

SATA 6Gb/s 2.5" SSD Manual

The SATA SSD is a non-volatile, solid-state storage device. With its Serial ATA interface and industry-standard form factors, it is a drop in replacement for hard disk drives. The SSD delivers extremely high levels of performance, reliability and ruggedness for I/O intensive or environmentally challenging applications.

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Revision History

| Date | Revision | Description | Checked By |
|---------|----------|---|------------|
| 2/7/17 | A | Revise from modified PSFS22xxxGSxxx_D. | |
| 3/13/17 | B | Revise from modified PSFS22xxxGSxxx_D with new PN's, performance, block diagram, TBW power consumption and DEVSLP | |
| 7/27/17 | C | Add IOP values. Revise capacities to 64GB to 960GB | |
| 8/14/17 | D | Add IT PN's | |

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Legal Information

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Ordering Information: 2.5" SSD Solid-State Drive

| Part Number | Interface | User GB | NAND | Temp | NAND |
|------------------|-----------|---------|------|----------------|--------------|
| VPFS22064GZCBMTL | SATA 6GB | 64 | MLC | (0 to +70'c) | TSB 15nm MLC |
| VPFS22120GZCBMTL | SATA 6GB | 120 | MLC | (0 to +70'c) | TSB 15nm MLC |
| VPFS22240GZCBMTL | SATA 6GB | 240 | MLC | (0 to +70'c) | TSB 15nm MLC |
| VPFS22480GZCAMTL | SATA 6GB | 480 | MLC | (0 to +70'c) | TSB 15nm MLC |
| VPFS22960GZCZMTL | SATA 6GB | 960 | MLC | (0 to +70'c) | TSB 15nm MLC |
| VPFS22120GZIAMTL | SATA 6GB | 120 | MLC | (-40 to +85'c) | TSB 15nm MLC |
| VPFS22240GZIAMTL | SATA 6GB | 240 | MLC | (-40 to +85'c) | TSB 15nm MLC |
| VPFS22480GZIZMTL | SATA 6GB | 480 | MLC | (-40 to +85'c) | TSB 15nm MLC |

Product Picture(s)



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1 Introduction

Viking SSD's offer the highest flash storage reliability and performance as well as support for many functional features.

1.1 Features

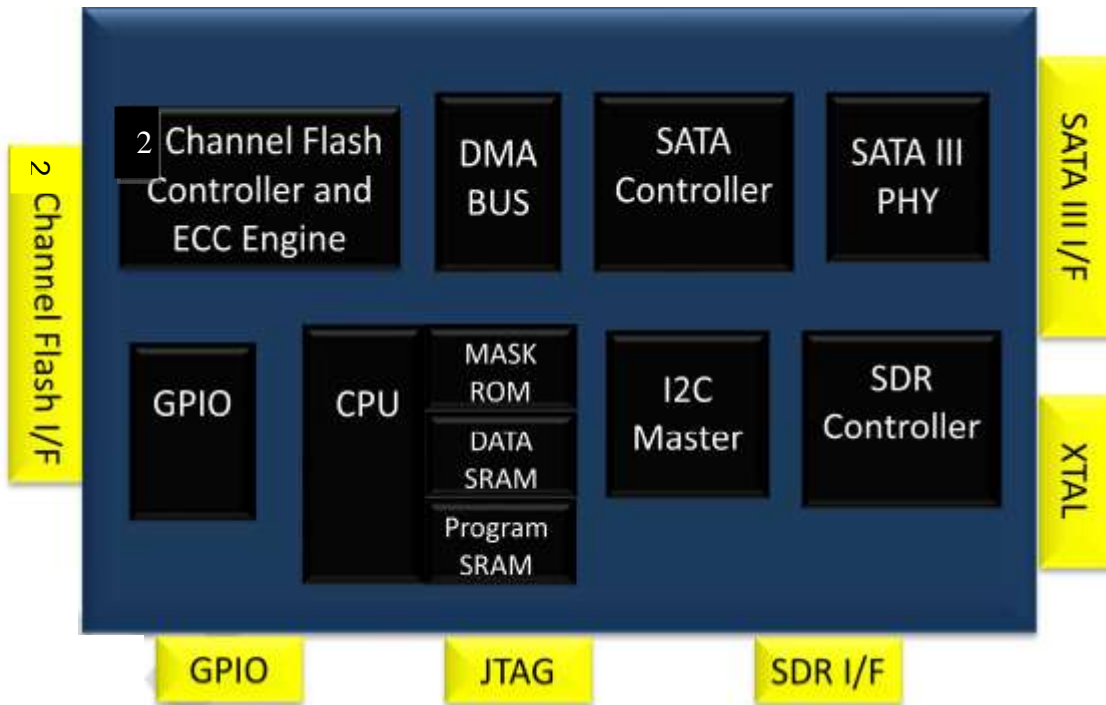
The SSD delivers the following features:

- Offers seamless SATA Revision 3.0 interface support for SATA up to 6Gb/s
- Low overall SSD power consumption
- Supports Native Command Queuing (NCQ) to 32 commands
- Compatible with all major SLC and MLC flash technologies
- S.M.A.R.T.
- Superior wear-leveling algorithm
- Efficient error recovery
- TRIM

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1.2 Block Diagram

Figure 1-1: High-Level Block Diagram



Notes: Support for up to 2-channels and 2 CE in the NAND Flash interface

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1.3 SATA Interface

- The Serial ATA (SATA) interface is compliant with the SATA IO Serial ATA specification, revision 3.0 that supports SATA up to 6Gb/s.
- The SATA interface connects the host computer to the SSD subsystem.
- The SATA interface runs at a maximum speed of 6 Gbps (Giga-bits per second). If the host computer is unable to negotiate a speed of 6 Gbps, the SATA interface automatically renegotiates to a speed of 3 Gbps or 1.5 Gbps.

