Slim SATA

Slim SATA is a non-volatile, solid-state storage device. With its Serial ATA interface and Slim SATA (MO-297) form factor, it is a drop in replacement for hard disk drives. Slim SATA delivers extremely high levels of performance, reliability and ruggedness for I/O intensive or environmentally challenging applications.

Revision History

Date	Revision	Description
1/14/13	A	Initial release of product datasheet where first generation products were removed.
6/14/13	B1	Update SMART attribute to Worst=1

Legal Information

Legal Information

Export Control

Sanmina, Viking Technology must ensure that our customers understand that our family of Solid-State Drives (SSD) are subject to US export control restrictions. In summary, our products cannot be exported or re-exported to any foreign government; and their use in the design, development, production or use of nuclear, chemical or biological weapons or missiles requires a separate license for export or re-export. They also may not be exported or re-exported to Cuba, Iran, North Korea, Sudan or Syria.

Ordering Information: Slim SATA SSD Solid-State Drive

Part Number	SATA Interface	Application	Raw Capacity (GB)	Useable Capacity (GB)[1]	Minimum Total User Addressable Sectors in LBA Mode	NAND Technology	Temperature Range
VRFEM1008GPCQMMC	6Gbps	Client	16	8	15,649,200	MLC	0 to 70°C
VRFEM1012GPCQMMC	6Gbps	Client	16	12	31,277,232	MLC	0 to 70°C
VRFEM1025GPCWMMA	6Gbps	Client	32	25	48,858,768	MLC	0 to 70°C
VRFEM1032GPCYMMA	6Gbps	Client	48	32	62,533,296	MLC	0 to 70°C
VRFEM1055GPCYMMA	6Gbps	Client	64	55	107,463,888	MLC	0 to 70°C
VRFEM1080GPCTMMA	6Gbps	Client	128	80	156,301,488	MLC	0 to 70°C
VRFEM1120GPCTMMA	6Gbps	Client	128	120	234,441,648	MLC	0 to 70°C

Notes:

1) Usable capacity based on a level of over-provisioning applied to wear leveling, bad sectors, index tables etc.
2) Higher usable capacity points may be available based on customer application. Consult your local Viking Field Application Engineer.
3) SSD's ship unformatted from the factory unless otherwise requested.
4) 1 GB = 1,000,000,000 Byte s. Not all of the memory can be used for data storage. Usable capacity based on % over-provisioning applied to wear leveling, bad sectors, index tables etc.
5) One Sector = 512 Byte.

Many Viking solid state drives are available in Enterprise and Client versions:

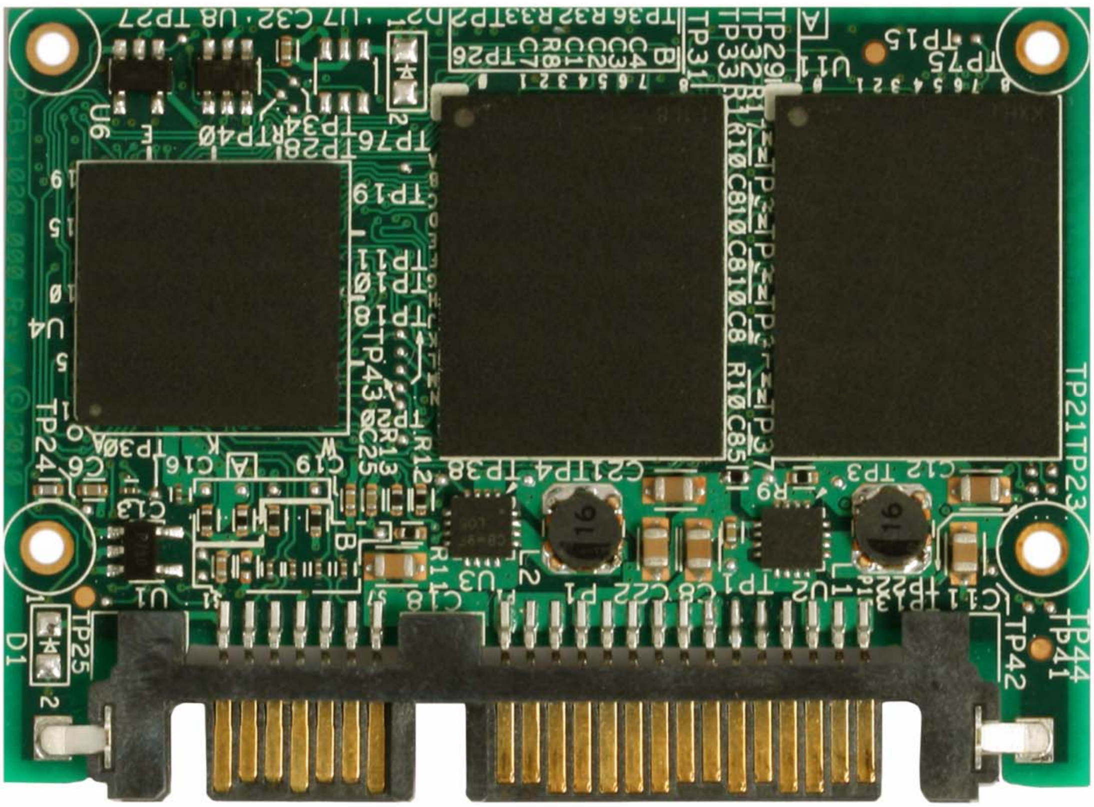
Enterprise – An Enterprise SSD contains hardware and firmware that detect and manage power failures. This allows the drive to flush the controller cache and harden data to NAND flash. No data is lost or corrupted.

Client – A Client SSD does not include specialized hardware provisions to handle all power failure scenarios. MLC NAND, as opposed to SLC NAND, can become corrupted if power is removed during a write, also known as lower page corruption. Therefore, a Client SSD using MLC NAND is well-suited in a system that already manages power fail events, allowing for graceful SSD shutdown. Accordingly, system support should include issuing a Standby Immediate command to the SSD while maintaining power for at least 50ms.

If a Client drive with MLC NAND is used in a system that does not manage power failures and shutdowns, there is a small chance of data corruption. Viking Client SSDs take sophisticated hardware and firmware measures to prevent or mitigate such issues making the chance of corruption very small.

If the SSD controller detects data corruption, the drive will be locked so as not to deliver bad data to the host. The only way to recover the drive is to return it to the factory for reprogramming; all data will be lost.

Product Picture(s)



Slim SATA Top View

Table of Contents

1 INTRODUCTION 10

1.1 Features 10

1.2 Block Diagram 12

1.3 SATA Interface for VRFEM1xxxGP 13

1.4 Indicator LEDs 13

2 PRODUCT SPECIFICATIONS 13

2.1 Performance 13

2.2 Timing 14
2.2.1 STANDBY IMMEDIATE Command 14

2.3 Electrical Characteristics 15
2.3.1 Absolute Maximum Ratings 15
2.3.2 Supply Voltage 15
2.3.3 Supply Current 15
2.3.4 Power Consumption 16

2.4 Environmental Conditions 16
2.4.1 Temperature and Altitude 16
2.4.2 Shock and Vibration 16
2.4.3 Electromagnetic Immunity 17

2.5 Reliability 18
2.5.1 Data, MetaData, and Firmware Code Protection 18
2.5.2 Intelligent Read Disturb Management 20
2.5.3 Intelligent Write Operation Management 20

2.6 Data Security 21

3 MECHANICAL INFORMATION 22

3.1 SlimSATA SSD Weight 23

4 PIN AND SIGNAL DESCRIPTIONS 23

4.1 Pin Locations 23

4.2 Signal and Power Description Tables 23

4.3 Hot Plug Support **24**

5 COMMAND SETS **25**

5.1 ATA Commands **26**
5.1.1 48-Bit Address Command Set 29
5.1.2 ATA General Feature Command Set 30
5.1.3 Device Configuration Overlay Command Set 30
5.1.4 General Purpose Log Command Set 30
5.1.5 Host Protected Area Command Set 30
5.1.6 Power Management Command Set 31
5.1.7 Security Mode Feature Set 31
5.1.1 S.M.A.R.T. Support 31
5.1.2 S.M.A.R.T. Command Set 32
5.1.3 S.M.A.R.T. Attributes 34
5.1.4 Threshold Sector 45
5.1.5 S.M.A.R.T. Command Transport (SCT) 46

