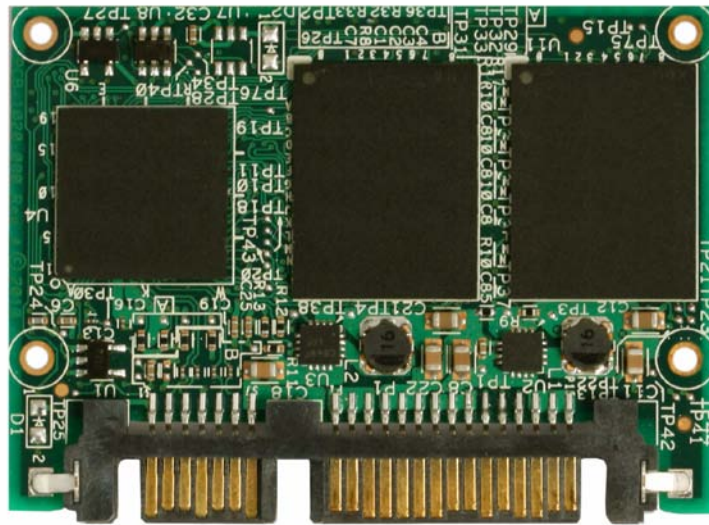


SATA 3Gb/s Industrial Slim SATA Manual



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.

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 1 of 33

Revision History

Date	Revision	Description	Checked by
5/10/13	A	Initial Release	
6/27/13	A1	Update PN table for new PN's	
7/11/13	A2	Labeled and revised SMART table	
7/24/13	A3	Add SMART table for 3Gps. Revised performance numbers per lab data. Added AES info	
9/09/13	A4	Add product image to 1 st page. Create separate datasheets for 3Gbps. Revised extended SMART attributes. Changed Client to Industrial. Add MLC PN's. Revised performance #s. Revised PN table to avoid confusion on I- temperature and commercial temperature PN's.	
1/02/14	A5	Revised datasheet format	
9/11/14	B	Revise IOP values (7/29/14, A6)	

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Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 3 of 33

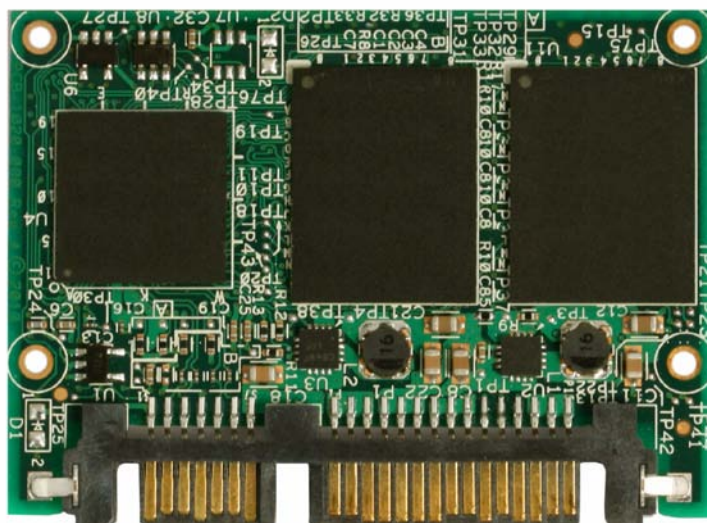
Ordering Information: Slim SATA SSD Solid-State Drive