For a list of supported commands and other specifics, please see Chapter 5.

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2 Product Specifications

2.1 Capacity and LBA count

| Raw Capacity (GB) | User Capacity (GB) | LBA Count |
|-------------------|--------------------|---------------|
| 64 | 60 | 117,231,408 |
| 64 | 64 | 125,045,424 |
| 128 | 120 | 234,441,648 |
| 128 | 128 | 250,069,680 |
| 256 | 240 | 468,862,128 |
| 256 | 256 | 500,118,192 |
| 512 | 480 | 937,703,088 |
| 512 | 512 | 1,000,215,216 |
| 1024 | 960 | 1,875,385,008 |
| 1024 | 1024 | 2,000,409,264 |

Notes:

- Per www.idema.org, LBA1-03 spec,
 $LBA\ counts = (97,696,368) + (1,953,504 * (Advertised\ Capacity\ in\ GBytes - 50))$
- GB capacities based on power of 10, GiB capacities are based on powers of 2

2.2 Performance

Table 2-1: Maximum Sustained Read and Write Bandwidth

| Capacity | Flash Structure | Performance | | | |
|-----------|--------------------------------|-----------------|--------------|-------------|--------------|
| | | CrystalDiskMark | | ATTO | |
| | | Read (MB/s) | Write (MB/s) | Read (MB/s) | Write (MB/s) |
| 8GB | 8GBx1, TSOP, TSB 15nm | 320 | 100 | 320 | 100 |
| 16GB | 16GBx1, TSOP, TSB 15nm | 320 | 100 | 320 | 100 |
| 30/32GB | 16GBx2, TSOP, TSB 15nm | 550 | 175 | 560 | 540 |
| 60/64GB | 16GBx4, TSOP, TSB 15nm | 550 | 335 | 560 | 540 |
| 120/128GB | 32GBx4, TSOP, TSB 15nm | 550 | 465 | 560 | 540 |
| 240/256GB | 64GBx4, TSOP, TSB 15nm | 550 | 465 | 560 | 540 |
| 480/512GB | 128GBx4, TSOP, TSB 15nm | 550 | 465 | 560 | 540 |
| 120/128GB | 64GBx2, BGA, Micron L06B 16nm | 525 | 480 | 560 | 540 |
| 240/256GB | 64GBx4, BGA, Micron L06B 16nm | 530 | 515 | 560 | 540 |
| 480/512GB | 128GBx4, BGA, Micron L06B 16nm | 530 | 515 | 560 | 540 |

Notes:

1. Performance measured using CrystalDiskMark and ATTO
2. Performance may vary from flash configuration, SDR configuration, and platform.
3. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.
4. Data is based on SSD's using Toshiba A15nm Toggle NAND devices
5. L95A data not currently available

Table 2-2: Random Read and Write Input/Output Operations per Second (IOPS)

| Access Type | IOPS |
|-------------|--------------|
| Read, 4K | Up to 95,000 |
| Write, 4K | Up to 85,000 |

Notes:

3. Performance measured using Iometer 08 with queue depth set to 32.
4. Write Cache enabled with DDR cache.
5. Random IOPS cover the entire range of legal logical block addresses (LBA's). Measurements are performed on a full drive (all LBA's have valid content).
6. Performance may vary by NAND type and host.
7. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.
8. Data is based on SSD's using Toshiba A19nm NAND devices

2.3 Timing

Table 2-3: Timing Specifications

| Type | Average Latency |
|----------------------------------|-----------------|
| Power-On-to-Ready (POR) | TBD |
| Command to DRQ | TBD |
| Time to Erase (ATA Secure Erase) | TBD |

Notes:

1. Device measured using Drivemaster.
2. Sector Read/Write latency measured up to 2048 block transfers (512B/sector = 1 Block)
3. Queue depth set to 32 for NCQ
4. Sequential IOPS cover the entire range of legal logical block addresses (LBA's). Measurements are performed on a full drive (all LBA's have valid content)
5. DRQ (Data Transfer Requested) bit being asserted

2.3.1 STANDBY IMMEDIATE Command

The Power-On-to-Ready time assumes a proper shutdown (power removal preceded by STANDBY IMMEDIATE command. A STANDBY IMMEDIATE before power down always performs a graceful shutdown and does not require the use of the hold-up circuit. Note that SMART attribute 174 "Unexpected Power Loss" records the number of non-graceful power cycle events.

Table 2-4: STANDBY IMMEDIATE Timing

| Power Cycle Endurance | Min | Max | Unit |
|-----------------------------------|-----|------|------|
| STANDBY IMMEDIATE to WE completed | - | 72.9 | ms |

Notes: From Standby Immediate command to NAND Write Protect enable.

2.4 Electrical Characteristics

2.4.1 Absolute Maximum Ratings

Values shown are stress ratings only. Functional operation outside normal operating values is not implied. Extended exposure to absolute maximum ratings may affect reliability.

Table 2-5: Absolute Maximum Ratings

| Description | Min | Max | Unit |
|------------------------------------|------|-----|------|
| Maximum Voltage Range for V_{in} | -0.2 | 6 | V |
| Maximum Temperature Range | -40 | 85 | c |

2.4.2 Supply Voltage

The operating voltage is 5.0v

Table 2-6: Operating Voltage

| Description | Min | Max | Unit |
|--------------------------------------|------|------|------|
| Operating Voltage for 5.0 V (+/- 5%) | 4.75 | 5.25 | V |

2.4.3 Power Consumption

All onboard power requirements of the SSD are derived from the SATA 5.0V input rail.