5.2 SATA Commands **46**
5.2.1 Native Command Queuing (NCQ) 46

6 CERTIFICATIONS AND COMPLIANCE **47**

7 REFERENCES **47**

8 GLOSSARY **48**

Table of Tables

Table 1-1: Slim SATA SSD Features ______ *10*
Table 2-1: Maximum Sustained Read and Write: MB/sec and IOPS ______ *14*
Table 2-2: Timing Specifications ______ *14*
Table 2-3: STANDBY IMMEDIATE Timings ______ *14*
Table 2-4: Absolute Maximum Ratings ______ *15*
Table 2-5: Operating Voltage ______ *15*
Table 2-6: Current Draw ______ *15*
Table 2-7: Typical Power Consumption ______ *16*
Table 2-8: Temperature and Altitude Related Specifications ______ *16*
Table 2-9: Shock and Vibration Specifications ______ *16*
Table 2-10: Reliability Specifications ______ *18*
Table 4-1: Serial ATA Connector Pin Signal Definitions ______ *23*
Table 4-2: Serial ATA Power Pin Definitions for VRFEM1xxA, VRFEM1xxxGP ______ *24*
Table 4-3: Serial ATA Power Pin Definitions for VRFEM1xxB ___ ***Error! Bookmark not defined.***
Table 5-1: ATA Feature Set ______ *25*
Table 5-2: ATA Commands ______ *26*
Table 5-3: S.M.A.R.T. Command Set ______ *32*
Table 5-4: Supported S.M.A.R.T. EXECUTE OFF-LINE IMMEDIATE Subcommands ______ *33*
Table 5-5: Baseline S.M.A.R.T. Attribute Summary for VRFEM1xxA & VRFEM1xxxP Models _ *34*
Table 5-6: Baseline S.M.A.R.T. Attribute Summary for VRFEM1xxB _____ ***Error! Bookmark not defined.***
Table 5-7: Baseline S.M.A.R.T. Attribute Details for VRFEM1xxA & VRFEM1xxxGP ______ *36*
Table 5-8: Baseline S.M.A.R.T. Attribute Details for VRFEM1xxxGB _____ ***Error! Bookmark not defined.***
Table 5-9: S.M.A.R.T. Attribute Data Structure ______ *45*
Table 5-10: S.M.A.R.T. Threshold Data Structure ______ *46*
Table 6-1: Device Certifications ______ *47*

Table of Figures

Figure 1-1: High-Level Block Diagram for VRFEM1xxxGB ______ ***Error! Bookmark not defined.***
Figure 1-2: High-Level Block Diagram for VRFEM1xxA ______ ***Error! Bookmark not defined.***
Figure 1-3: High-Level Block Diagram for VRFEM1xxP ______ *12*
Figure 3-1: Dimensions ______ *22*
Figure 4-1: Layout of Signal and Power Segment Pins ______ *23*
Figure 5-1: S.M.A.R.T. ECC and RAISE Error Summary for VRFEM1xxA & VRFEM1xxxGP __ *44*
Figure 5-2: S.M.A.R.T. ECC and RAISE Error Summary for VRFEM1xxxGB ***Error! Bookmark not defined.***

1 Introduction

Viking's rugged designed SSD's offer the highest flash storage reliability and performance in harsh environments such as shock, vibration, humidity, altitude, ESD, and extreme temperatures. Viking SSD's meet JEDEC JESD22 standards and pass numerous qualifications including MIL-STDs and NEBS.

Viking can also provide specialized services to OEMs designing customized hardware and systems by offering:

- Locked BOM control with customer product change notification (PCN)
- Pre-installed software, custom software imaging and ID strings
- Custom packaging and labeling
- Comprehensive supply-chain management
- Customer specified testing
- 30K volt ESD protection
- Conformal coating
- Localized Field Application Engineering for complete pre and post sale technical support

1.1 Features

Table 1-1: Slim SATA SSD Features

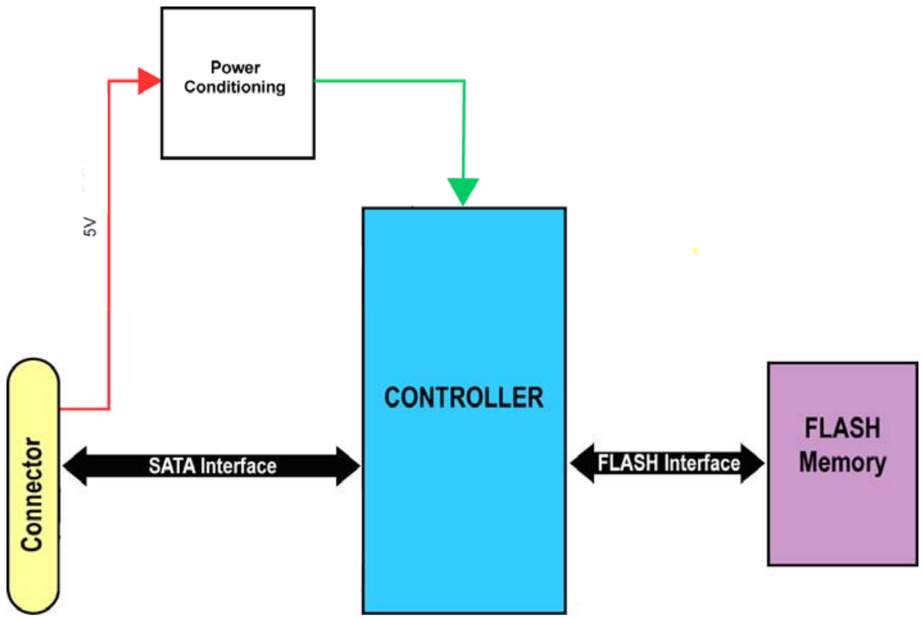
The Slim SATA SSD delivers the following features:

Feature	VRFEM1xxxGP
Best in class sequential and random Read/Write performance	•
Seamless SATA Revision 2.x interface support for SATA up to 3Gbps)	•
Seamless SATA Revision 3.x interface support for SATA up to 6Gbps)	•
Power hold-up circuit technology ensures no data loss resulting from an unexpected power loss and is supported for industrial temperatures (requires host provisions)	
PFAIL/DHARD signaling with the host	
Support for ONFi and Toggle Mode NAND	•
Patented architecture for SSD longevity, reliability and data integrity	•
Supports Native Command Queuing (NCQ) to 32 commands	•
Native support for 512 and non-512 host LBA sizes	•
Automatic Trim Command support	•
Compatible with all major SLC and MLC NAND flash technologies	•
Protection against catastrophic flash page and block failures	•

Feature	VRFEM1xxxGP
AES-128 encryption in CTR mode	•
S.M.A.R.T. command transport (SCT) technology	•
Superior wear-leveling algorithm	•
Intelligent flash memory block management and read disturb management	•
Efficient error recovery	•
Power-throttling support	•
Thermal sensing energy management	•
RoHS and WEEE compliant	•

1.2 Block Diagram

Figure 1-1: High-Level Block Diagram for VRFEM1xxP



1.3 SATA Interface for VRFEM1xxxGP

- The Serial ATA (SATA) interface is compliant with the SATA IO Serial ATA specification, revision 3.x that supports SATA up to 6 Gbps.
- The SATA interface connects the host computer to the SSD subsystem.
- The SATA interface runs at a maximum speed of 6.0 Gbps (gigabits per second). If the host computer is unable to negotiate a speed of 6.0 Gbps, the SATA interface automatically renegotiates to a speed of 3.0 or 1.5 Gbps.

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

1.4 Indicator LEDs

There is an optional LED indicator on the Slim SATA module that will flash to indicate an SATA activity condition. There is also a remote LED indicator at Pin 11 of the Power Segment Connector, called “Device Activity Signal”. For a remote LED application, an LED should be tied high through a current limiting resistor on the host side. The Slim SATA will sink current on the module to allow the LED to flash to indicate an ACTIVITY. If a remote LED is not implemented, pin 11 may be connected to GND to allow the ACTIVITY LED to remain on and indicate a Power On condition when using a standard ATX type power supply.

2 Product Specifications

2.1 Performance

Maximum SSD performance can be achieved for certain workloads by:

- Initiating read and write transfers for random accesses with small block sizes of 4K bytes to optimize IOPs performance for applications such as databases, OLTP etc.
- Initiating read and write transfers for sequential accesses with large blocks (128K or larger) to optimize performance toward throughput (MBps) for applications such as video streaming, data acquisition etc.
- Issuing transfers at starting LBAs which align the access on 4K boundaries:
    - Minimizes or eliminates internal Read-Modify-Write operations
    - Align on 4K boundaries is optimal for SSD capacities up to 256 GB
    - For SSD capacities greater than 256 GB, aligning on 8K boundaries is optimal
- Avoid mixing NCQ and non-NCQ commands

Table 2-1: Maximum Sustained Read and Write: MB/sec and IOPS

Access Type	VRFEM1xxxGP	Units
Sequential Read, 128K block size	Up to 500	MB/s
Sequential Write, 128K block size	Up to 500	MB/s
Random Read, 4K block size	Up to 60,000	IOPS
Random Write, 4K block size	Up to 20,000	IOPS

Notes:

1. Performance measured using IOmeter 08 with queue depth set to 32.
2. Write Cache enabled.
3. Random IOPS cover the entire range of legal logical block addresses (LBAs). Measurements are performed on a full drive (all LBAs have valid content).
4. Performance may vary by NAND type and host.
5. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.