Part Numbers	SATA Interface	Application	Raw Capacity (GB)	Useable Capacity (GB) ¹	Addressable Sectors in LBA Mode	NAND Technology	Temperature Range
VRFEM1008GQCQMxx	3Gbps	Industrial	8	8	15,625,000	MLC	0 to 70c
VRFEM1016GQCQMxx	3Gbps	Industrial	16	16	31,277,232	MLC	0 to 70c
VRFEM1032GQCRMxx	3Gbps	Industrial	32	32	62,533,296	MLC	0 to 70c
VRFEM1064GQC SMxx	3Gbps	Industrial	64	64	125,045,424	MLC	0 to 70c
VRFEM1008GQIQMxx	3Gbps	Industrial	8	8	15,625,000	MLC	-40 to 85c
VRFEM1016GQIQMxx	3Gbps	Industrial	16	16	31,277,232	MLC	-40 to 85c
VRFEM1032GQIRMxx	3Gbps	Industrial	32	32	62,533,296	MLC	-40 to 85c
VRFEM1064GQISMxx	3Gbps	Industrial	64	64	125,045,424	MLC	-40 to 85c
VRFEM14096QC GSxx	3Gbps	Industrial	4	4	7,812,500	SLC	0 to 70c,
VRFEM18192QC HSxx	3Gbps	Industrial	8	8	15,625,000	SLC	0 to 70c
VRFEM18192QC QSxx	3Gbps	Industrial	8	8	15,625,000	SLC	0 to 70c
VRFEM1016GQC QSxx	3Gbps	Industrial	16	16	31,277,232	SLC	0 to 70c
VRFEM1032GQC RSxx	3Gbps	Industrial	32	32	62,533,296	SLC	0 to 70c
VRFEM1064GQC SSxx	3Gbps	Industrial	64	64	125,045,424	SLC	0 to 70c
VRFEM14096QIG Sxx	3Gbps	Industrial	4	4	7,812,500	SLC	-40 to 85c
VRFEM18192QI HSxx	3Gbps	Industrial	8	8	15,625,000	SLC	-40 to 85c
VRFEM18192QIQ Sxx	3Gbps	Industrial	8	8	15,625,000	SLC	-40 to 85c
VRFEM1016GQIQ Sxx	3Gbps	Industrial	16	16	31,277,232	SLC	-40 to 85c
VRFEM1032GQIR Sxx	3Gbps	Industrial	32	32	62,533,296	SLC	-40 to 85c
VRFEM1064GQISSxx	3Gbps	Industrial	64	64	125,045,424	SLC	-40 to 85c

Notes:

- 1) Usable capacity based on a level of over-provisioning applied to wear leveling, bad sectors, index tables etc.
- 2) Higher 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
- 5) One Sector = 512 Byte.
- 6) Contact Viking for the characters that "x" and "y" represent in the part number.
- 7) xx is a wild card to indicate customer specific BOM, NAND configuration and/or manufacturing location

Product Picture(s)



Slim SATA Top View

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 5 of 33

Industrial SSD – Viking’s Industrial SSD contains sophisticated provisions to protect firmware and data from corruption due to unexpected power loss. However, a Industrial SSD by industry definition does not contain on-board capacitance. Should power fail unexpectedly, “in-flight” write data may be lost. Industrial SSD’s are best used in designs that manage power fail events at the system level.

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 6 of 33

Table of Contents

1	INTRODUCTION	10
1.1	Features	10
1.2	Block Diagram	11
1.3	SATA Interface	12
2	PRODUCT SPECIFICATIONS	13
2.1	Performance	13
2.2	Timing	13
2.2.1	STANDBY IMMEDIATE Command	14
2.3	Electrical Characteristics	14
2.3.1	Absolute Maximum Ratings	14
2.3.2	Supply Voltage	14
2.3.3	Power Consumption	15
2.4	Environmental Conditions	15
2.4.1	Temperature and Altitude	15
2.4.2	Shock and Vibration	15
2.4.3	Electromagnetic Immunity	15
2.5	Reliability	16
2.6	Data Security	16
3	MECHANICAL INFORMATION	17
3.1	Slim SATA SSD Weight	18
4	PIN AND SIGNAL DESCRIPTIONS	18
4.1	Pin Locations	18
4.2	Signal and Power Description Tables	18
4.3	Hot Plug Support	19
5	COMMAND SETS	19

