

SATA 6Gb/s M.2 SATA Manual

M.2 SATA is a non-volatile, solid-state storage device delivering Serial ATA performance, reliability and ruggedness for environmentally challenging applications.

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 1 of 36 |

Revision History

| Date | Revision | Description | Checked By |
|----------|----------|--|------------|
| 10/13/14 | X1 | Initial Release from modified PSFEM2XXXGSXXX | |
| 10/15/14 | X2 | Add key slots | |
| 1/25/15 | X3 | Update PN table per PSG | |
| 2/5/15 | A | Update photo, revise PN table per PSG, update per product doc 1.9 (1/30/15), add length dimension to PN table. (2/3/15) Update formatting of tables, add TBW values(2/4/15). Revise PN for 80mm products and update mechanicals (2/5/15) | |
| 2/10/15 | B | Change name of Table 4-1 to M.2 SATA Connector Pinouts and pin58 to N/C | |
| 3/27/15 | C | Revise PN table per PSG | |
| 4/23/15 | D | Revise PN table per PSG. Add Photo's | |
| 8/10/15 | E | Add 15nm PN's. Fix font sizes. Correct the capacity coding. Add capacity and LBA table. Remove picture until 60mm is available. Revise performance values. Remove dimensions for 42mm and 80mm M.2 | |
| 10/27/15 | F | Revise performance DVT test results | |
| 9/20/16 | G | Revise logo and color scheme. Remove temp sensor and SATA attribute. | |
| | | | |

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 2 of 36 |

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| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 3 of 36 |

Ordering Information: M.2 SATA SSD Solid-State Drive

| Part Number | Length (mm) | Interface | Client/Ent | User Capacity (GB) | NAND | Temp. (C) | NAND |
|------------------|-------------|-----------|------------|--------------------|------|--------------|-----------------|
| VPFEM4128GSCBMTL | 60 | SATA 6GB | Client | 128 | MLC | (0 to +70'c) | TSB 15nm L-die |
| VPFEM4064GSCDMTL | 60 | SATA 6GB | Client | 64 | MLC | (0 to +70'c) | TSB 15nm L-die |
| VPFEM4032GSCDMTL | 60 | SATA 6GB | Client | 32 | MLC | (0 to +70'c) | TSB 15nm L-die |
| VPFEM4032GSCWMTK | 60 | SATA 6GB | Client | 32 | MLC | (0 to +70'c) | TSB A19nm K-die |
| VPFEM4064GSCYMTK | 60 | SATA 6GB | Client | 64 | MLC | (0 to +70'c) | TSB A19nm K-die |
| VPFEM4128GSCTMTK | 60 | SATA 6GB | Client | 128 | MLC | (0 to +70'c) | TSB A19nm K-die |

Notes:

- Refer to Product Specifications for Capacity and LBA count

Client SSD's – Viking's client SSD contains sophisticated provisions to protect firmware and data from corruption due to unexpected power loss. However, should power fail unexpectedly, "in-flight" write data may be lost if the SSD power is not managed at the system level for these power fail events.

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 5 of 36 |

Table of Contents

| | | |
|----------|-------------------------------------|-----------|
| 1 | INTRODUCTION | 9 |
| 1.1 | Features | 9 |
| 1.2 | Block Diagram | 10 |
| 1.3 | SATA Interface | 11 |
| 2 | PRODUCT SPECIFICATIONS | 12 |
| 2.1 | Capacity and LBA count | 12 |
| 2.2 | Performance | 12 |
| 2.3 | Timing | 13 |
| 2.3.1 | STANDBY IMMEDIATE Command | 13 |
| 2.4 | Electrical Characteristics | 14 |
| 2.4.1 | Absolute Maximum Ratings | 14 |
| 2.4.2 | Supply Voltage | 14 |
| 2.4.3 | Supply Current | 15 |
| 2.4.4 | Power Consumption | 15 |
| 2.5 | Environmental Conditions | 15 |
| 2.5.1 | Temperature and Altitude | 15 |
| 2.5.2 | Shock and Vibration | 16 |
| 2.5.3 | Electromagnetic Immunity | 16 |
| 2.6 | Reliability | 16 |
| 3 | MECHANICAL INFORMATION | 17 |
| 3.1 | Dimensions | 17 |
| 3.2 | Card Edge Detail | 19 |
| 3.3 | M.2 SSD Weight | 21 |
| 4 | PIN AND SIGNAL DESCRIPTIONS | 21 |
| 4.1 | Signal and Power Description Tables | 21 |