Table 2-7: Typical Power Consumption

| Capacity | Flash Structure | Power Consumption | | |
|-----------|--------------------------------|-------------------|------------|-------------|
| | | Read (mW) | Write (mW) | DEVSLP (mW) |
| 8GB | 8GBx1, TSOP, TSB 15nm | 1,080 | 1,300 | 4.9 |
| 16GB | 16GBx1, TSOP, TSB 15nm | 1,085 | 1,350 | 4.9 |
| 30/32GB | 16GBx2, TSOP, TSB 15nm | 1,090 | 1,350 | 4.9 |
| 60/64GB | 16GBx4, TSOP, TSB 15nm | 1,095 | 1,360 | 4.9 |
| 120/128GB | 32GBx4, TSOP, TSB 15nm | 1,000 | 1,600 | 4.9 |
| 240/256GB | 64GBx4, TSOP, TSB 15nm | 1,015 | 1,605 | 4.9 |
| 480/512GB | 128GBx4, TSOP, TSB 15nm | 1,565 | 1,910 | 4.9 |
| 120/128GB | 64GBx2, BGA, Micron L06B 16nm | 1,265 | 1,705 | 4.9 |
| 240/256GB | 64GBx4, BGA, Micron L06B 16nm | 1,280 | 2,780 | 4.9 |
| 480/512GB | 128GBx4, BGA, Micron L06B 16nm | 1,290 | 3,620 | 4.9 |

NOTES:

1. The average value of power consumption is achieved based on 100% conversion efficiency.
2. The measured power voltage is 5V.
3. Samples were built using Toshiba 15nm MLC and Micron 16nm MLC NAND.
It's measured under ambient temperature.
4. DEVSLP is measured while entering device sleep mode for 5 minutes.
5. Power Consumption may differ according to flash configuration and platform.

2.5 Environmental Conditions

2.5.1 Temperature and Altitude

Table 2-8: Temperature and Altitude Related Specifications

| Conditions | Operating | Shipping | Storage |
|---------------------------------|---------------|---------------|---------------|
| Commercial Temperature- Ambient | 0 to 70°C | -40 to 85°C | -40 to 85°C |
| Industrial Temperature- Ambient | -40 to 85°C | -40 to 85°C | -40 to 85°C |
| Humidity (non-condensing) | 90% under 40C | 93% under 40C | 93% under 40C |

Notes:

1. SLC flash based products may be available in the following temperature ranges:

2.5.2 Shock and Vibration

SSD products are tested in accordance with environmental specification for shock and vibration

Table 2-9: Shock and Vibration Specifications

| Stimulus | Description | | |
|-----------------|------------------------|------------------------|------------------------------|
| Shock | 500G (2ms) | | |
| Vibration | Condition | | Vibration Orientation |
| | Frequency/Displacement | Frequency/Acceleration | |
| Non-operational | 20Hz~80Hz/1.52mm | 80Hz~2000Hz/20G | X, Y, Z axis/30 min for each |

2.5.3 Electromagnetic Immunity

This SSD is an embedded product for host systems and is designed not to impair with system functionality or hinder system EMI/FCC compliance.

2.6 Reliability

Table 2-10: Reliability Specifications

| Parameter | Value |
|----------------|------------------------------|
| ECC | 72-bit per 1KByte |
| MTBF | ~ 2,000,000 hours |
| Read Endurance | Unlimited |
| Data retention | > 90 days at NAND expiration |

Table 2-11: Write Endurance Specifications

| Capacity | Flash Structure | TBW |
|-----------|--------------------|-----|
| 8GB | 8GB x 1 | 15 |
| 16GB | 16GB x 1 | 26 |
| 30/32GB | 16GB x 2 | 48 |
| 60/64GB | 16GB x 4 | 90 |
| 120/128GB | 32GB x 4, 64GB x 2 | 181 |
| 240/256GB | 64GB x 4 | 262 |
| 480/512GB | 128GB x 4 | 544 |

Notes:

1. Samples were built using Toshiba 15nm MLC and Micron 16nm MLC NAND.
2. The test followed JEDEC219A client endurance workload.
3. TBW may differ according to flash configuration and platform.
4. The endurance of SSD could be estimated based on user behavior, NAND endurance cycles, and write amplification factor. It is not guaranteed by flash vendor.