2.2 Timing

Table 2-2: Timing Specifications

Type	Average Latency or Timing
Power On to Ready	115 ms
Reset to Ready	115 ms
Sleep to Ready	<1000 µs
Command to DRQ	<1000 µs
Time to Erase (ATA Secure Erase)	4 seconds
Time to Erase (ATA Secure Erase with flash erase)	~ 1 GB/second

Notes:

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

2.2.1 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 2-3: STANDBY IMMEDIATE Timings

Power Cycle Endurance	Min	Max	Unit
STANDBY IMMEDIATE to WE completed	15	25	ms

2.3 *Electrical Characteristics*

2.3.1 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 2-4: Absolute Maximum Ratings

Description	Min	Max	Unit
Maximum Voltage Range for Vin	-0.2	6	V
Maximum Temperature Range	-40	85	c

2.3.2 Supply Voltage

The operating voltage is 5.0V.

Table 2-5: Operating Voltage

Description	Min	Max	Unit
Operating Voltage for 5.0 V (+/- 10%)	4.5	5.5	V

2.3.3 Supply Current

Table 2-6: Current Draw

Mode	VRFEM1xxxGPxx[1]	Unit
Read/Writes	400	mA
Peak	600	mA
Idle	<80	mA

Notes:

1. Typical power workload: 16K block size, 50% read, 50% sequential write. Maximum power workload: 256K block size, 0% read, 100% sequential write.
2. Table values based on 100GB drive.

2.3.4 Power Consumption

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

Table 2-7: Typical Power Consumption

Mode	VRFEM1xxxGPxx[1]	Unit
Read/Writes	2.0	W
Idle	<0.4	W

Notes:

1. Typical power workload: 16K block size, 50% read, 50% sequential write. Maximum power workload: 256K block size, 0% read, 100% sequential write.
2. Typical power consumption is that of a device with 64GB of physical capacity.

2.4 Environmental Conditions

2.4.1 Temperature and Altitude

Table 2-8: Temperature and Altitude Related Specifications

Conditions	Operating	Shipping	Storage
Commercial Temperature - Ambient	0 to 70°C (32 to 158° F)	-40 to 85°C (-40 to 185° F)	-40 to 85°C (-40 to 185° F)
Humidity (non-condensing)	10% to 80%	5% to 95%	5% to 95%
Max Temperature Gradient	20°C/Hour (36°F/Hour)	n/a	n/a
Altitude[2]	-304.8 to 24,384 m (-1,000 to 80,000 ft)	-304.8 to 24,384 m (-1,000 to 80,000 ft)	-304.8 to 24,384 m (-1,000 to 80,000 ft)
Storage Time Duration	n/a	n/a	1 year

Notes:

1. Flash based products are available in the following temperature ranges:
   a) Commercial temperature range of 0 to 70°C (32 to 158° F)
   b) Storage temperature range of -40 to 85°C is limited by LED and ferrite bead

2.4.2 Shock and Vibration

Slim SATA products are tested in accordance with environmental specification MIL-STD-810F.

Table 2-9: Shock and Vibration Specifications

	Description
Shock	50g, 11ms, 3 shocks applied in each direction on 3 mutually perpendicular axes X, Y, Z

	Description
Vibration	16.4g rms 10-2,000 Hz, 3 axes

2.4.3 Electromagnetic Immunity

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

2.5 Reliability

Table 2-10: Reliability Specifications

Parameter	Value
Nonrecoverable read errors (BER)[1]	<1 sector in 10^{17} bits read, max
Mean Time Between Failures (MTBF)[2]	3,000,000 hours
Power On/Off Cycles[3]	50,000 cycles
Read Endurance	Unlimited
Write or Erase Endurance[4]	(specified by the flash component)
Global wear-leveling	~ 2% between least worn and most worn
Data retention	>10 years when new, 90 days at drive EOL

Notes:

1. BER will not exceed one sector in the specified number of bits read. In the extremely unlikely event of a non-recoverable read error, the drive will report it as a read failure to the host; the sector in error is considered corrupt and is not returned to the host.
2. MTBF is calculated based on a Part Stress Analysis. It assumes nominal voltage, with all other parameters within specified range. Telcordia method SR-332, component FIT rate at 55^{o}c.
3. Power On/Off Cycles defined as power being removed from the drive, and then restored. Note that host systems and drive enclosures may remove power from the drive for reasons other than a system shutdown.
4. SLC NAND has a higher endurance then MLC NAND

2.5.1 Data, MetaData, and Firmware Code Protection

Slim SATA implements data protection throughout its data path. Protection techniques include:

- Data ECC Algorithms
- Datapath CRC Error Detection
- RAISE™ Data Protection Against Catastrophic Flash Page/Block Failure

2.5.1.1 DATA ECC Algorithms

The following data error correction is provided:

- Up to 55 bytes of redundancy applied to 512 bytes of data

2.5.1.2 Data Path CRC Error Detection

CRC error detection is applied against data along internal data paths. CRC detection uses a 32-bit checksum (CRC32) to protect data along all internal data paths.

2.5.1.3 RAISE™ Data Protection Against Catastrophic Flash Page/Block Failure

R.A.I.S.E.™ (Redundant Array of Independent Silicon Elements) provides data protection to overcome the probabilistic risk of page or block failure inherent in all Flash memory technology. In a tiered approach to detecting and correcting NAND errors, RAISE™ takes over where ECC leaves off.

Flash technology can exhibit a finite probability that a block or page will fail within the rated Program-Erase (P-E) cycle count lifetime of the Flash device. While this probability may appear tolerable for a given application, note that it is for a particular Flash die. For an SSD incorporating up to 128 Flash die, the additive probability of this phenomenon can reveal measurable risk to the SSD over its multi-year lifetime.

RAISE™ technology addresses this risk. In the event of a catastrophic failure of an entire Flash page or Flash block, RAISE™ off-line protection rebuilds the data in the failed page or block and relocates it elsewhere in the Flash array. Performance during recovery is minimally impacted, but after recovery is complete, Slim SATA returns to full performance and full functionality. The performance impact period is only the amount of time required to rebuild and relocate the page or block data, and to map out the problematic Flash block.

In contrast to other SSD Flash controllers, Slim SATA with RAISE™ technology uniquely, reliably and seamlessly overcomes these catastrophic data loss risks with only temporary impact to throughput and latency and no impact to power consumption. In a RAID drive array application, Slim SATA can auto-rebuild data locally, without passing the problem upstream to the system level and without incurring the associated significant system rebuild hit. The difference in impact between a standard approach and Slim SATA with RAISE™ approach is significant. Additionally, following recovery from a page failure or block failure, Slim SATA is fully functional and fully reliable, whereas a page-failed or block-failed drive recovered by system RAID must be immediately replaced.

2.5.1.4 Firmware Code Protection

Firmware requires special attention to ensure the code is execution-worthy. For this reason, firmware is stored in multiple redundant images in the Flash array. Image checksums are compared between all stored copies to ensure identical code. Any image not corroborated by at least one other image is discarded. In this way a reliable firmware image is always chosen on boot-up for execution.

If a firmware image is discarded, a new redundant image is created from the good images to ensure original levels of protection.

Firmware images are also protected in Flash memory and during fetch by the maximum ECC correction power, and by RAISE™ correction technology.

2.5.2 Intelligent Read Disturb Management

Flash memory is primarily at risk from writes and erasures. However, reads also affect data longevity. Excessive reads of Flash memory cells induce inter-cell voltage shift, although the effect not as accelerated as write-induced cell damage. The degradation occurs in data stored in nearby cells, rather than in the cell being read. Read-induced data degradation is called “Read Disturb.”

The controller provides read operation management to overcome Flash Memory “Read Disturb” concerns by ensuring that data integrity is not impacted by multiple reads of the same Flash Memory address. It tracks reads and automatically and seamlessly recovers and refreshes data in proximity before that data is negatively impacted. Its superior throughput and latency performance, delivered over the life of the drive, is not diminished by this process and the expected data retention capability is assured throughout the warranted life of the SSD.

2.5.3 Intelligent Write Operation Management

The controller makes data location/relocation decisions which greatly increase the life of the SSD.

2.5.3.1 Sophisticated Wear-Leveling

Wear leveling refers to the practice of equalizing the impact of write and erase operations over the larger pool of Flash memory blocks. Industry-standard wear leveling techniques focus on conventional schemes that attempt to equalize writes and erases across blocks. While on the surface this appears to be a reasonable approach, it is clear that it assumes all blocks will “wear” equally when written or erased. This is far from the truth. The NAND processor takes much more into account. It measures a variety of parameters to determine the actual wear of blocks during P-E cycles, to determine which blocks are impacted more by erasures and writes over time. That is, it determines actual cell wear, not simply assumed wear normalized to write/erase events. The controller employs this information in its superior wear-leveling algorithm along with its ongoing record of writes and erasures, to ensure each block is impacted by P-E cycles no more than the average. The result is an SSD that is far more reliable across its full capacity and over a far greater length of time. The controller uses both static and dynamic wear-leveling algorithms to globally manage cell degradation to approximately 2% between least worn and most worn cells or to the value specified in the S.M.A.R.T Wear Range Delta command (ID=177, Opcode=0xB1)

2.5.3.2 Write Operation Reduction

The controller uses intelligent algorithms to minimize P-E cycles through aggregation, virtualization, and difference processing. It is uniquely effective in reducing the wear and maintaining the reliability of the overall pool of Flash memory blocks by intelligently minimizes re-writes of identical data, to maximize the effectiveness of the wear-leveling process.