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 6 of 36 |

| | | |
|------------|--|-----------|
| 4.2 | Hot Plug Support | 22 |
| 5 | COMMAND SETS | 22 |
| 5.1 | ATA Commands | 22 |
| 5.1.1 | 48-Bit Address Command Set | 23 |
| 5.1.2 | ATA General Feature Command Set | 23 |
| 5.1.3 | Device Configuration Overlay Command Set | 24 |
| 5.1.4 | General Purpose Log Command Set | 24 |
| 5.1.5 | Host Protected Area Command Set | 24 |
| 5.1.6 | Power Management Command Set | 25 |
| 5.1.7 | Security Mode Feature Set | 25 |
| 5.1.8 | Identify Device Data | 26 |
| 5.1.1 | S.M.A.R.T. Support | 30 |
| 5.1.2 | SATA 3.0 S.M.A.R.T. Command Set | 31 |
| 5.2 | SATA Commands | 35 |
| 5.2.1 | Native Command Queuing (NCQ) | 35 |
| 6 | REFERENCES | 35 |
| 7 | GLOSSARY | 36 |

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 7 of 36 |

Table of Tables

| | |
|--|----|
| Table 2-1: Maximum Sustained Read and Write Bandwidth _____ | 12 |
| Table 2-2: Random Read and Write Input/Output Operations per Second (IOPS) _____ | 13 |
| Table 2-3: Timing Specifications _____ | 13 |
| Table 2-4: STANDBY IMMEDIATE Timing _____ | 14 |
| Table 2-5: Absolute Maximum Ratings _____ | 14 |
| Table 2-6: Operating Voltage _____ | 14 |
| Table 2-7: Current Draw _____ | 15 |
| Table 2-8: Typical Power Consumption at 3.3V _____ | 15 |
| Table 2-9: Temperature and Altitude Related Specifications _____ | 15 |
| Table 2-10: Shock and Vibration Specifications _____ | 16 |
| Table 2-11: Reliability Specifications _____ | 16 |
| Table 3-1: M.2 SSD weight _____ | 21 |
| Table 4-1: M.2 SATA Connector Pin Signal Definitions _____ | 21 |
| Table 5-1: Supported ATA Commands _____ | 22 |
| Table 5-2: List of Device Identification _____ | 26 |
| Table 5-3: S.M.A.R.T. Command Set _____ | 31 |
| Table 5-4: Extended SMART Attribute Table _____ | 31 |
| Table 5-5: Extended SMART Attribute Actual Data _____ | 32 |
| Table 5-6: Supported S.M.A.R.T. EXECUTE OFF-LINE IMMEDIATE Subcommands _____ | 35 |

Table of Figures

| | |
|---|----|
| Figure 1-1: High-Level Block Diagram _____ | 10 |
| Figure 3-1: Dimensions _____ | 17 |
| Figure 3-2: Dimension Details for M.2 60mm length _____ | 18 |
| Figure 3-3: Dimension Details for M.2 card edge _____ | 19 |
| Figure 3-4: Dimension Details for M.2 connector and notch _____ | 20 |