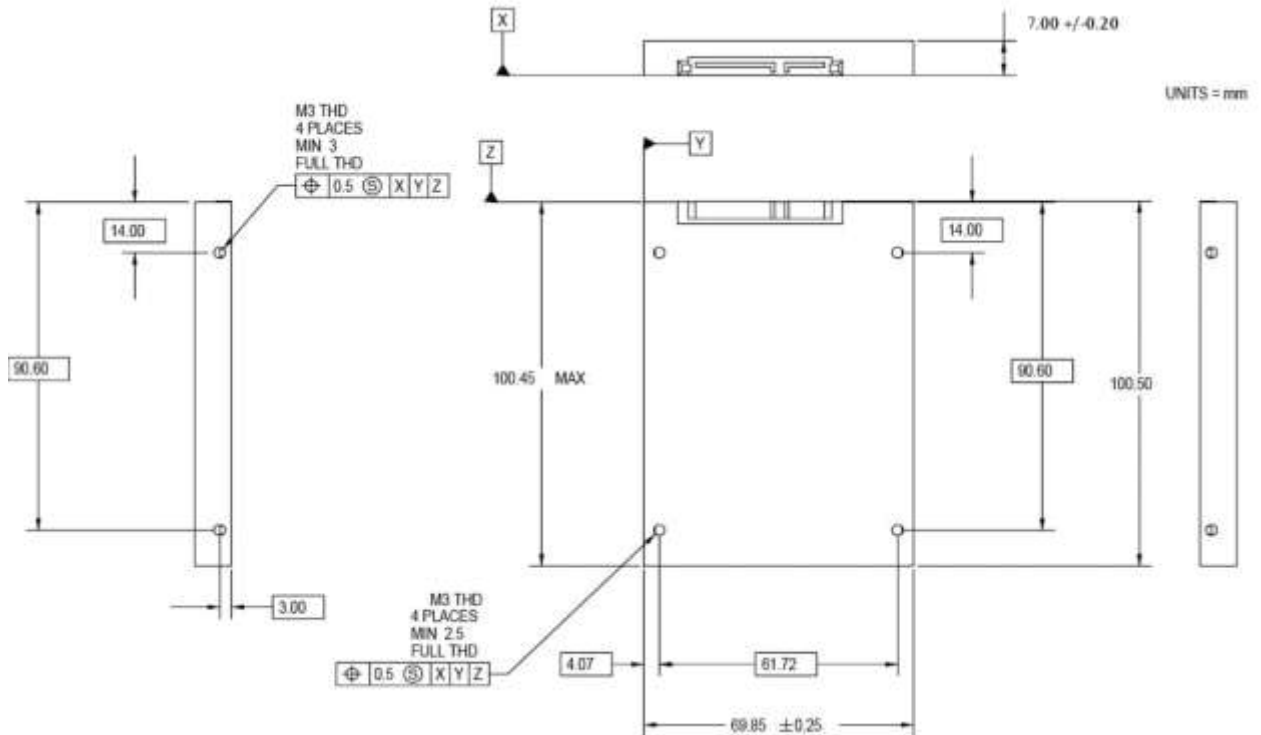
3 Mechanical Information

3.1 SSD Physical Dimensions

Table 3-1: Physical Dimensions

| | Dimensions | Units |
|--------------------|------------|-------|
| Height / Thickness | 7.00 | mm |
| Width | 69.85 | mm |
| Length | 100.5 Max | mm |

Figure 3-1: 2.5" SSD Case Dimensions



Notes: All dimensions are in millimeters, +/- 0.2mm, unless otherwise stated. Reference SATA connector specifications

3.2 SSD Weight

The weight of the 2.5" SSD is approximately 100 grams.

4 Pin and Signal Descriptions

4.1 SSD Signal and Power Description Tables

Table 4-1: Serial ATA Connector Pin Signal Definitions

| Pin | Function | Definition | Mating Order |
|-----|-------------------------|---------------------|--------------|
| S1 | SGND_1 | Signal Ground | 2nd |
| S2 | RX+ on SSD, TX+ on Host | Differential Signal | 1st |
| S3 | RX- on SSD, TX- on Host | Differential Signal | 1st |
| S4 | SGND_2 | Signal Ground | 2nd |
| S5 | TX- on SSD, RX- on Host | Differential Signal | 1st |
| S6 | TX+ on SSD, RX+ on Host | Differential Signal | 1st |
| S7 | SGND_3 | Signal Ground | 2nd |

Notes: Key and spacing separate signal and power segments. Pin locations and layout are consistent with SATA specification.

Table 4-2: Serial ATA Power Pin Definitions

| Pin | Function | Definition | Mating Order |
|-----|----------|---|--------------|
| P1 | 3.3V_1 | No connection (open circuit) | 2nd |
| P2 | 3.3V_2 | No connection (open circuit) | 2nd |
| P3 | DEVSLP | Enter/Exit Device sleep mode | 1st |
| P4 | GND_1 | Ground | 1st |
| P5 | GND_2 | Ground | 1st |
| P6 | GND_3 | Ground | 1st |
| P7 | 5V_1 | 5VDC Power precharge | 1st |
| P8 | 5V_2 | 5VDC Power | 2nd |
| P9 | 5V_3 | 5VDC Power | 2nd |
| P10 | GND_4 | Ground | 1st |
| P11 | Activity | No connection (open circuit) | 2nd |
| P12 | GND_5 | Ground | 1st |
| P13 | 12V_1 | No connection (open circuit) | |
| P14 | 12V_2 | Optional 10k-ohm PD for legacy support on old versions. | |
| P15 | 12V_3 | | |

4.2 Hot Plug Support

Hot Plug insertion and removal are supported in the presence of a proper connector and appropriate operating system (OS) support as described in the SATA 2.6 specification. This product supports Asynchronous Signal Recovery

and will issue an unsolicited COMINIT when first mated with a powered connector to guarantee reliable detection by a host system without hardware device detection.

5 Command Sets

5.1 ATA Commands

Table 5-1: Supported ATA Commands

| Description | Op Code | Description | Op Code |
|-----------------------------------|---------|-----------------------------|---------|
| Check power mode | E5h | Security Disable Password | F6h |
| Data Set management | 06h | Security Erase Prepare | F3h |
| DCO | B1h | Security Erase Unit | F4h |
| Download Microcode PIO | 92h | Security Freeze Lock | F5h |
| Download Microcode DMA | 93h | Security Set Password | F1h |
| Execute drive diagnostic | 90h | Security Unlock | F2h |
| Flush cache | E7h | Seek | 70h |
| Flush cache Ext | EAh | Set features | EFh |
| Identify device | ECh | Set Max Address | F9h |
| Idle | E3h | Set Max Address Ext | 37h |
| Idle immediate | E1h | Set multiple mode | C6h |
| Initialize drive parameters | 91h | Sleep | E6h |
| Read buffer | E4h | Smart | B0h |
| Read DMA (w/o retry) | C9h | Standby | E2h |
| Read DMA (w/retry) | C8h | Standby immediate | E0h |
| Read DMA Ext | 25h | Write buffer | E8h |
| Read FPDMA QUEUED | 60h | Write DMA (w/o retry) | CBh |
| Read Log Ext | 2Fh | Write DMA (w/retry) | CAh |
| Read multiple | C4h | Write DMA Ext | 35h |
| Read multiple Ext | 29h | Write DMA FUA Ext | 3Dh |
| Read native max address | F8h | Write FPDMA QUEUED | 61h |
| Read native max Ext | 27h | Write Log Ext | 3Fh |
| Read sector(s) (w/o retry) | 21h | Write multiple | C5h |
| Read sector(s) (w/retry) | 20h | Write multiple Ext | 39h |
| Read sector(s) Ext | 24h | Write multiple FUA Ext | CEh |
| Read Verify Ext | 42h | Write sector(s) (w/o retry) | 31h |
| Read verify sector(s) (w/o retry) | 41h | Write sector(s) (w/retry) | 30h |

| Description | Op Code | Description | Op Code |
|---------------------------------|---------|---------------------|---------|
| Read verify sector(s) (w/retry) | 40h | Write sector(s) Ext | 34h |
| Recalibrate | 10h | Write uncorrectable | 45h |