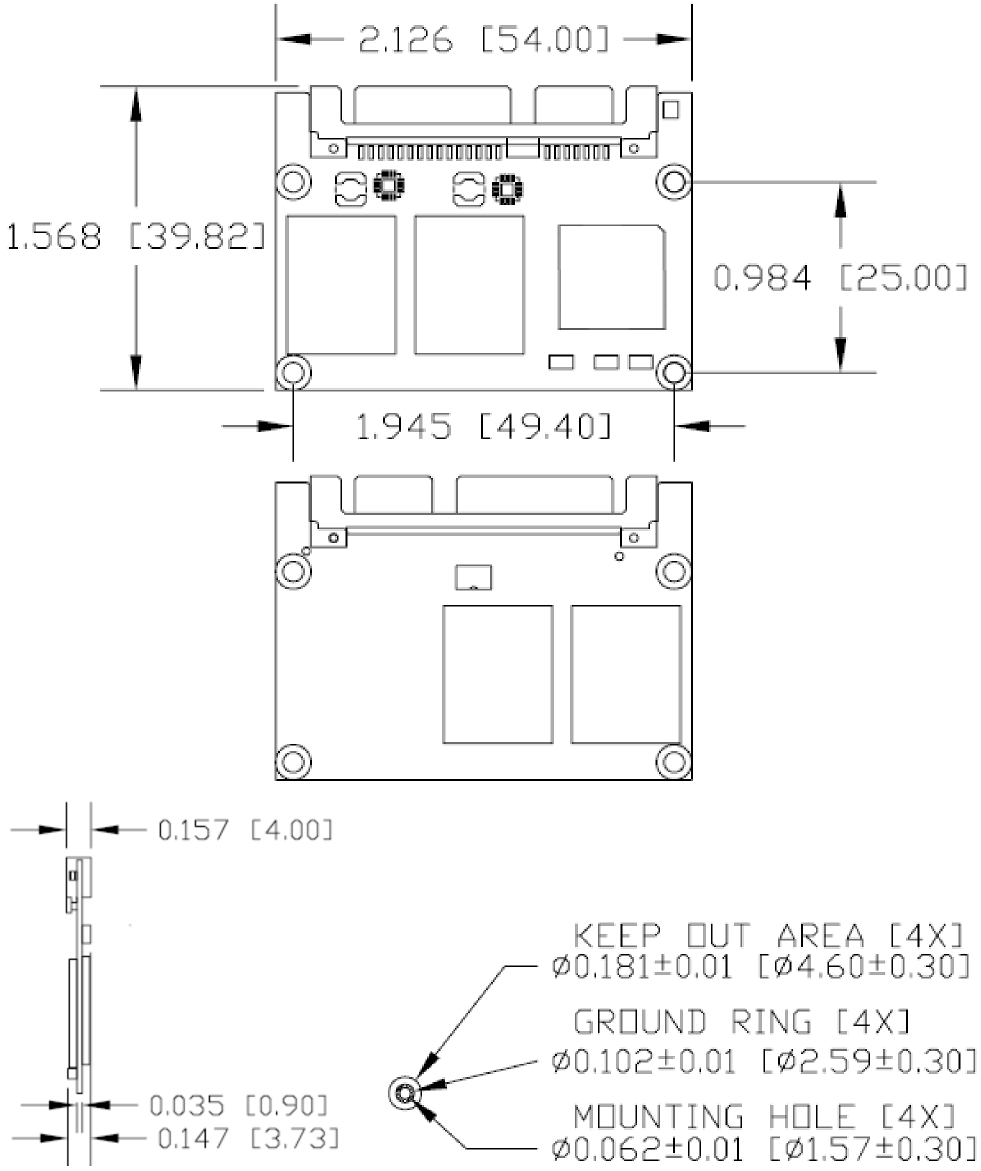
2.6 Data Security

Element SSD supports AES-128 encryption and ATA Secure Erase features to protect sensitive data.

3 Mechanical Information

Capacity (GB)	Height (mm)	Width (mm)	Length (mm)
8 to 120	4.00 max	54 max	39.82 max

Figure 3-1: Dimensions



Note:

- All dimensions are in inches [millimeters].

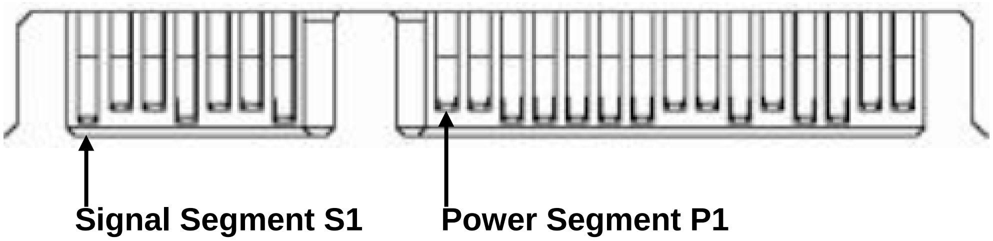
3.1 SlimSATA SSD Weight

The weight of a SlimSATA (MO-297) is approximately 8.0 grams.

4 Pin and Signal Descriptions

4.1 Pin Locations

Figure 4-1: Layout of Signal and Power Segment Pins



4.2 Signal and Power Description Tables

Table 4-1: Serial ATA Connector Pin Signal Definitions

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

Note: 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	2nd
P2	3.3V_2	No connection	2nd
P3	3.3V_3	No connection	1st
P4	GND_1	Ground	1st
P5	GND_2	Ground	1st
P6	GND_3	Ground	1st
P7	5V_1	5VDC Power (pre-charge)	1st
P8	5V_2	5VDC Power	2nd
P9	5V_3	5VDC Power	2nd
P10	GND_4	Ground	1st
P11	Activity	Device Activity Signal (See note1)	2nd
P12	GND_5	Ground	1st
P13	12V_1	No connection	1st
P14	12V_2	No connection	2nd
P15	12V_3	No connection	2nd

1) For Remote LED application, an LED should to be tied high thru a current limiting resistor on the host side. If a Remote LED is not implemented, pin 11 may be connected to GND to allow the ACTIVITY LED to remain on to indicate a Power On condition when using a standard ATX type power supply.

4.3 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

The Element SSD complies with ATA-8. All mandatory and many optional commands and features are supported. The tables below summarize the supported ATA feature set and commands.

Table 5-1: ATA Feature Set

		Support	
Feature Set	**ATA-8 REF**	**ATA Device**	**Element SSD**
General feature set	4.2	M	YES
PACKET feature set	4.3	P	NO
48-Bit Address feature set	4.4	O	YES
Advanced Power Management (APM) feature set	4.5	O	NO
Automatic Acoustic Management (AAM) feature set	4.6	O	NO
CompactFlash Association (CFA) feature set	4.7	N	NO
Device Configuration Overlay (DCO) feature set	4.8	O	YES
Free-fall Control feature set	4.9	O	NO
General Purpose Logging (GPL) feature set	4.10	O	YES
Host Protected Area (HPA) feature set	4.11	O	YES
Long Logical Sector (LLS) feature set	4.12	O	NO
Long Physical Sector (LPS) feature set	4.13	O	NO
Media Card Pass Through Command feature set	4.14	N	NO
Native Command Queuing (NCQ) feature set	4.15	O	YES
NV Cache feature set	4.16	O	NO
NV Cache Power Management feature set	4.17	O	NO
Power Management feature set	4.18	M	YES
Power-Up In Standby (PUIS) feature set	4.19	O	YES
Security feature set	4.20	O	YES
S.M.A.R.T. feature set	4.21	O	YES
Software Settings Preservation (SSP) feature set	4.22	O	YES
Streaming feature set	4.23	O	NO
Tagged Command Queuing (TCQ) feature set	4.24	O	NO
Trusted Computing feature set	4.25	O	NO
Write-Read-Verify feature set	4.26	O	NO
Key: M – Mandatory, O – Optional, P – Prohibited, N – Not defined, YES – Supported, NO – Not Supported			