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

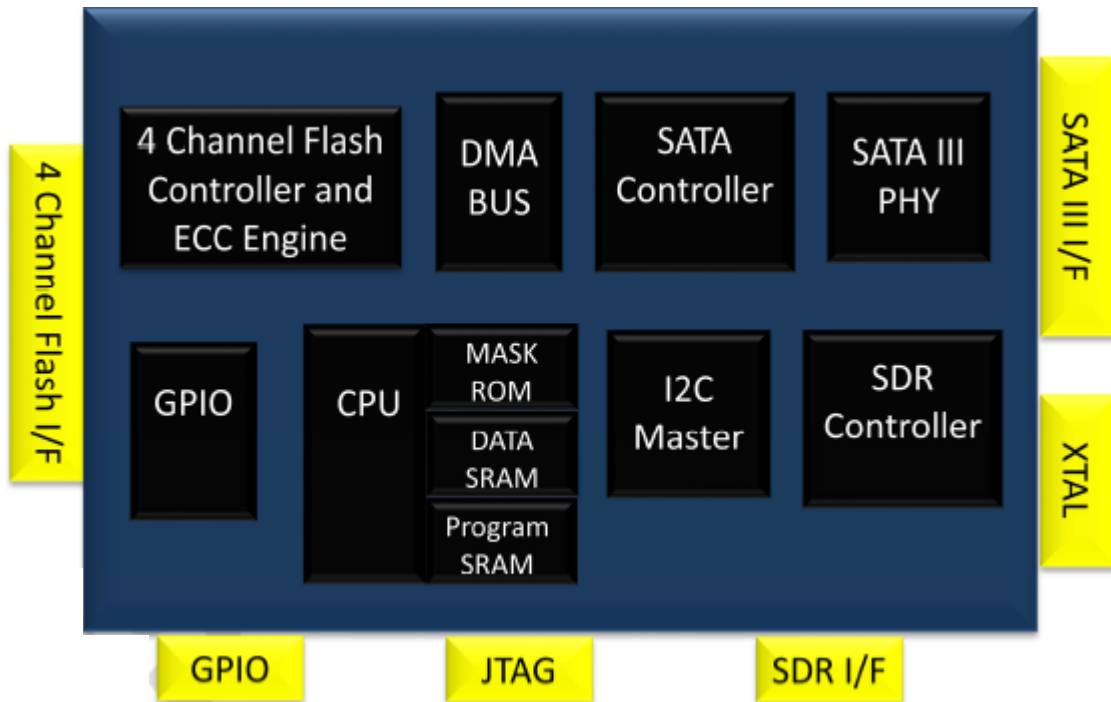
The SSD delivers the following features:

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

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 9 of 36 |

1.2 Block Diagram

Figure 1-1: High-Level Block Diagram



Notes:

1. Support for up to 4-channels and 4 CE in the NAND Flash interface

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 10 of 36 |

1.3 SATA Interface

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

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

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 11 of 36 |

2 Product Specifications

2.1 Capacity and LBA count

| Raw Capacity (GB) | User Capacity (GB) | LBA Count |
|-------------------|--------------------|-------------|
| 16 | 14 | 27,370,224 |
| 16 | 16 | 31,277,232 |
| 32 | 30 | 58,626,288 |
| 32 | 32 | 62,533,296 |
| 64 | 60 | 117,231,408 |
| 64 | 64 | 125,045,424 |
| 128 | 120 | 234,441,648 |
| 128 | 128 | 250,069,680 |
| 256 | 240 | 468,862,128 |
| 256 | 256 | 500,118,192 |

Notes:

1. Per LBA1-03 spec, LBA counts = (97,696,368) + (1,953,504 * (Advertised Capacity in GBytes – 50))

2.2 Performance

Table 2-1: Maximum Sustained Read and Write Bandwidth

| Capacity | Flash Structure | Flash Type | Sequential Read MB/s | Sequential Write MB/s | Notes |
|----------|-----------------|------------|----------------------|-----------------------|-------|
| 32GB | 8GB x 4 | A19nm | 510 | 180 | |
| 64GB | 16GB x 4 | A19nm | 447 | 95 | 6 |
| 128GB | 32GB x 4 | A19nm | 515 | 180 | |
| 32GB | 8GB x 4 | L84A | 130 | 100 | |
| 64GB | 16GB x 4 | L84A | 135 | 110 | |
| 128GB | 32GB x 4 | L84A | - | - | |
| 32GB | 8GB x 4 | L85A | 245 | 70 | |
| 64GB | 16GB x 4 | L85A | 475 | 140 | |
| 128GB | 32GB x 4 | L85A | 480 | 175 | |

Notes:

1. Performance measured using CrystalDiskMark.
2. Performance may vary from flash configuration, SDR configuration, and platform.
3. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.
4. Data is based on SSD's using Toshiba A19nm Toggle NAND devices
5. L95A data not currently available
6. Performance measured using VPFEM4064GSCDMT and IOMETER06

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

| Capacity | Flash Type | Random Read IOPS | Random Write IOPS | Notes |
|----------|------------|------------------|-------------------|-------|
| 32GB | A19nm | 45K | 30K | |
| 64GB | A19nm | 18K | 732 | 6 |
| 128GB | A19nm | 39K | 26K | |
| 32GB | L84A | 49K | 21K | |
| 64GB | L84A | 41K | 19K | |
| 128GB | L84A | - | - | |
| 32GB | L85A | 23K | 17K | |
| 64GB | L85A | 42K | 28K | |
| 128GB | L85A | 42K | 33K | |

Notes:

1. Performance measured using Iometer 08 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. Performance measured using VPFEM4064GSCDMT and IOMETER06
7. Data is based on SSD's using Toshiba A19nm NAND devices
8. L95A data not currently available

2.3 Timing

Table 2-3: Timing Specifications

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

Notes:

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

2.3.1 STANDBY IMMEDIATE Command

The Power-On-to-Ready time assumes a proper shutdown (power removal preceded by STANDBY IMMEDIATE command. A STANDBY IMMEDIATE

before power down always performs a graceful shutdown and does not require the use of the hold-up circuit. Note that SMART attribute 174 "Unexpected Power Loss" records the number of non-graceful power cycle events.