5.1.1 48-Bit Address Command Set

SSD supports the 48-Bit Address command set consisting of:

- Flush Cache Ext
- Read DMA Ext
- Read native Max Address Ext
- Read Sector(s) Ext
- Set Max Address Ext
- Write DMA Ext
- Write Multiple Ext
- Write Sector(s) Ext

5.1.2 ATA General Feature Command Set

SSD supports the ATA General Feature command set consisting of:

- Download Microcode
- Executive Device Diagnostics
- Flush Cache
- Identify Device
- NOP (optional)
- Read Buffer (optional)
- Read DMA
- Read Multiple
- Read Sector(s)
- Read Verify Sector(s)
- Seek
- Set Features
- Set Multiple Mode
- Write Buffer (optional)
- Write DMA
- Write Multiple
- Write Sector(s)

5.1.3 Device Configuration Overlay Command Set

SSD supports the Device Configuration Overlay command set consisting of:

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- Device Configuration Freeze Lock
- Device Configuration Identity
- Device Configuration Restore
- Device Configuration Set

5.1.4 General Purpose Log Command Set

SSD supports the General Purpose Log command set consisting of:

- Read Log Ext
- Write Log Ext

5.1.5 Host Protected Area Command Set

SSD supports the Host Protected Area command set consisting of:

- Read Native Max Address
- Read Native Max Address Ext
- Set Max Address
- Set Max Address Ext
- Set Max Freeze Lock (optional)
- Set Max Lock (optional)
- Set Max Set Password (optional)
- Set Max Unlock (optional)

5.1.6 Power Management Command Set

SSD supports the Power Management command set consisting of:

- Check Power Mode
- Idle
- Idle Immediate
- Sleep
- Standby
- Standby Immediate
- Slumber
- Partial Mode

5.1.7 Security Mode Feature Set

SSD supports the Security Mode command set consisting of:

- Security Set Password (OPCODE: F1h)
- Security Unlock (OPCODE: F2h)
- Security Erase Prepare (OPCODE: F3h)
- Security Erase Unit (OPCODE: F4h)
- Security Freeze Lock (OPCODE: F5h)
- Security Disable Password (OPCODE: F6h)
- Standby Immediate

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5.1.8 Identify Device Data

The table below lists the sector data that will be returned by the SSD upon an IDENTIFY DEVICE command.

Table 5-2: List of Device Identification

| Word | F: Fixed V: Variable X: Both | Default Value | Description |
|-------|------------------------------------|---------------|---|
| 0 | F | 0040h | General configuration bit-significant information |
| 1 | X | See *1 | Obsolete – Number of logical cylinders (16383) |
| 2 | V | C837h | Specific configuration |
| 3 | X | 0010h | Obsolete – Number of logical heads (16) |
| 4-5 | X | 00000000h | Retired |
| 6 | X | 003Fh | Obsolete – Number of logical sectors per logical track (63) |
| 7-8 | V | 00000000h | Reserved for assignment by the Compact Flash Association |
| 9 | X | 0000h | Retired |
| 10-19 | F | Varies | Serial number (20 ASCII characters) |
| 20-21 | X | 0000h | Retired |
| 22 | X | 0000h | Obsolete |
| 23-26 | F | Varies | Firmware revision (8 ASCII characters) |
| 27-46 | F | Varies | Model number (xxxxxxx) |
| 47 | F | 8010h | 7:0- Maximum number of sectors transferred per interrupt on MULTIPLE commands |
| 48 | F | 0000h | Reserved |
| 49 | F | 2F00h | Capabilities |
| 50 | F | 4000h | Capabilities |
| 51-52 | X | 00000000h | Obsolete |
| 53 | F | 0007h | Words 88 and 70:64 valid |
| 54 | X | See *1 | Obsolete – Number of logical cylinders (16383) |
| 55 | X | 0010h | Obsolete – Number of logical heads (16) |
| 56 | X | 003Fh | Obsolete – Number of logical sectors per track (63) |
| 57-58 | X | See *2 | Obsolete – Current capacity in sectors – |
| 59 | F | 0110h | Number of sectors transferred per interrupt on MULTIPLE commands |
| 60-61 | F | See *3 | Total number of user addressable sectors |
| 62 | X | 0000h | Obsolete |
| 63 | F | 0407h | 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 |