5.1 ATA Commands

Table 5-2: ATA Commands

ATA-8 REF	Commands	ATA-8	Sup p	Key Word Option	Feature Set	OP
7.2	CFA ERASE SECTORS	N	NO	CfaEraseSec, CFES	CFA	C0h
7.3	CFA REQUEST EXTENDED ERROR CODE	O	NO	CfaReqErr, CFRE	CFA	03h
7.4	CFA TRANSLATE SECTOR	O	NO	CfaTransSec, CFTS	CFA	87h
7.5	CFA WRITE MULTIPLE WITHOUT ERASE	O	NO	CfaWrMul, CFWM	CFA	CDh
7.6	CFA WRITE SECTOR(S) WITHOUT ERASE	O	NO	CfaWrSec, CFWS	CFA	38h
7.7	CHECK MEDIA CARD TYPE	O	NO	ChkMedType, CHMT	Media Card	D1h
7.8	CHECK POWER MODE	M	YES	ChkPwrMode, CKPW, CHPW	Power Manage	E5h
7.9	CONFIGURE STREAM	O	NO	CfgStr, CFST	Streaming	51h
7.10.2	DEVICE CONFIGURATION FREEZE LOCK	O	YES	DevCfgFrzLock, DCOF, DCFL	DCO	B1h/C1h
7.10.3	DEVICE CONFIGURATION IDENTIFY	O	YES	DevCgfIdfy, DCOI, DCFI	DCO	B1h/C2h
7.10.4	DEVICE CONFIGURATION RESTORE	O	YES	DevCfgRestore, DCOR, DEFR	DCO	B1h/C0h
7.10.5	DEVICE CONFIGURATION SET	O	YES	DevCfgSet, DCOS, DCFS	DCO	B1h/C3h
7.11	DEVICE RESET	N	NO	DevRst, DRST	Packet	08h
7.12	DOWNLOAD MICROCODE	O	YES	Download, DNLD	General	92h
7.13	EXECUTE DEVICE DIAGNOSTIC	M	YES	Diagnose, DIAG	General	90h
7.14	FLUSH CACHE	M	YES	FlushCache, FLSH	General	E7h
7.15	FLUSH CACHE EXT	M	YES	FlushCacheEx, FLSE, FLEX	48-bit Address	EAh
7.16	IDENTIFY DEVICE	M	YES	Identify, IDFY	General	ECh
7.17	IDENTIFY PACKET DEVICE	N	NO	IdfyPktDev, IDPD	Packet	A1h
7.18	IDLE	M	YES	IDLE	Power Manage	E3h
7.19	IDLE IMMEDIATE	M	YES	IDLI	Power Manage	E1h
-	IDLE/UNLOAD IMMEDIATE	O	YES			E1h-41h
-	INITIALIZE DRIVE PARAMETERS	M	YES			91h
7.20.3	ADD LBA(S) TO NV CACHE PINNED SET	O	NO		NV Cache	B6h/10h
7.20.4	FLUSH NV CACHE	O	NO		NV Cache	B6h/14h
7.20.5	NV CACHE DISABLE	O	NO		NV Cache	B6h/16h
7.20.6	NV CACHE ENABLE	O	NO		NV Cache	B6h/15h

ATA-8 REF	Commands	ATA-8	Supp	Key Word Option	Feature Set	OP
7.20.7	QUERY NV CACHE MISSES	O	NO		NV Cache	BRh/13h
7.20.8	QUERY NV CACHED PINNED SET	O	NO		NV Cache	B6h/12h
7.20.9	REMOVE LBA(S) FROM CACHED PINNED SET	O	NO		NV Cache	B6h/11h
7.20.10	RETURN FROM NV CACHE POWER MODE	O	NO		NV Cache	B6h/01h
7.20.11	SET NV CACHE POWER MODE	O	NO		NV Cache	B6h/00h
7.21	NOP	O	YES	NOP	General	00h
7.22	PACKET	O	NO	Packet, PAKT	Packet	A0h
7.23	READ BUFFER	O	YES	RdBuf, RBUF	General	E4H
7.24	READ DMA	M	YES	RdDma, RDMA	General	C8h
7.25	READ DMA EXT	M	YES	RdDmaEx, RDMX	48-bit Address	25h
7.26	READ DMA QUEUED	O	NO	RdDmaQ, RDMQ	TCQ	C7h
7.27	READ DMA QUEUED EXT	O	NO	RdDmaQEx, RDQX	TCQ	26h
-	READ DMA (w/o retry)	Obs	YES			C9h
7.28	READ FPDMA QUEUED	M	YES	RFPDMAQ, RDMA_NCQ	NCQ	60h
7.29	READ LOG EXT	M	YES	RdLogEx, RLEX	GPL	2Fh
7.30	READ LOG DMA EXT	O	YES		48-bit Address	47h
7.31	READ MULTIPLE	M	YES	RdMul, RMUL	General	C4h
7.32	READ MULTIPLE EXT	M	YES	RdMulEx, RDME, RMEX	48-bit Address	29h
7.33	READ NATIVE MAX ADDRESS	M	YES	RdNativeMax, RNMA	HPA	F8h
7.34	READ NATIVE MAX ADDRESS EXT	M	YES	RdNativeMaxEx, RNME	HPA	27h
7.35	READ SECTOR(S)	M	YES	RdSec, RDSK, REC	General	20h
7.36	READ SECTOR(S) EXT	M	YES	RdSecEx, RDSE, RSEX	48-bit Address	24h
7.37	READ STREAM DMA EXT	O	NO	RdStrDma, RSTD	Streaming	2Ah
7.38	READ STREAM EXT	O	NO	RdStrPio, RSTP	Streaming	2Bh
7.39	READ VERIFY SECTOR(S)	M	YES	RdVfy, RVFE	General	40h
7.40	READ VERIFY SECTOR(S) EXT	M	YES	RdVfyEx, RVFE	48-bit Address	42h
-	READ VERIFY SECTORS(S) (w/o retry)	Obs	YES			41h
-	RECALIBRATE	Obs	YES			10h
7.41	SECURITY DISABLE PASSWORD	M	YES	SecuDisPsw, SEDP	Security	F6h
7.42	SECURITY ERASE PREPARE	M	YES	SecuErasePrep, SERP	Security	F3h
7.43	SECURITY ERASE UNIT	M	YES	SecuEraseUnit, SEEU	Security	F4h
7.44	SECURITY FREEZE LOCK	O	YES	SecuFrzLock, SFZL	Security	F5h

ATA-8 REF	Commands	ATA-8	Supp	Key Word Option	Feature Set	OP
7.45	SECURITY SET PASSWORD	M	YES	SecuSetPsw, SESP	Security	F1h
7.46	SECURITY UNLOCK	M	YES	SecuUnlock, SEUL	Security	F2h
-	SEEK	M	YES			70h-7Fh
7.47	SERVICE	O	NO	Service, SRVC	TCQ	A2h
7.48	SET FEATURES	M	YES	SetFeature, SETF	General	EFh
7.49.2	SET MAX ADDRESS	M	YES	SetMaxAddr, SMXA, SMAX	HPA	F9h
7.49.3	SET MAX FREEZE LOCK	O	YES	SetMaxFrzLock, SMFL	HPA	F9h/04h
7.49.4	SET MAX LOCK	O	YES	SetMaxLock, SMLK	HPA	F9h/02h
7.49.5	SET MAX SET PASSWORD	O	YES	SetMaxSetPswd, SMSP	HPA	F9h/01h
7.49.6	SET MAX UNLOCK	O	YES	SetMaxUnlock, SMUN	HPA	F9h/03h
7.50	SET MAX ADDRESS EXT	M	YES	SetMaxEx, SAME	HPA	37h
7.51	SET MULTIPLE MODE	M	YES	SetMul, SMUL	General	C6h
7.52	SLEEP	M	YES	Sleep, SLEP	Power Manage	E6h
7.53.2	SMART DISABLE OPERATION	M	YES	SmDisable, SDSO, SMDI	SMART	B0h/D9h
-	SMART ENABLE/DISABLE AUTO OFF-LINE	Obs	YES		SMART	B0h-DBh
7.53.3	SMART ENABLE/DISABLE AUTOSAVE	M	YES	SmAutoSv, SAAS, SMAS	SMART	B0h/D2h
7.53.4	SMART ENABLE OPERATION	M	YES	SmEnable, SESO, SMEN	SMART	B0h/D8h
7.53.5	SMART EXECUTE OFFLINE IMMEDIATE	O	YES	ExeSmOL, SEOI, SMOI	SMART	B0h/D4h
7.53.6	SMART READ DATA	O	YES	SmRdData, SRLS, SMRD	SMART	B0h/D0h
7.53.7	SMART READ LOG	O	YES	SmRdLog, SRLS, SMRL	SMART	B0h/D5h
-	SMART READ THRESHOLD	Obs	YES		SMART	B0h-D1h
7.53.8	SMART RETURN STATUS	O	YES	SmStatus, SRSS	SMART	B0h/DAh
-	SMART SAVE ATB VALUES	Obs	YES		SMART	B0h-D3h
7.53.9	SMART WRITE LOG	O	YES	SmWrLog, SWLS, SMWL	SMART	B0h/D6h
7.54	STANDBY	M	YES	Standby, STBY	Power Manage	E2h
7.55	STANDBY IMMEDIATE	M	YES	StandbyIm, STBI	Power Manage	E0h
7.56	TRUSTED NON-DATA	O	NO		Trusted	5Bh
7.57	TRUSTED RECEIVE	O	NO		Trusted	5Ch
7.58	TRUSTED RECEIVE DMA	O	NO		Trusted	5Dh
7.59	TRUSTED SEND	O	NO		Trusted	5Eh
7.60	TRUSTED SEND DMA	O	NO		Trusted	5Fh