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 7 of 33

5.1	ATA Commands	19
5.1.1	48-Bit Address Command Set	20
5.1.2	ATA General Feature Command Set	21
5.1.3	Device Configuration Overlay Command Set	21
5.1.4	General Purpose Log Command Set	21
5.1.5	Host Protected Area Command Set	21
5.1.6	Power Management Command Set	22
5.1.7	Security Mode Feature Set	22
5.1.8	Identify Device Data	23
5.1.1	S.M.A.R.T. Support	26
5.1.2	S.M.A.R.T. Command Set	27
5.2	SATA Commands	31
5.2.1	Native Command Queuing (NCQ)	31
6	REFERENCES	32
7	GLOSSARY	33

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 8 of 33

Table of Tables

<i>Table 2-1: Maximum Sustained Read and Write Bandwidth</i>	13
<i>Table 2-2: Random Read and Write Input/Output Operations per Second (IOPS)</i>	13
<i>Table 2-3: Timing Specifications</i>	13
<i>Table 2-4: STANDBY IMMEDIATE Timing</i>	14
<i>Table 2-5: Absolute Maximum Ratings</i>	14
<i>Table 2-6: Operating Voltage</i>	14
<i>Table 2-7: Typical Power Consumption</i>	15
<i>Table 2-8: Temperature and Altitude Related Specifications</i>	15
<i>Table 2-9: Shock and Vibration Specifications</i>	15
<i>Table 2-10: Reliability Specifications</i>	16
<i>Table 4-1: Serial ATA Connector Pin Signal Definitions</i>	18
<i>Table 4-2: Serial ATA Power Pin Definitions</i>	19
<i>Table 5-1: Supported ATA Commands</i>	19
<i>Table 5-2: List of Device Identification</i>	23
<i>Table 5-3: Capacity specific Device Identification</i>	26
<i>Table 5-4: S.M.A.R.T. Command Set</i>	28
<i>Table 5-5: Extended SMART Attribute Table</i>	28
<i>Table 5-6: Extended SMART Attribute Actual Data</i>	29
<i>Table 5-7: Supported S.M.A.R.T. EXECUTE OFF-LINE IMMEDIATE Subcommands</i>	31

Table of Figures

<i>Figure 1-1: High-Level Block Diagram for VRFEM1xxxGQxxx</i>	11
<i>Figure 3-1: Dimensions</i>	17
<i>Figure 4-1: Layout of Signal and Power Segment Pins</i>	18

1 Introduction

Viking's rugged industrial designed SSD's offer the highest flash storage reliability and performance in harsh environments such as shock, vibration, humidity, altitude, ESD, and extreme temperatures.

1.1 Features

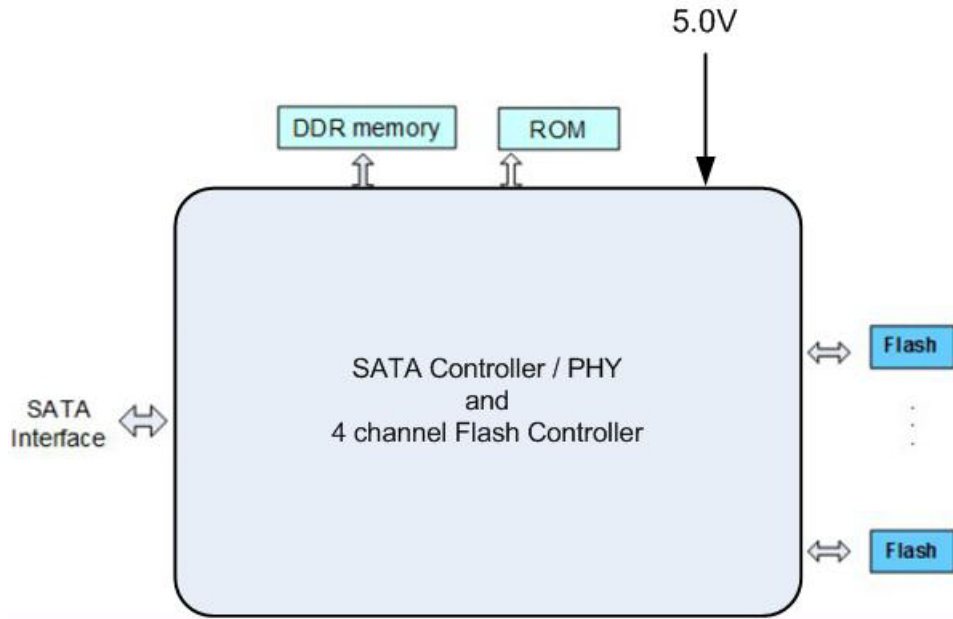
The SSD delivers the following features:

- Offers seamless SATA Revision 2.6 interface support for SATA up to 3Gb/s
- Low overall SSD power consumption
- Supports Native Command Queuing (NCQ) to 32 commands
- Compatible with all major SLC, MLC and eMLC flash technologies
- S.M.A.R.T.
- Superior wear-leveling algorithm
- Efficient error recovery

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 10 of 33

1.2 Block Diagram

Figure 1-1: High-Level Block Diagram for VRFEM1xxxGQxxx



Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 11 of 33

1.3 SATA Interface

- The Serial ATA (SATA) interface is compliant with the SATA IO Serial ATA specification, revision 2.6 that supports SATA up to 3Gb/s.
- The SATA interface connects the host computer to the SSD subsystem.
- The SATA interface runs at a maximum speed of 3.0Gbps (Giga-bits per second). If the host computer is unable to negotiate a speed of 3.0Gbps, the SATA interface automatically renegotiates to a speed of 1.5Gbps.

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

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 12 of 33

2 Product Specifications

2.1 Performance

Table 2-1: Maximum Sustained Read and Write Bandwidth

Access Type	VRFEM1xxxGQxxx
Sequential Read, 256K	Up to 197 MB/s
Sequential Write, 256K	Up to 85 MB/s

Notes:

1. Performance measured using IOMeter 06 with queue depth set to 32.
2. Write Cache enabled with DDR cache.
3. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.

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

Access Type	VRFEM1xxxGQxxx
Read, 4K	Up to 5270 IOPS
Write, 4K	Up to 65 IOPS

Notes:

1. Performance measured using Iometer 06 with queue depth set to 32.
2. Write Cache enabled with DDR cache.
3. 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)
4. Performance may vary by NAND type and host.
5. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.
6. Data is based on SSD's using Synchronous NAND devices (ONFI or toggle mode) 32GB TosMLC

2.2 Timing

Table 2-3: Timing Specifications

Type	Average Latency
Power-On-to-Ready (POR)	550 ms
Command to DRQ	600 μ sec ⁶
Time to Erase (ATA Secure Erase)	9 sec

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
6. Data is based on SSD's using Synchronous NAND devices (ONFI or toggle mode)

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 2-4: STANDBY IMMEDIATE Timing

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

Notes:

1. From Standby Immediate command to NAND Write Protect enable.

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 2-5: 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 5V.

Table 2-6: Operating Voltage

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

Table 2-8: Current Draw – SATA

Mode	Typical ¹	Unit
Read/Writes (Average RMS)	215 / 310	mA
Idle	25	mA
Slumber	10	mA

Notes:

1. Measured using 16GB SLC, VRFEM1016GQCQS

2.3.3 Power Consumption

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

Table 2-7: Typical Power Consumption

Mode	Typical	Unit
Active	tbd	W
Idle	tbd	W

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)
Industrial Temperature - Ambient	-40 to 85°C (-40 to 185° F)	-40 to 85°C (-40 to 185° F)	-40 to 85°C (-40 to 185° F)
Humidity (non-condensing)	95% under 55C	95% under 55C	95% under 55C

Notes:

1. SLC flash based products may be available in the following temperature ranges:
 - a) Commercial temperature range of 0 to 70°C (32 to 158° F)
 - b) Industrial temperature range -40 to 85°C (-40 to 185° F)

2.4.2 Shock and Vibration

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

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

2.4.3 Electromagnetic Immunity

SSD 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	VRFEM1xxxGQxxx
ECC	44-bit per 1KByte
Read Endurance	Unlimited
Write Endurance	(specified by the flash component)
Data retention	> 90 days at NAND expiration

2.6 Data Security

Viking’s Slim SATA SSD’s are self-encrypting drives (SED), with a bulk data encryption feature that provides automatic hardware-based data security and enhanced secure erase capability.