Table 2-4: STANDBY IMMEDIATE Timing

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

Notes:

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

2.4 Electrical Characteristics

2.4.1 Absolute Maximum Ratings

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

Table 2-5: Absolute Maximum Ratings

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

2.4.2 Supply Voltage

The operating voltage is 3.3V

Table 2-6: Operating Voltage

| Description | Min | Max | Unit |
|--------------------------------------|-------|-------|------|
| Operating Voltage for 3.3 V (+/- 5%) | 3.135 | 3.465 | V |

2.4.3 Supply Current

Table 2-7: Current Draw

| Voltage | Mode | Typical ¹ | Unit |
|---------|----------------------|----------------------|------|
| 3.3V | Read (Average RMS) | 395 | mA |
| | Writes (Average RMS) | 305 | mA |
| | Idle | 61 | mA |
| | Partial | 11 | mA |
| | Slumber | 6.9 | mA |
| | DEVSLP | 0.98 | mA |

Notes:

1. Measured using 128GB MLC Toshiba A19nm NAND

2.4.4 Power Consumption

All onboard power requirements of the SSD are derived from the SATA 3.3V rail.

Table 2-8: Typical Power Consumption at 3.3V

| Capacity | Flash Structure | Read | Write | Idle | Partial | Slumber | DEVSLP | Unit |
|----------|-----------------|------|-------|------|---------|---------|--------|------|
| 16GB | 8GB x 2 | 904 | 838 | 276 | 62 | 43 | 4.9 | mW |
| 32GB | 8GBx4 | 1369 | 1210 | 292 | 76 | 58 | 4.6 | mW |
| 64GB | 32GBx2 | 1577 | 1278 | 301 | 81 | 63 | 4.3 | mW |
| 128GB | 32GBx4 | 1623 | 1283 | 299 | 85 | 66 | 4.3 | mW |
| 256GB | 64GBx4 | TBD | TBD | TBD | TBD | TBD | 4.3 | mW |

Notes:

1. Measured using Toshiba A19 Toggle MLC NAND

2.5 Environmental Conditions

2.5.1 Temperature and Altitude

Table 2-9: Temperature and Altitude Related Specifications

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

2.5.2 Shock and Vibration

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

Table 2-10: Shock and Vibration Specifications

| Stimulus | Description |
|-----------|---|
| Shock | 500G, 2ms |
| Vibration | 20 – 80 Hz/1.52mm 80 – 2000 Hz/20G (X,Y,Z axis / 30 min for each) |

2.5.3 Electromagnetic Immunity

M.2 is an embedded product for host systems and is designed not to impair with system functionality or hinder system EMI/FCC compliance.

2.6 Reliability

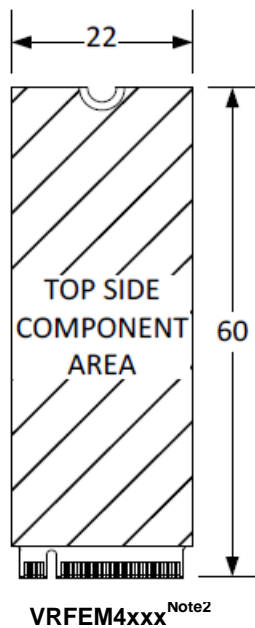
Table 2-11: Reliability Specifications

| Parameter | Description | | | |
|-----------------|------------------------------|-------------|--------------|--------------|
| ECC | 72-bit per 1KByte | | | |
| Read Endurance | Unlimited | | | |
| Write Endurance | 32GB | 64GB | 128GB | 256GB |
| | 79 TBW | 158 TBW | 317 TBW | 635 TBW |
| Data retention | > 90 days at NAND expiration | | | |