ATA-8 REF	Commands	ATA-8	Supp	Key Word Option	Feature Set	OP
7.61	WRITE BUFFER	O	YES	WrBuf, WBUF	General	E8h
7.62	WRITE DMA	M	YES	WdDma, WDMA	General	CAh
7.63	WRITE DMA EXT	M	YES	WrDmaEx, WDMX	48-bit Address	35h
7.64	WRITE DMA FUA EXT	M	YES	WrDmaFuaEx, WDFE	48-bit Address	3Dh
7.65	WRITE DMA QUEUED	O	NO	WrDmaQ, WDMQ	TCQ	CCh
7.66	WRITE DMA QUEUED EXT	O	NO	WrDmaQEx, WDQX	TCQ	36h
7.67	WRITE DMA QUEUE FUA EXT	O	NO	WrDmaQFuaEx, WDQF	TCQ	3Eh
-	WRITE DMA (w/o retry)	Obs	YES			CBh
7.68	WRITE FPDMA QUEUED	M	YES	WFPDMAQ, WDMA_NCQ	NCQ	61h
7.69	WRITE LOG EXT	M	YES	WrLogEx, WRLE	GPL	3Fh
7.70	WRITE LOG DMA EXT	O	YES			57h
7.71	WRITE MULTIPLE	M	YES	WrMul, WMUL	General	C5h
7.72	WRITE MULTIPLE EXT	M	YES	WrMulEx, WDME, WMEX	48-bit Address	39h
7.73	WRITE MULTIPLE FUA EXT	M	YES	WrMulFuaEx, WMFE	48-bit Address	CEh
7.74	WRITE SECTOR(S)	M	YES	WrSec, WDSK, WSEC	General	30h
7.75	WRITE SECTOR(S) EXT	M	YES	WrSecEx, WDSE, WSEX	48-bit Address	34h
-	WRITE SECTOR(S) (w/o retry)	Obs	YES			31h
7.76	WRITE STREAM DMA EXT	O	NO	WrStrDma, WSTD	Streaming	3Ah
7.77	WRITE STREAM EXT	O	NO	WrStrPio, WSTP	Streaming	3Bh
7.78	WRITE UNCORRECTABLE EXT	O	YES			45h
-	DATA SET MANAGEMENT EXT (I.E. TRIM)	O	YES			06h
Key: M – Mandatory, O – Optional, Obs – Obsolete, P – Prohibited, N – Not defined, YES – Supported, NO – Not Supported						

5.1.1 48-Bit Address Command Set

Slim SATA 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

Slim SATA 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

Slim SATA supports the Device Configuration Overlay command set consisting of:

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

5.1.4 General Purpose Log Command Set

Slim SATA supports the General Purpose Log command set consisting of:

- Read Log Ext
- Write Log Ext

5.1.5 Host Protected Area Command Set

Slim SATA 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

Slim SATA supports the Power Management command set consisting of:

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

5.1.7 Security Mode Feature Set

Slim SATA 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)

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 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.

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

5.1.2 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 Off-line Mode

The Element SSD supports 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 Element 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 5-4: 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

5.1.2.2 Captive Mode

When executing a self-test in captive mode, the Element SSD executes the self-test routine after receipt of the command. At the end of the routine the Element SSD places the results of this routine in the self-test execution status byte and reports command completion. If an error occurs while the Element SSD is performing the routine it discontinues its testing, place the results of this routine in the self-test execution status byte and the DST log page, and complete the command.

5.1.2.3 S.M.A.R.T. Logs

S.M.A.R.T. logs are intended to enhance S.M.A.R.T. Attribute information by capturing additional drive details at appropriate times. This information may lead to improved error detection and reporting capability. The controller supports S.M.A.R.T. logs, and relevant tests, events, and conditions each have an associated log. S.M.A.R.T. logs conform to industry-standard structures.

The reported size of each log is reported by the Log Directory (Log 0). Note that the information returned via S.M.A.R.T. Read Log access to Log 0 is more limited than that via GP Read Log. Log size is only reported the LSB (max 255 blocks) when access via S.M.A.R.T. Read Log command; and full 2 bytes (max 65535 blocks) when access via Read Log EXT command.

The frequency at which S.M.A.R.T. logs are updated is the frequency at which checkpoint information is saved. That frequency is related to data volume, and can range between approximately 2 seconds and 2 minutes, depending on how much data is being transferred. Therefore, constant host system IOs cause check-pointing and S.M.A.R.T. log update relatively frequently (approximately every 2 seconds); very slow or idle host transaction rates result in check-pointing and S.M.A.R.T. log update less frequently (worst-case around every 2 minutes).

All logs are non-volatile except as within each of the log description.

Handling and reporting error conditions relating to the updating of S.M.A.R.T. logs and S.M.A.R.T. Attributes is accomplished the same as handling error conditions experienced while saving user data. Likewise, handling and reporting error conditions relating to other processes (including background processes) that occur while updating S.M.A.R.T. logs and S.M.A.R.T. Attributes is accomplished the same as handling such error conditions while saving user data. S.M.A.R.T. logs are validated by affecting the events being detected and logged; the S.M.A.R.T. log always reflects the event that occurred, whether that event is injected artificially or occurs independently.

5.1.3 S.M.A.R.T. Attributes

5.1.3.1 Supported (Baseline) Attributes

The following table shows the supported S.M.A.R.T. attributes.

Table 5-5: Baseline S.M.A.R.T. Attribute Summary

ID	Hex	Attribute Name	Description
1	0x01	Raw Read Error Rate	Raw error rate related to ECC errors. Correctable and uncorrectable RAISE errors are included in the error event count. (UECC + URAISE)
5	0x05	Retired Block Count	Tracks the total number of retired blocks.
9	0x09	Power-On Hours (POH)	Count of hours in power-on state. The raw value of this attribute shows total count of hours in power-on state.
12	0x0C	Device Power Cycle Count	This attribute indicates the count of full hard disk power on/off cycles.
171	0xAB	Program Fail Count	Counts the number of flash program failures
172	0xAC	Erase Fail Count	Counts the number of flash erase failures
174	0xAE	Unexpected Power Loss Count	Counts the number of unexpected power loss events since the drive was deployed.
177	0xB1	Wear Range Delta	Returns the percentage difference in wear between the most worn block and the least worn block.
181	0XB5	Program Fail Count	(Identical to Attribute 171)
182	0XB6	Erase Fail Count	(Identical to Attribute 172)
187	0xBB	Reported Uncorrectable Errors	This attribute tracks the number of uncorrectable RAISE (URAISE) errors reported back to the host for all data access commands.
194	0xC2	Temperature	Temperature assuming an on-board sensor connected via Industry Standard Two Wire Interface (ISTW) interface to the controller.

ID	Hex	Attribute Name	Description
195	0xC3	ECC On the Fly Count	This attribute tracks the number of uncorrectable errors (UECC).
196	0xC4	Reallocation Count	This attribute tracks the # of blocks failing programming which are reallocated.
201	0xC9	Uncorrectable Soft Read Error Rate	Number of soft read errors that cannot be fixed on-the-fly and requires deep recovery via RAISE. (ie UECC)
204	0xCC	Soft ECC Correction Rate	Number of errors corrected by RAISE that cannot be fixed on-the-fly and requires ECC (multilevel) to correct. (ie UECC)
231	0xE7	SSD Life Left	Indicates the approximate percentage of SSD life left.
241	0xF1	Lifetime Writes from Host	Indicates the total amount of data written from hosts since the drive was deployed.
242	0xF2	Lifetime Reads to Host	Indicates the total amount of data read to hosts since the drive was deployed.

Notes

1. SMART ID# 233 and 234 are for Internal Use only.

5.1.3.2 Supported Baseline Attribute Details

The table below provides a detailed description of supported S.M.A.R.T. attributes and how they may be used.

Table 5-6: Baseline S.M.A.R.T. Attribute Details

ID	Attribute Name	Description	Rational
1	Raw Read Error Rate	Raw error rate related to ECC errors. Errors are counted as ECC errors above a threshold. For the controller, this attribute includes Uncorrectable ECC (UECC) errors, and Uncorrectable RAISE (URAISE)errors. Normalized Equation: 10log10(BitsRead/ReadErrors + 1) SectorsRead= Number of sectors read SectorsToBits= 512*8 BitsRead= SectorsRead*SectorsToBits Normalized Value Range: Best = 130 Worst = 38 Invalid = 0 Raw Usage: [3-0] : Number of sectors read [6-4]: Read errors (UECC+URAISE)	The Raw Read error rate includes two types of ECC errors that are tracked by the controller: UECC and URAISE. The normalized equation for Raw read error rate is logarithmic since the valid BER range of the attribute spans from 1.00E-10 to 1.00E-12. To force positive numbers, the numerator and denominator are flipped. One is then added to the number of errors in the denominator to avoid a divide-by-0 condition if no errors are encountered. By taking the log of the inverted BER and multiplying by ten a reasonable range of normalized values from 130 to 38 (representing a BER range of 1.00E-13 to 1.68E-04) are presented. This Attribute reads ‘0’ until a sample size between 10E10 and 10E12 is available to be tracked by this Attribute.