| Word | F: Fixed V: Variable X: Both | Default Value | Description |
|---------|------------------------------------|------------------------|---|
| | | | 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 | 0100h | Additional Supported (support download microcode DMA) |
| 70 | F | 0000h | Reserved |
| 71-74 | F | 0000000000000000 0h | Reserved for the IDENTIFY PACKET DEVICE command |
| 75 | F | 001Fh | Queue depth |
| 76 | F | 670eh | Serial SATA capabilities |
| 77 | F | 0084h | Reserved for future Serial ATA definition |
| 78 | F | 0014h | Serial ATA features supported |
| 79 | V | 0040H | Serial ATA features enabled |
| 80 | F | 01F8h | Major Version Number |
| 81 | F | 0000h | Minor Version Number |
| 82 | F | 346Bh | Command set supported |
| 83 | F | 7D09h | Command set supported |
| 84 | F | 6063h | Command set/feature supported extension |
| 85 | V | 3469h | Command set/feature enabled |
| 86 | V | BC01h | Command set/feature enabled |
| 87 | V | 6063h | Command set/feature default |
| 88 | V | 003Fh | Ultra DMA Modes |
| 89 | F | 001Eh | Time required for security erase unit completion |
| 90 | F | 001Eh | Time required for Enhanced security erase completion |
| 91 | V | 0000h | Current advanced power management value |
| 92 | V | FFFEh | Master Password Revision Code |
| 93 | F | 0000h | Hardware reset result. The contents of the bits (12:0) of this word shall change only during the execution of s hardware reset. |
| 94 | V | 0000h | Vendor's recommended and actual acoustic management value |
| 95 | F | 0000h | Stream Minimum Request Size |
| 96 | V | 0000h | Streaming Transfer Time – DMA |
| 97 | V | 0000h | Streaming Access Latency – DMA and PIO |
| 98-99 | F | 0000h | Streaming Performance Granularity |
| 100-103 | V | See *4 | Maximum user LBA for 48 bit Address feature set |
| 104 | V | 0000h | Streaming Transfer Time – PIO |
| 105 | F | 0000h | Maximum number of 512-byte blocks per DATA SET MANAGEMENT command |
| 106 | F | 4000h | Physical sector size / Logical sector size |

| Word | F: Fixed V: Variable X: Both | Default Value | Description |
|---------|------------------------------------|--|--|
| 107 | F | 0000h | Inter-seek delay for ISO-7779 acoustic testing in microseconds |
| 108-111 | F | 0000000000000000 0h | Unique ID |
| 112-115 | F | 0000000000000000 0h | Reserved |
| 116 | V | 0000h | Reserved |
| 117-118 | F | 00000000h | Words per logical Sector |
| 119 | F | 4014h | Supported settings |
| 120 | F | 4014h | Command set/Feature Enabled/Supported |
| 121-126 | F | 0h | Reserved |
| 127 | F | 0h | Removable Media Status Notification feature set support |
| 128 | V | 0021h | Security status |
| 129-159 | X | 0h | Vendor specific |
| 160 | F | 0h | Compact Flash Association (CFA) power mode 1 |
| 161-167 | X | 0h | Reserved for assignment by the CFA |
| 168 | F | 3h: 2.5 inch 4h: 1.8 inch 5h: < 1.8 inch | Device Nominal Form Factor |
| 169 | F | 0001h | DATA SET MANAGEMENT command is supported |
| 170-173 | F | 0h | Additional Product Identifier |
| 174-175 | | 0h | Reserve |
| 176-205 | V | 0h | Current media serial number |
| 206 | F | 0h | SCT Command Transport(|
| 207-208 | F | 0h | Reserved |
| 209 | F | 4000h | Alignment of logical blocks within a physical block |
| 210-211 | V | 0000h | Write-Read-Verify Sector Count Mode 3 (not supported) |
| 212-213 | F | 0000h | Write-Read-Verify Sector Count Mode 2 (not supported) |
| 214-216 | | 0000h | NV Cache relate (not supported) |
| 217 | F | 0001h | Non-rotating media device |
| 218 | F | 0h | Reserved |
| 219 | F | 0h | NV Cache relate (not supported) |
| 220 | V | 0h | Write read verify feature set current mode |
| 221 | | 0h | Reserved |
| 222 | F | 107Fh | Transport major version number |
| 223 | F | 0h | Transport minor version number |
| 224-229 | | 0h | reserved |
| 230-233 | | 0h | Extend number of user addressable sectors |
| 234 | | 0001h | Minimum number of 512-byte data blocks per |

| Word | F: Fixed V: Variable X: Both | Default Value | Description |
|---------|------------------------------------|-------------------------|--|
| | | | DOWNLOAD MICROCODE command for mode 03h |
| 235 | | 0080h | Maximum number of 512-byte data blocks per DOWNLOAD MICROCODE command for mode 03h |
| 236-254 | F | 0h | Reserved |
| 255 | X | XXA5h XX is variable | Integrity word (Checksum and Signature) |

Notes for Capacity specific Device Identification

| Capacity (GB) | *1 | *2 | *3 | *4 |
|------------------|------------------|--------------|--------------|----------------|
| | (Word 1/Word 54) | (Word 57-58) | (Word 60-61) | (Word 100-103) |
| 4 | 1E5Dh | 778E30h | 778E30h | 778E30h |
| 8 | 3CA5h | EEC9BOh | EEC9BOh | EEC9BOh |
| 16 | 3FFFh | FBFC10h | 1DD4OBOh | 1DD4OBOh |
| 24 | 3FFFh | FBFC10h | 2CBB7BOh | 2CBB7BOh |
| 32 | 3FFFh | FBFC10h | 3BA2EBOh | 3BA2EBOh |
| 64 | 3FFFh | FBFC10h | 774OABOh | 774OABOh |
| 128 | 3FFFh | FBFC10h | EE7C2BOh | EE7C2BOh |
| 256 | 3FFFh | FBFC10h | FFFFFFFFh | 1DCF32BOh |

5.1.1 S.M.A.R.T. Support

Data storage drives capture a variety of information during operation that may be used to analyze drive —health. SATA drives provide Self-Monitoring, Analysis and Reporting Technology (SMART) features that include monitoring and storing critical performance and calibration parameters to attempt to predict the likelihood of near-term degradation or fault conditions. Drive manufacturers have adopted S.M.A.R.T. to help warn system software, a system administrator, or a user of impending drive failure, while time remains to take preventive action. It provides the host system with the knowledge of a negative reliability condition to allow the host system to warn the user of the impending risk of data loss and advise the user of the appropriate action.