3 Mechanical Information

3.1 Dimensions

Figure 3-1: Dimensions

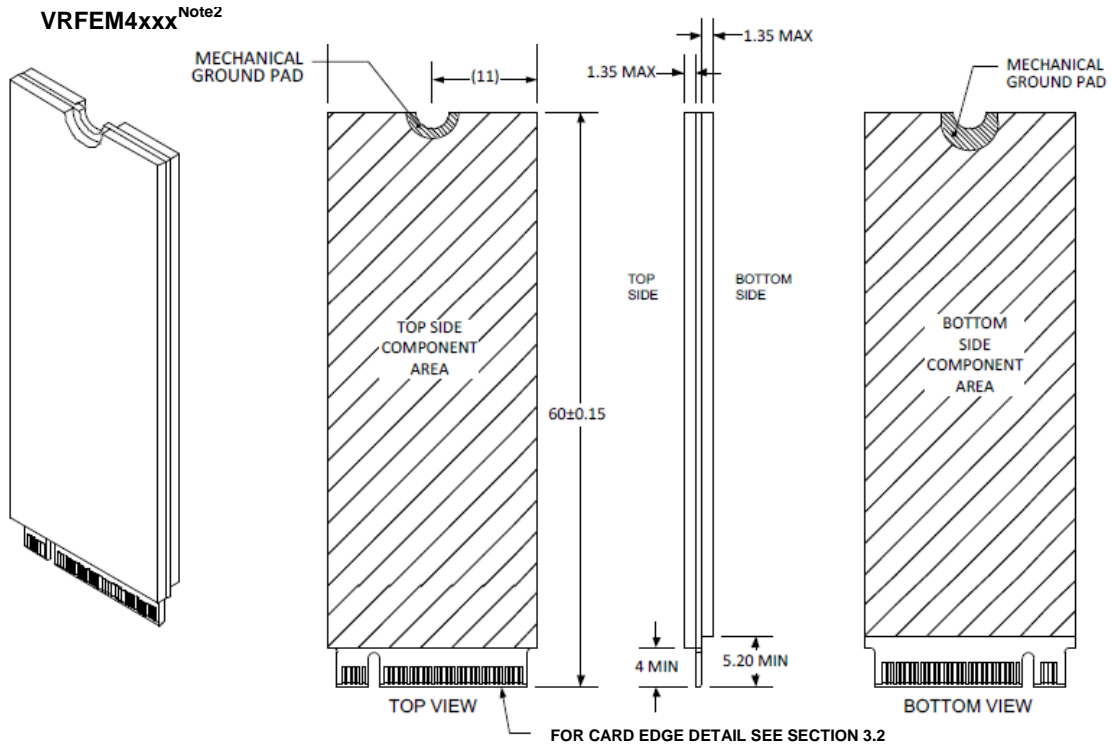


Notes:

1. All dimensions are in millimeter. General tolerance is ± 0.15 . PCB thickness 0.8 ± 0.08
2. Refer to Ordering Information table for the complete Viking part number that describes the “xxx”.