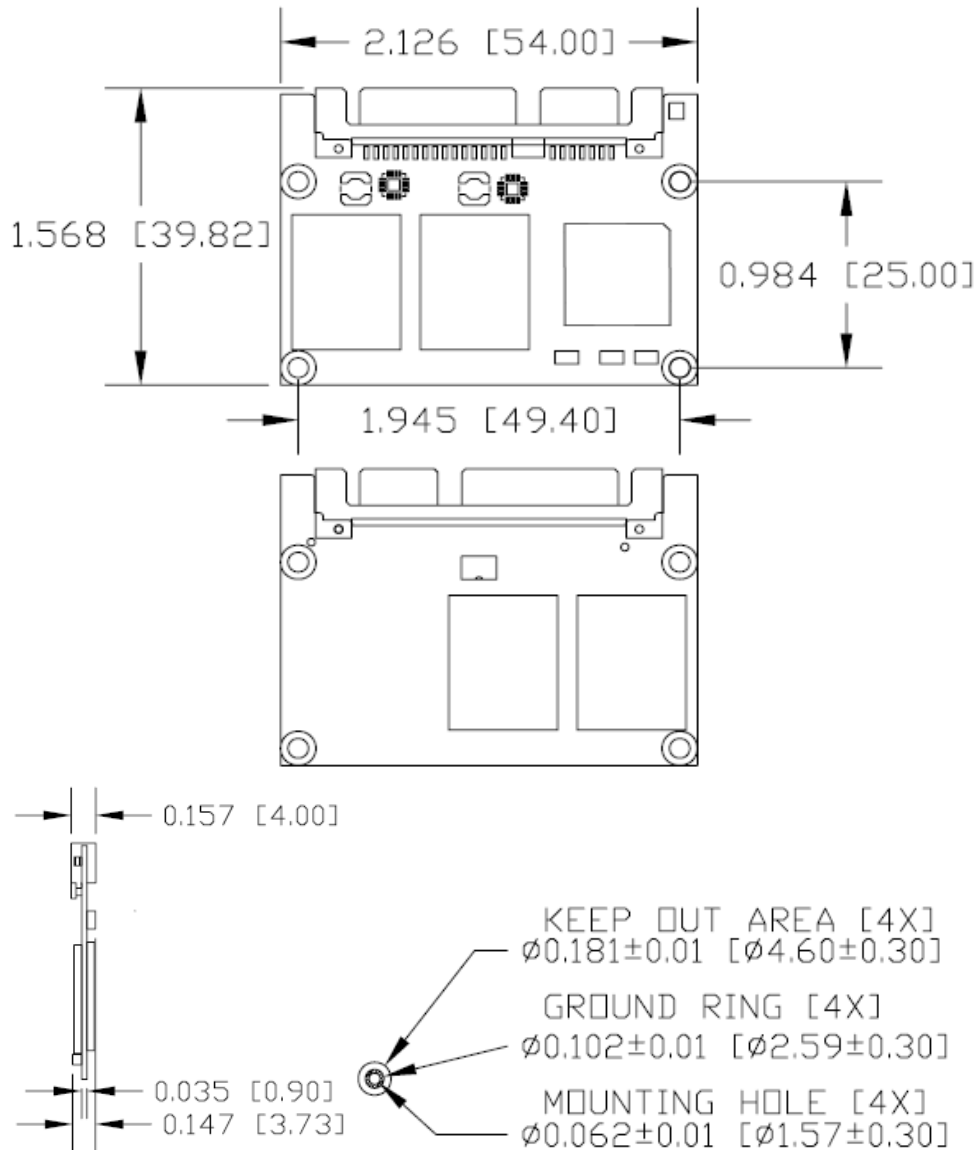
A self-encrypting drive, scrambles data using a data encryption key as it is written to the drive and then descrambles it with the key as it is retrieved. This gives the user the highest level of data protection available and provides a fast erase simply by deleting the encryption key, eliminating the need for time consuming data-overwrite. Data on the drive is instantly rendered unreadable.