ID	Attribute Name	Description	Rational
5	Retired Block Count	Tracks the total number of retired blocks. <u>Normalized Equation:</u> Count = 100 - (100* RBC / MRB) *RBC = RetiredBlockCount = Number of retired blocks.* *MRB = MinimumReqBlocks = Minimum number of reserve blocks available for controller use. This value is set at factory configuration time.* <u>Normalized Value Range:</u> Best = 100 Worst = 1 <u>Raw Usage:</u> [3-0] : Retired block count [6-4] : None (0x00)	The normalized equation for this attribute decrements as blocks are retired and the reserve (over-provisioned) block count is decremented. (Note that all blocks, including reserve blocks, are in service at all times; reserve blocks constitute Flash memory space over and above the drive's logical capacity.) As defined, this attribute is identical to the Reallocation Event Count attribute (#196).
9	Power-On Hours (POH)	Count of hours in power-on state. The raw value of this attribute shows total count of hours in the power-on state. <u>Normalized Equation:</u> 100 - (POH / HPY * 10) <u>Normalized Value Range:</u> Best = 100 Worst = 1 <u>Raw Usage:</u> [3-0] : Total number of power-on hours [6-4]: total number of milliseconds since last hour update	The normalized equation for Power-On hours decrements by 1 each 1/10 year. Note that some manufacturers elect to decrement by 1 for each 1/12 year of POH.
12	Device Power Cycle Count	This attribute indicates the count of full hard disk power on/off cycles. <u>Normalized Equation:</u> 100 - (PCC / 1024) <u>Normalized Value Range:</u> Best = 100 Worst = 1 <u>Raw Usage:</u> [3-0] : Cumulative lifetime power cycle count (PCC)	The normalized equation for Power Cycle Count decrements by 1 for each 1024 power cycle.

ID	Attribute Name	Description	Rational
		[6-4] : None (0x00)	
171	Program Fail Count	Counts the number of flash program failures. <u>Usage:</u> [3-0] : Program Error Count [6-4] : None (0x00)	This Attribute returns the total number of Flash program operation failures since the drive was deployed. This Attribute is identical to Attribute 181.
172	Erase Fail Count	Counts the number of flash erase failures. <u>Usage:</u> [3-0] : Erase Error Count [6-4] : None (0x00)	This Attribute returns the total number of Flash erase operation failures since the drive was deployed. This Attribute is identical to Attribute 182.
174	Unexpected Power Loss	Counts the number of unexpected power loss events, as determined by the number of times PFAIL has been asserted (or other criteria?). <u>Usage:</u> [3-0] : Unexpected Power Loss Event Count [6-4] : None (0x00)	This Attribute returns the total number of unexpected power loss events over the life of the drive.

ID	Attribute Name	Description	Rational
177	Wear Range Delta	Provides a value equal to the delta between the max worn Flash block and the least worn Flash block, as a percentage of the max rated wear of the SSD. Equation: Wear Range Delta = [(MW - LW) / MRW] x 100 *MW = P-E Cycles experienced by Most Worn block* *LW = P-E Cycles experienced by Least Worn block* *MRW = Max Rated Wear = P-E Cycle rating for the Flash memory* Usage: [3-0] : Wear Range delta [6-4] : None (0x00)	This Attribute identifies the "delta" between most-worn and least-worn Flash blocks, as a percentage of the max rated wear of the Flash memory on the SSD. For 10,000-cycle Flash, where 1% of rated cycles is 100 cycles, a value of 1.5 for this Attribute means the difference in wear between the least worn block and the most-worn block is 150 Erase cycles. This attribute may not be accurate until approximately 10% of drive life has been used.
181	Program Fail Count	Counts the number of flash program failures. Usage: [3-0] : Program Error Count [6-4] : None (0x00)	This Attribute returns the total number of Flash program operation failures since the drive was deployed. This Attribute is identical to Attribute 171.
182	Erase Fail Count	Counts the number of flash erase failures. Usage: [3-0] : Erase Error Count [6-4] : None (0x00)	This Attribute returns the total number of Flash erase operation failures since the drive was deployed. This Attribute is identical to Attribute 172.

ID	Attribute Name	Description	Rational
187	Reported Uncorrectable Errors (URAISE)	Uncorrectable Errors (URAISE) This attribute tracks the number of uncorrectable RAISE (URAISE) errors reported back to the host for all data access commands. Normalized Equation: 100 - (URAISE) Normalized Value Range: Best = 100 Worst = 1 Raw Usage: [1-0] : Cumulative lifetime URAISE errors [6-2] : None (0x00)	The uncorrectable ECC error rate tracks the controller Uncorrectable RAISE (URAISE) errors. The normalized equation for Uncorrectable Error Count decrements by 1 for each URAISE error. Uncorrectable errors reported in this field are uncorrectable by any level of ECC protection including RAISE.
194	Temperature	Temperature of the SSD assembly. That is,the temperature inside the SSD housing. Normalized Equation: Temperature = Temperature (Celsius) Normalized Value Range: Lowest = -127 Highest = 127 Raw Usage: [1-0] : Current temperature (C; from sensor) [3-2]: Highest temperature (C; since power-on) [5-4]: Lowest temperature (C; since power-on) [6] : None (0x00)	The normalized temperature is a straight Celsius value as obtained from the primary SSD temperature sensor. The raw values represent current and historical Celsius temperature values from the primary SSD temperature sensor. For SSD designs incorporating multiple temperature sensors, current temperature is taken from the sensor with the highest reading; historical values are highest or lowest of all sensors polled.

ID	Attribute Name	Description	Rational
195	ECC On-the-Fly Error Count	This attribute tracks the number of uncorrectable ECC errors (UECC). The normalized value is only computed when the number of bits in the "BitsRead" count is in the range of 10^10 to 10^12. The count is cleared at power on reset and when >10^12 bits have been read. <u>Normalized Equation:</u> 10log10(BitsRead/ECCOnTheFlyErrors + 1) *SectorsRead= Number of sectors read* *SectorsToBits= 512*8* *BitsRead= SectorsRead*SectorsToBits* <u>Normalized Value Range:</u> Best = 130 Worst = 38 Invalid = 0 <u>Raw Usage:</u> [3-0] : Number of sectors read [6-4]: ECCOnTheFlyErrors (UECC) count	The ECC On The Fly error rate includes all uncorrectable ECC errors (UECC) tracked by the controller. The normalized equation for ECC On The Fly error rate is logarithmic since the valid BER range of the attribute spans from 1.00E-10 to 1.00E-12. To force positive numbers, the numerator and denominator are flipped. One is then added to the number of errors in the denominator to avoid a divide-by-0 condition if no errors are encountered. By taking the log of the inverted BER and multiplying by ten a reasonable range of normalized values from 130 to 38 (representing a BER range of 1.00E-13 to 1.68E-04) are presented. As defined, this Attribute is identical to Attribute 201 and Attribute 204. This Attribute reads ‘0’ until a sample size between 10E10 and 10E12 is available to be tracked by this Attribute. Note that many UECC errors counted by this Attribute are corrected by RAISE correction.

ID	Attribute Name	Description	Rational
196	Reallocation Event Count	Tracks the total number of reallocated Flash blocks. <u>Normalized Equation:</u> Count = 100 - (100* RBC / MRB) RBC = RetiredBlockCount = Number of retired blocks. MRB = MinimumReqBlocks = Minimum number of reserve blocks available for contoller use. This value is set at factory configuration time. <u>Normalized Value Range:</u> Best = 100 Worst = 1 <u>Raw Usage:</u> [3-0] : Retired block count [6-4] : None (0x00)	The normalized equation for this attribute decrements as blocks are retired and the reserve (over-provisioned) block count is decremented. (Note that all blocks, including reserve blocks, are in service at all times; reserve blocks constitute Flash memory space over and above the drive's logical capacity.) As defined, this attribute is identical to the Retired Block Count attribute (#5).
201	Uncorrectable Soft Read Error (UECC)	Number of soft read errors that cannot be fixed on-the-fly and requires deep recovery provided by RAISE. The normalized value is only computed when the number of bits in the "BitsRead" count is in the range of 10^10 to 10^12. The count is cleared at power on reset and when >10^12 bits have been read. Normalized Equation: 10log10(BitsRead/UECC + 1) SectorsRead= Number of sectors read SectorsToBits= 512*8 BitsRead= SectorsRead*SectorsToBits Normalized Value Range: Best = 130 Worst = 38 Invalid = 0 Raw Usage: [3-0] : Number of sectors read [6-4]: Uncorrectable Soft error count (UECC)	The Uncorrectable Soft Read Error Rate includes all uncorrectable ECC (UECC) errors tracked by the CONTROLLER. The normalized equation for Uncorrectable Soft Read Error Rate is logarithmic since the valid BER range of the attribute spans from 1.00E-10 to 1.00E-12. To force positive numbers, the numerator and denominator are flipped. One is then added to the number of errors in the denominator to avoid a divide-by-0 condition if no errors are encountered. By taking the log of the inverted BER and multiplying by ten a reasonable range of normalized values from 130 to 38 (representing a BER range of 1.00E-13 to 1.68E-04) are presented. As defined this attribute is identical to 195 and 204. This Attribute reads '0' until a sample size between 10E10 and 10E12 is available to be tracked