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 17 of 36 |

Figure 3-2: Dimension Details for M.2 60mm length



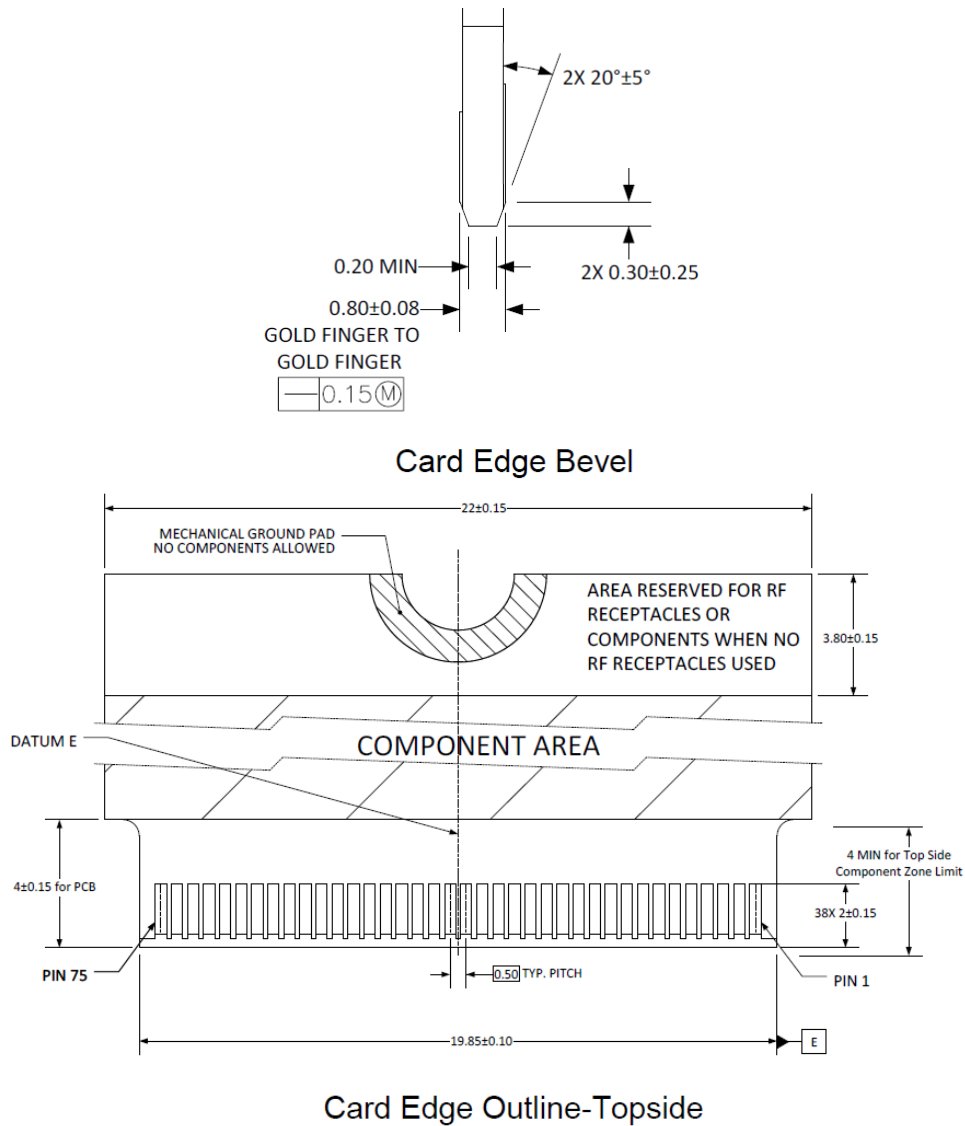
Notes:

1. All dimensions are in millimeter. General tolerance is ± 0.15 . PCB thickness 0.8 ± 0.08
2. Refer to Ordering Information table for the complete Viking part number that describes the "xxx".