The technical documentation for S.M.A.R.T. is captured in the AT Attachment (ATA) standard. The standard defines the protocols for reporting errors and for invoking self-tests to collect and analyze data on demand. The ATA specification is flexible and provides for individual manufacturers to define their own unique vendor specific information. This section describes the baseline supported

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S.M.A.R.T. command attributes. The information herein should be used in conjunction with the ATA standard and related documents, which may serve as references for topics and details not addressed here. Further, it is recommended to consult the list of public S.M.A.R.T. attributes.

See the AT Attachment standard for implementation details.

5.1.2 SATA 3.0 S.M.A.R.T. Command Set

The supported S.M.A.R.T. command set is listed in the table below. See the AT Attachment standard for implementation details.

Table 5-3: S.M.A.R.T. Command Set

| Value (hex) | Command |
|--|--|
| 00-CF | Reserved |
| D0 | S.M.A.R.T. read attributes |
| D1* | S.M.A.R.T. read threshold |
| D2 | S.M.A.R.T. enable/disable attribute autosave |
| D3* | S.M.A.R.T. save attribute values |
| D4 | S.M.A.R.T. execute off-line immediate |
| D5 | S.M.A.R.T. read log sector |
| D6 | S.M.A.R.T. write log sector |
| D7* | S.M.A.R.T. write attribute threshold |
| D8 | S.M.A.R.T. enable operations |
| D9 | S.M.A.R.T. disable operations |
| DA | S.M.A.R.T. return status |
| DB | S.M.A.R.T. enable/disable automatic off-line |
| DC-FF | Reserved (Vendor Specific) |
| * Note that D1, D3, and D7 have been made obsolete in the ATA-8 specification. | |

5.1.2.1 Extended SMART Attributes

Table 5-4: Extended SMART Attribute Table

| SMART Attribute ID | Description |
|--------------------|--|
| 01h | Number of accumulated Uncorrectable errors (Range 0-255) Read Error Rate |
| 05h | Reallocated Sector Count |
| 09h | Power-On hours Count (Range 0-4294967295) |

| SMART Attribute ID | Description |
|--------------------|--|
| 0Ch | Drive Power Cycle Count (Number of accumulated power on/off cycles) |
| A8h | SATA PHY Error Count (only record from power on, when power off this value will clear to zero) this value include all PHY error count, ex data FIS CRC ,code error, disparity error ,command FIS CRC |
| AAh | Max Bad Block Count (will show early bad and later bad block count) |
| ADh | Erase count (average, max, erase count) |
| B1h | Wear Range delta [(most wear block – average wear block)/Max P/E cycles] x 100 |
| B5h | Program Fail Count |
| B6h | Erase Failure Block Count |
| BBh | Reported Uncorrectable Errors (ECC fail count) 4bytes 01h only 1 bytes |
| C0h | Unexpected Power Loss Count |
| C2h | N/A |
| C7h | Number of accumulated CRC Error (read/write data FIS CRC error) CRC Error Count (R CRC + W CRC) |
| DAh | Number of accumulated CRC Error (read/write data FIS CRC error) Number of CRC Errors |
| E7h | SSD life remaining |
| E8h | Read Failure Block Count |
| E9h | Lifetime Writes to Flash ((GB) |
| F1h | Lifetime Writes from Host (each G) |
| F2h | Lifetime Reads from Host (each G) |
| F3h | Total internal copy ecc error count |
| F4h | Average erase count (4bytes) |
| F5h | Max erase count (4 bytes) |
| F6h | Total Erase Count (6 bytes) |
| FAh | Read retry count |
| FBh | Do wearleveling count |
| FCh | CRC error write count |

Notes: Dummy is null and not used

Table 5-5: Extended SMART Attribute Actual Data

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|----|----|--|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
|---|---|---|---|---|---|---|---|---|---|----|----|--|

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| ID | Flag | Flag | Value | Worse | DATA | | | | | | | Threshold |
|-----|------|------|---------------|---------------|---------------------------------------|---|---------------------------------|---|--------------------|---|-----|-----------|
| | | | | | | | | | | | | |
| 01h | 0Bh | 00h | 64h | 64h | 0 | 0 | ECC error | 0 | 0 | 0 | 0 | 32h |
| 05h | 13h | 00h | 64h | 64h | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32h |
| 09h | 12h | 00h | 64h | 64h | Power on hour | | 0 | 0 | 0 | 0 | 0 | 00h |
| 0Ch | 12h | 00h | 64h | 64h | Power on/off cycles | | | | 0 | 0 | 0 | 00h |
| A8h | 12h | 00h | 64h | 64h | SATA PHY error count | | | | 0 | 0 | 0 | 00h |
| AAh | 03h | 00h | Note 1 | Note 1 | Early bad block NO | | 0 | 0 | Later bad block NO | | 0 | 0Ah |
| ADh | 12h | 00h | 64h | 64h | Max erase count (MAX 65535) | | Average erase count (MAX 65535) | | 0 0 | | 0 | 00h |
| B1h | 00h | 00h | 00h | 00h | The value | | | | 0 | 0 | 0 | 00h |
| B5h | 12h | 00h | 00h | 00h | Total program bad blocks count | | | | 0 | 0 | 0 | 00h |
| B6h | 32h | 00h | 00h | 00h | Total erase bad blocks count | | | | 0 | 0 | 0 | 00h |
| BBh | 03h | 00h | 00h | 00h | Total ECC error count | | | | 0 | 0 | 0 | 00h |
| C0h | 12h | 00h | 64h | 64h | number of accidental power loss count | | | | 0 | 0 | 0 | 00h |
| C2h | N/A | N/A | N/A | N/A | N/A | | N/A | | N/A | | N/A | N/A |
| C7h | 12h | 00h | 64h | 64h | CRC Error Count (R CRC + W CRC) | | | | 0 | 0 | 0 | 00h |
| DAh | 0Bh | 00h | 64h | 64h | Number of CRC Error | | | | 0 | 0 | 0 | 32h |
| E7h | 13h | 00h | 64h | 64h | % SSD life remaining (Note 2) | | | | 0 | 0 | 0 | 00h |
| E8h | 0Bh | 00h | 64h | 64h | Total Read bad Block Count | | | | 0 | 0 | 0 | 00h |
| E9h | 0Bh | 00h | 64h | 64h | Flash write 64GB each count | | | | 0 | 0 | 0 | 00h |
| F1h | 32h | 00h | 00h | 00h | Host write 64GB count | | | | 0 | 0 | 0 | 00h |
| F2h | 32h | 00h | 00h | 00h | Host read 64GB count) | | | | 0 | 0 | 0 | 00h |
| F3h | 02h | 00h | 64h | 64h | Total internal copy ecc error count | | | | 0 | 0 | 0 | 00h |
| F4h | 02h | 00h | 64h | 64h | Total Average erase count | | | | 0 | 0 | 0 | 00h |
| F5h | 02h | 00h | 64h | 64h | Max erase count | | | | 0 | 0 | 0 | 00h |
| F6h | 02h | 00h | 64h | 64h | Total Erase Count | | | | | | 0 | 00h |