ID	Attribute Name	Description	Rational
			by this Attribute.
204	Soft ECC Correction Rate (UECC)	Number of errors corrected by RAISE that cannot be fixed on-the-fly and requires RAISE to correct. The normalized value is only computed when the number of bits in the "BitsRead" count is in the range of 10^10 to 10^12. The count is cleared at power on reset and when >10^12 bits have been read. Normalized Equation: 10log10(BitsRead/UECC + 1) SectorsRead= Number of sectors read SectorsToBits= 512*8 BitsRead= SectorsRead*SectorsToBits Normalized Value Range: Best = 130 Worst = 38 Invalid = 0 Raw Usage: [3-0] : Number of sectors read [6-4]: Soft ECC correction count (UECC)	The Soft ECC Correction Rate includes all uncorrectable ECC (UECC) errors tracked by the CONTROLLER. The normalized equation for Soft ECC Correction Rate is logarithmic since the valid BER range of the attribute spans from 1.00E-10 to 1.00E-12. To force positive numbers, the numerator and denominator are flipped. One is then added to the number of errors in the denominator to avoid a divide-by-0 condition if no errors are encountered. By taking the log of the inverted BER and multiplying by ten a reasonable range of normalized values from 130 to 38 (representing a BER range of 1.00E-13 to 1.68E-04) are presented. As defined this attribute is identical to 195 and 201. This Attribute reads '0' until a sample size between 10E10 and 10E12 is available to be tracked by this Attribute.
231	SSD Life Left	Indicates the approximate SSD life left, in terms of PE cycles and Flash blocks currently available for use. Normalized Equation: SSD Life Left = MIN[MAX(termA, 10), termB] termA = (Unused)/(Rated) x 100 Unused = (unused PE cycles) Rated = (rated PE cycles) termB = (AvailExcess)/(OrigExcess) AvailX = (Blocks above min req'd) OrigX = (Original blks above min req'd)	SSD life left is based on actual usage and takes into account PE cycle consumption and Flash block retirement. PE cycle usage at a rate less than the rate used for performance throttling will result in extending drive life. Actual Flash endurance remaining is normally greater than the unused rated PE cycles. Note that block retirement rate also affects SSD life and this

ID	Attribute Name	Description	Rational
		Normalized Value Range: 100 = Best = Full SSD life remains 10 = Replace = Sufficient Flash blocks still in service, but rated PE Cycles consumed 1 = Worst = Insufficient Flash blocks remain in service; EOL; drive is read-only	Attribute value.
241	Lifetime Writes from Host System	Indicates the number of bytes (in 64GB resolution) written to the drive by a host system, over the life of the drive. Usage: [3-0]: Count of 64GB units written [6-4] : None (0x00)	This Attribute returns a byte count, in units of Gigabytes at an update resolution of 64 GBytes. The count represents the number of bytes written. The Attribute reads '0' until the number of bytes written reaches 64GB; at 64GB the Attribute increments to a value of '64' (decimal).
242	Lifetime Reads to Host System	Indicates the number of bytes (in 64GB resolution) read from the drive by a host system, over the life of the drive. Usage: [3-0]: Count of 64GB units read [6-4] : None (0x00)	This Attribute returns a byte count, in units of Gigabytes at an update resolution of 64 GB. The count represents the number of bytes read. The Attribute reads '0' until the number of bytes read reaches 64GB; at 64GB the count increments to a value of '64' (decimal).

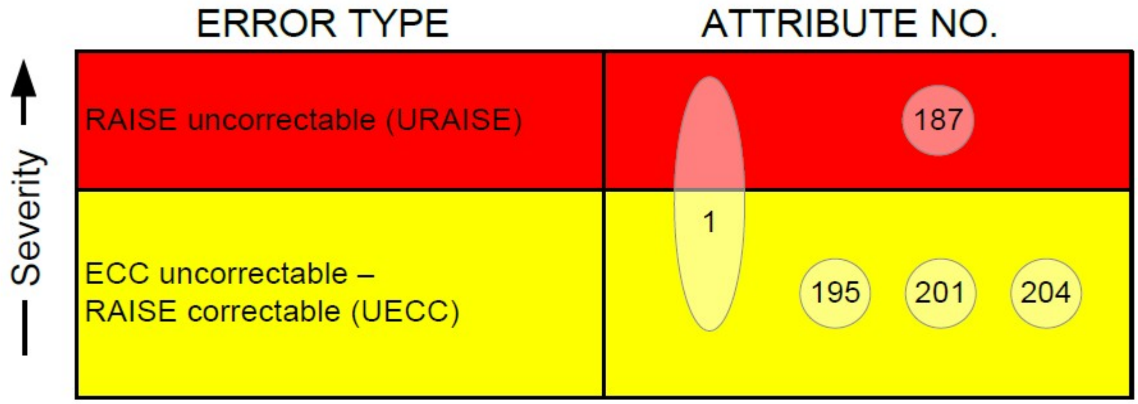


Figure 5-1: S.M.A.R.T. ECC and RAISE Error Summary

Attribute Sector

The S.M.A.R.T. Attribute Sector defines attribute format and the data structure is defined in the following table.

Table 5-7: S.M.A.R.T. Attribute Data Structure

Byte	Description
0:1	S.M.A.R.T. structure version number
2	First Stored Attribute Number (i.e. “1” for RawErrorRate)
3:4	Status
5	Nominal value
6	Worst value since SSD was deployed
7:12	Raw Data
13	Reserved
14:25	Next Stored Attribute Number (ie “3” for “Retired Block Count”)
26:361	Next Stored Attribute Numbers (max 30 collected Attributes, including above)
362	Off-line data collection status
363	Self-test execution status byte
364:365	Total time to complete off-line data collection (in seconds)
366	Reserved
367	Off-line Data Collection capability
368:369	S.M.A.R.T. capability
370	Error Logging Capability (bit 0 set = device error logging supported)
371	Next Self Test Step
372	Short Self Test routine recommended polling time (in minutes)
373	Extended Self Test routine recommended polling time (in minutes)
374	Recommended polling time for Conveyance Self Test
375:376	Time for Extended Self Test if > 255 (ie, 373 to FFh)
377:385	Reserved
386:510	Vendor Information
511	Checksum of data structure (generated on retrieval of stored data)

Note: Bytes 2:361 are vendor unique

5.1.4 Threshold Sector

The S.M.A.R.T. Threshold Sector defines attribute trip thresholds. Attributes are compared to the thresholds when the S.M.A.R.T. Return Status Command (DA) retrieves drive reliability Status. The S.M.A.R.T. Read Threshold Sector Command (DI) then used to read this information. Threshold information may be modified or written via the S.M.A.R.T. Write Threshold Value Command (D7). Threshold values are obtained from the Saved Configuration Page.

Table 5-8: S.M.A.R.T. Threshold Data Structure

Byte	Description
0:1	S.M.A.R.T. structure version number
2	First Stored Attribute Number (i.e. “1” for RawErrorRate)
3	Threshold Value for first attribute
4:13	Reserved
14	Next Stored Attribute Number
15	Threshold Value for next attribute
16:25	Reserved
26:361	Attribute Number, Threshold and 10 reserved bytes for supported attributes, (max 30 collected Attributes, including above)
362:379	Reserved
380:510	Vendor Unique
511	Checksum

5.1.5 S.M.A.R.T. Command Transport (SCT)

The Element SSD supports the S.M.A.R.T. Command Transport (SCT). SCT allows the host to send commands, send and receive data, and receive status to and from the Element SSD using log page 0xE0 and log page 0xE1. SCT uses S.M.A.R.T. READ/WRITE LOG commands, READ/WRITE LOG EXT commands, or READ/WRITE LOG DMA EXT commands to access the log pages. For additional SCT information please reference ATA8-ACS.

5.2 SATA Commands

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

5.2.1 Native Command Queuing (NCQ)

The Element SATA SSD supports 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 Certifications and Compliance

Table 6-1: Device Certifications

Certification/Compliance	Description
RoHS	Viking Modular Solutions(TM), Sanmina Corporation ("Viking") shall use commercially reasonable efforts to provide components, parts, materials, products and processes to customers that do not contain: (i) lead, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) above 0.1% by weight in homogeneous material or (ii) cadmium above 0.01% by weight of homogeneous material, except as provided in any exemption(s) from RoHS requirements (including the most current version of the "Annex" to Directive\ 2002/95/EC of 27 January, 2003), as codified in the specific laws of the EU member countries. Viking strives to obtain appropriate contractual protections from its suppliers in connection with the RoHS Directives.
China RoHS	Restriction of hazardous substances
Serial ATA	Requirements for logo
EU WEEE Compliant	The Waste Electrical and Electronic Equipment Directive (WEEE Directive) is the European Community directive 2002/96/EC on waste electrical and electronic equipment (WEEE) which, together with the RoHS Directive 2002/95/EC, became European Law in February 2003, setting collection, recycling and recovery targets for all types of electrical goods.

7 References

- JEDEC Mechanical Outline MO-297A
- Environmental Specification: MIL-STD-810F
- Amphenol SATA Connector, SATA-001-0095-3-T
- Serial ATA Specification, revision 2.6 and 3.x

8 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 $1x10^9$ 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 $1x10^6$ 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