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 18 of 36 |

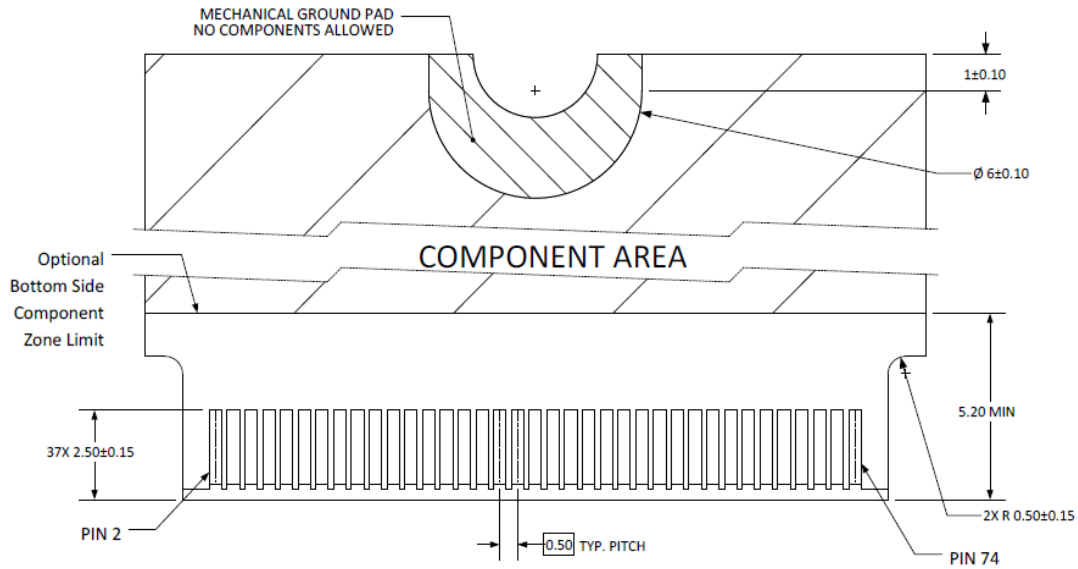
3.2 Card Edge Detail

Figure 3-3: Dimension Details for M.2 card edge

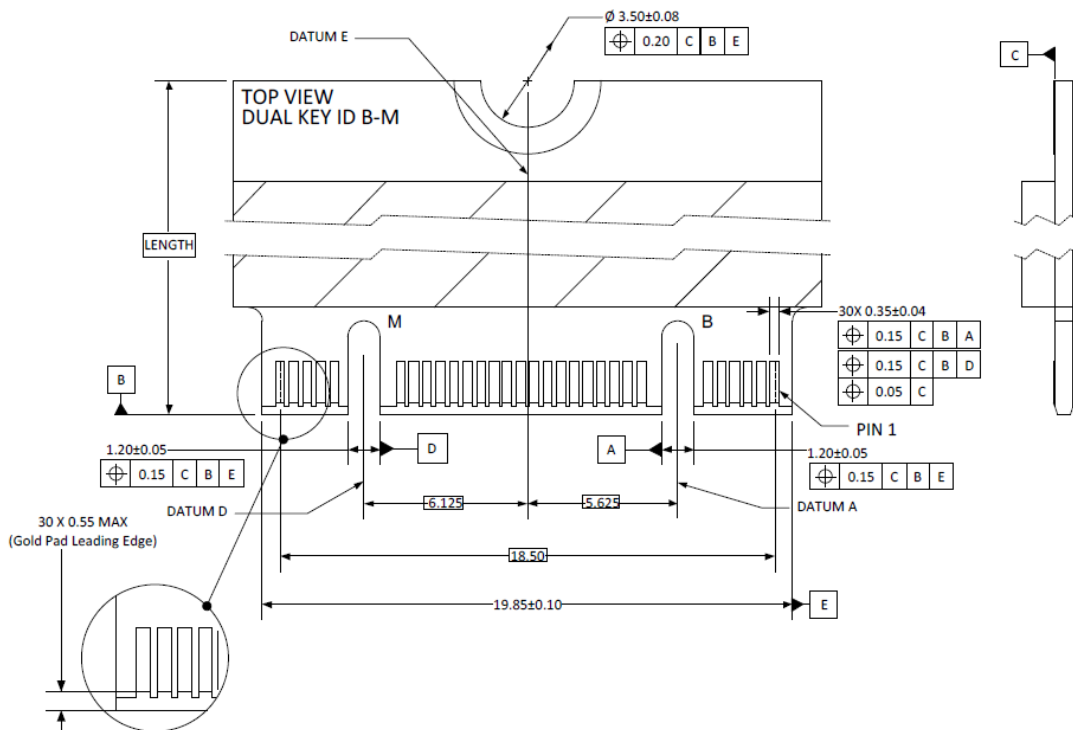


| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 19 of 36 |

Figure 3-4: Dimension Details for M.2 connector and notch



Card Edge Outline-Backside



Key notch detail

3.3 M.2 SSD Weight

Table 3-1: M.2 SSD weight

| Length | Weight | Unit of measure |
|--------|--------|-----------------|
| 60 mm | < 7 | Grams |

4 Pin and Signal Descriptions

4.1 Signal and Power Description Tables

Table 4-1: M.2 SATA Connector Pin Signal Definitions

| Pin | Description | Description | Pin |
|-----|---------------------------|----------------|-----|
| 74 | 3.3V | CONFIG_2 = GND | 75 |
| 72 | 3.3V | GND | 73 |
| 70 | 3.3V | GND | 71 |
| 68 | SUSCLK(32kHz) (I)(0/3.3V) | CONFIG_1 = GND | 69 |
| 66 | Module Key | N/C | 67 |
| 64 | Module Key | Module Key | 65 |
| 62 | Module Key | Module Key | 63 |
| 60 | Module Key | Module Key | 61 |
| 58 | N/C | Module Key | 59 |
| 56 | Reserved for MFG_DATA | GND | 57 |
| 54 | N/C | N/C | 55 |
| 52 | N/C | N/C | 53 |
| 50 | N/C | GND | 51 |
| 48 | N/C | SATA-A+ | 49 |
| 46 | N/C | SATA-A- | 47 |
| 44 | N/C | GND | 45 |
| 42 | N/C | SATA-B- | 43 |
| 40 | N/C | SATA-B+ | 41 |
| 38 | DEVSLP (I)(0/3.3V) | GND | 39 |
| 36 | N/C | N/C | 37 |
| 34 | N/C | N/C | 35 |
| 32 | N/C | GND | 33 |
| 30 | N/C | N/C | 31 |
| 28 | N/C | N/C | 29 |
| 26 | N/C | GND | 27 |
| 24 | N/C | N/C | 25 |
| 22 | N/C | N/C | 23 |