The Slim SATA SSD supports AES-128 encryption, AES-256 encryption and ATA Secure Erase features to protect sensitive data. The drive is also available with TCG security enhancements.

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].

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 17 of 33

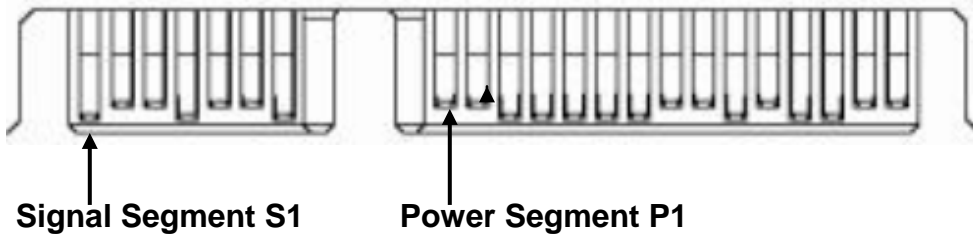
3.1 Slim SATA SSD Weight

The weight of a Slim SATA (MO-297) SSD 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

Notes:

1. 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

Notes:

- 1) 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

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

Description	Op Code	Description	Op Code
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
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:

- 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)

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 21 of 33

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

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 22 of 33

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	3FFFh	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	3FFFh	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	00FBFC10h	Obsolete – Current capacity in sectors –
59	F	0110h	Number of sectors transferred per interrupt on MULTIPLE commands
60-61	F	8GB-128GB	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

Word	F: Fixed V: Variable X: Both	Default Value	Description
66	F	0078h	Manufacturer's recommended Multiword DMA transfer cycle time
67	F	0078h	Minimum PIO transfer cycle time without flow control
68	F	0078h	Minimum PIO transfer cycle time with IORDY flow control
69	F	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	0706h	Serial SATA capabilities
77	F	0000h	Reserved for future Serial ATA definition
78	F	0044h	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	70D9h	Command set supported
84	F	6023h	Command set/feature supported extension
85	V	3469h	Command set/feature enabled
86	V	BC01h	Command set/feature enabled
87	V	6023h	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	8GB-256GB	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	4015h	Supported settings
120	F	4015h	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	101Fh	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 DOWNLOAD MICROCODE command for

Word	F: Fixed V: Variable X: Both	Default Value	Description
			mode 03h
235		00FFh	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)

Table 5-3: Capacity specific Device Identification

Capacity (GB)	*1	*2	*3	*4
	(Word 1/Word 54)	(Word 57-58)	(Word 60-61)	(Word 100-103)
64	tbd	tbd	tbd	tbd
128	tbd	tbd	tbd	tbd
256	tbd	tbd	tbd	tbd
512	tbd	tbd	tbd	tbd
1000	tbd	tbd	tbd	tbd

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.

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.

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 27 of 33

Table 5-4: 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 5-5: Extended SMART Attribute Table

SMART Attribute ID	Description
01h	Read Error Rate
05h	Reallocated sector Count
09h	Power-On hours Count
0Ch	Drive Power Cycle Count (Number of accumulation of power on/off cycles)
20h	Write Protect
A7h	SSD Protect Mode
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
A9h	Total Bad Block Count
AAh	Max Bad Block Count (will show early bad and later bad block count)
ACh	Erase Fail Count
ADh	Erase count (average, max, erase count)
B1h	Wear Range delta
B5h	Program Fail Count

SMART Attribute ID	Description
B6h	Erase Failure Block Count
B7h	Erase Count
BBh	Reported Uncorrectable Errors
C0h	Unexpected Power Loss Count
C2h	Temperature (only Toshiba or thermo sensor embedded)
C4h	Max Bad Block Count
C7h	Ultra CRC Error Count
DAh	Number of accumulation CRC error (read/write data FIS CRC error)
E7h	Wear Range delta/SSD life remaining
E8h	Read Failure Block Count
E9h	Lifetime Writes to Flash
F1h	Host Writes
F2h	Host Reads
F6h	Total Erase Count