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
|-----|------|------|-------|-------|------------------|---|---|---|---|----|----|-----------|
| ID | Flag | Flag | Value | Worse | DATA | | | | | | | Threshold |
| FAh | 02h | 00h | 64h | 64h | Read retry Count | | | | | | | 0 00h |
| FBh | 02h | 00h | 64h | 64h | Cool down Count | | | | | | | 0 00h |
| FCh | 02h | 00h | 64h | 64h | CRC write Count | | | | | | | 0 00h |

Note 1 Formula:

MABN: Maximum acceptable bad block number

CBBN: Current bad block number

Value = ((MABN – CBBN)/ (MABN)) x 100

This formula calculates percentage of spare blocks. Value will be from 100 to 1

Note 2:

Average erase count / MAX erase count (SLC 100000, MLC 5000) * 100 (percentage)

5.1.2.2 Off-line Mode

SSD’s support the optional 28-bit S.M.A.R.T. EXECUTION OFF-LINE IMMEDIATE (B0h/D4h) command per the ATA-8 specification. This command causes the SSD to initiate the collection of S.M.A.R.T. data in an off-line mode and then preserves this data across power and reset events. Supported subcommands include those shown in the table below. Reference the ATA-8 specification for subcommand detail.

Table 5-6: Supported S.M.A.R.T. EXECUTE OFF-LINE IMMEDIATE Subcommands

| Value | Description |
|-------|---|
| 00h | Execute S.M.A.R.T. off-line routine immediately in off-line mode |
| 01h | Execute S.M.A.R.T. Short self-test routine immediately in off-line mode |
| 02h | Execute S.M.A.R.T. Extended self-test routine immediately in off-line mode |
| 04h | Execute S.M.A.R.T. Selective self-test routine immediately in off-line mode |
| 7Fh | Abort off-line mode self-test routine |
| 81h | Execute S.M.A.R.T. Short self-test routine immediately in captive mode |
| 82h | Execute S.M.A.R.T. Extended self-test routine immediately in captive mode |
| 84h | Execute S.M.A.R.T. Selective self-test routine immediately in captive mode |

5.2 SATA Commands

The SATA 2.6 specification is a super set of the ATA/ATAPI-7 specification with regard to supported commands. SSD's support the following features that are unique to the SATA specification.

5.2.1 Native Command Queuing (NCQ)

SSD's support the Native Command Queuing (NCQ) command set, which consists of

- READ FPDMA QUEUED
- WRITE FPDMA QUEUED

Note: With a maximum queue depth less than or equal to 32.

6 References

- Serial ATA Specification, Revision 3

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7 Glossary

This document incorporates many industry and device-specific words. Use the following list to define a variety of terms and acronyms.

| Term | Definition |
|------------|--|
| ATA | Advanced Technology Attachment |
| ATAPI | Advanced Technology Attachment Packet Interface |
| BER | Bit error rate, or percentage of bits that have errors relative to the total number of bits received |
| DIPM | Device Initiated Link Power Management. The ability of the device to request SATA link power state changes. |
| DMA | Direct Memory Access |
| eMLC | Enterprise Multi-Level Cell |
| EXT | Extended |
| FP | First Party |
| GB | Giga-byte defined as 1×10^9 bytes |
| HDD | Hard Disk Drive |
| Hot Plug | A term used to describe the removal or insertion of a SATA storage drive when the system is powered on. |
| IOPS | Input output operations per second |
| LBA | Logical Block Address |
| MB | Mega-bytes defined as 1×10^6 bytes |
| MLC | Multi-Level Cell |
| MTBF | Mean Time Between Failures |
| NCQ | Native Command Queuing. The ability of the SATA hard drive to queue and re-order commands to maximize execution efficiency. |
| NOP | No Operation |
| OS | Operating System |
| Port | The point at which a SATA drive physically connects to the SATA controller. |
| RMS | Root Mean Squared |
| RPM | Revolutions Per Minute |
| SAS | Serial Attached SCSI |
| SATA | Serial ATA |
| SFF | Small Form Factor |
| SLC | Single Level Cell |
| S.M.A.R.T. | Self-Monitoring, Analysis and Reporting Technology: an open standard for developing hard drives and software systems that automatically monitors a hard drive's health and reports potential problems. |
| SSD | Solid-State Drive |