	V	001Ch	Vendor-specific
130-159	X	0h	Vendor-specific
160	X	0h	CompactFlash Association (CFA) power mode 1
161-167	X	0h	Reserved for assignment by the CFA

Word	F = Fixed V = Variable X = Both	Default Value	Description
168	X	0003h	Reserved for assignment by the CFA
169	X	0001h	Data set management Trim attribute support
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	X	0000h	NV Cache Capabilities
215-216	V	0000h	NV Cache Size in Logical Blocks (DWord)
217	F	0001h	Nominal media rotation rate
218	V	0000h	Reserved
219	F	0000h	NV Cache Options
220	V	0000h	Write-Read-Verify feature set
221	X	0000h	Reserved
222	F	101Fh	Transport major version number
223	F	0000h	Transport minor version number
224-229	F	0000h	Reserved
230-233	X	0000h	Extended Number of User Addressable Sectors (QWord)
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	46A5h	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.

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