Table 5-6: Extended SMART Attribute Actual Data

0	1	2	3	4	5	6	7	8	9	10	11	
ID	Flag	Flag	Value	Worse	DATA						Threshold	
01h	0Bh	00h	64h	64h	0	0	Uncorrectable ECC Count		0	0	0	32h
05h	13h	00h	64h	64h	0	0	0	0	0	0	0	32h
09b	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
A9h	13h	00h	Fla6	Fla6	E (Note)		D (Note)		Total Bad Block Count		0	0Ah
AAh	02h	00h	Fla10	Fla10	Early Bad Block		0	0	Later Bad Block		0	0Ah
ACh	32h	00h	64h	64h	Erase Fail Count		0	0	0	0	0	00h
ADh	12h	00h	64h	64h	Max Erase Count		Ave Erase Count (Fla4)		0	0	0	00h

0	1	2	3	4	5	6	7	8	9	10	11	
ID	Flag	Flag	Value	Worse	DATA							Threshold
B1h	00h	00h	00h	00h	Fla7	0	0	0	0	0	0	00h
B5h	12h	00h	64h	64h	Program Fail Count		0	0	0	0	0	00h
B6b	32h	00h	00h	00h	Erase Fail Count		0	0	0	0	0	00h
B7h	12h	00h	64h	64h	Fla4	Max Erase Count		Min Erase Count		0	64h	
BBh	32h	00h	64h	64h	Uncorrectable Count		0	0	0	0	0	00h
C0h	12h	00h	64h	64h	Number of Accidental Power Loss Count				0	0	0	00h
C2h	23h	00h	100-Current Temp	100-Highest Value	Current Temp		Lowest Temp		Highest Temp		0	1Eh
C4b	13h	00h	Fla8	Fla8	B (Note)		A (Note)		C (Note)			0Ah
C7h	32h	00h	64h	64h	CRC Error Count		0	0	0	0	0	00h
DAh	0Bh	00h	64h	64h	CRC Error Count				0	0	0	32h
E7h	13h	00h	64h	64h	Fla9	0	0	0	0	0	0	00h
E8h	0Bh	00h	64h	64h	Read Fail Count	0	0	0	0	0	0	00h
E9h	0Bh	00h	64h	64h	Lifetime Writes to Flash by Sector						0	00h
F1h	12h	00h	64h	64h	Lifetime Writes from Host by Sector						0	00h
F2h	12h	00h	64h	64h	Lifetime Reads from Host by Sector						0	00h
F6h	12h	00h	64h	64h	Total Erase Count						0	00h

Notes:

Formula:

Fla4 = Total Erase Count / disk Total Blocks (average Erase Count)
 Fla6 = (100 * (D- Total Bad Block Count) / (D-E)) Max = 100, Min = 1
 Fla7 = 100*((Max Erase Count- F1a4)/Flash PE Cycle (MLC 3000, SLC 10000))
 Fla8 = (100*(A-C))/A (Note) Min = 1
 Fla9 = 100- (100*(F1a4/ Flash PE Cycle (MLC 3000, SLC 10000))
 Fla10 = (100*G)/F Max = 100, Min = 1

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 30 of 33

- A: Number of free blocks when SSD changes to Write protect mode. (Plane)
- B: Maximum Acceptable Number of Bad Blocks (Plane)
- C: Number of Maximum Bad Blocks (Plane)
- D: Number of free blocks when SSD changes to Write protect mode. (All Plane)
- E: Acceptable Number of Bad Blocks (All Plane)

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 5-7: 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 2.6

Manual	9/11/2014
PSFEM1xxxGQxxx	Viking Technology
Revision B	Page 32 of 33

7 Glossary

This document incorporates many industry and device specific words. The following list defines a variety of these 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