| Pin | Description | Description | Pin |
|-----|----------------|----------------|-----|
| 20 | N/C | CONFIG_0 = GND | 21 |
| 18 | Module Key | Module Key | 19 |
| 16 | Module Key | Module Key | 17 |
| 14 | Module Key | Module Key | 15 |
| 12 | Module Key | Module Key | 13 |
| 10 | DAS/DSS# (I/O) | N/C | 11 |
| 8 | N/C | N/C | 9 |
| 6 | N/C | N/C | 7 |
| 4 | 3.3V | N/C | 5 |
| 2 | 3.3V | GND | 3 |
| | | CONFIG_3 = GND | 1 |

Notes:

1. No connect on the host side.
2. Socket-2 SATA-based SSD Module pinout per PCI Express M.2 Specification, Revision 1.0 (p134)

4.2 Hot Plug Support

Hot Plug insertion and removal are supported in the presence of a proper connector and appropriate operating system (OS) support as described in the SATA 2.6 specification. This product supports Asynchronous Signal Recovery and will issue an unsolicited COMINIT when first mated with a powered connector to guarantee reliable detection by a host system without hardware device detection.

5 Command Sets

5.1 ATA Commands

Table 5-1: Supported ATA Commands

| Description | Op Code | Description | Op Code |
|--------------------------|---------|---------------------------|---------|
| Check power mode | E5h | Security Disable Password | F6h |
| Data Set management | 06h | Security Erase Prepare | F3h |
| DCO | B1h | Security Erase Unit | F4h |
| Download Microcode PIO | 92h | Security Freeze Lock | F5h |
| Download Microcode DMA | 93h | Security Set Password | F1h |
| Execute drive diagnostic | 90h | Security Unlock | F2h |
| Flush cache | E7h | Seek | 70h |
| Flush cache Ext | EAh | Set features | EFh |
| Identify device | ECh | Set Max Address | F9h |

| Description | Op Code | Description | Op Code |
|-----------------------------------|---------|-----------------------------|---------|
| 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:

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 23 of 36 |

- 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)

| | |
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| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 24 of 36 |

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

5.1.8 Identify Device Data

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

Table 5-2: List of Device Identification

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

| Word | F: Fixed V: Variable X: Both | Default Value | Description |
|-------|------------------------------------|-------------------|---|
| | | | supported/selected |
| 64 | F | 0003h | PIO modes supported |
| 65 | F | 0078h | Minimum Multiword DMA transfer cycle time per word |
| 66 | F | 0078h | Manufacturer's recommended Multiword DMA transfer cycle time |
| 67 | F | 0078h | Minimum PIO transfer cycle time without flow control |
| 68 | F | 0078h | Minimum PIO transfer cycle time with IORDY flow control |
| 69 | F | 0100h | Additional Supported (support download microcode DMA) |
| 70 | F | 0000h | Reserved |
| 71-74 | F | 0000000000000000h | Reserved for the IDENTIFY PACKET DEVICE command |
| 75 | F | 001Fh | Queue depth |
| 76 | F | 670eh | Serial SATA capabilities |
| 77 | F | 0084h | Reserved for future Serial ATA definition |
| 78 | F | 0014h | Serial ATA features supported |
| 79 | V | 0040H | Serial ATA features enabled |
| 80 | F | 01F8h | Major Version Number |
| 81 | F | 0000h | Minor Version Number |
| 82 | F | 346Bh | Command set supported |
| 83 | F | 7D09h | Command set supported |
| 84 | F | 6063h | Command set/feature supported extension |
| 85 | V | 3469h | Command set/feature enabled |
| 86 | V | BC01h | Command set/feature enabled |
| 87 | V | 6063h | Command set/feature default |
| 88 | V | 003Fh | Ultra DMA Modes |
| 89 | F | 001Eh | Time required for security erase unit completion |
| 90 | F | 001Eh | Time required for Enhanced security erase completion |
| 91 | V | 0000h | Current advanced power management value |
| 92 | V | FFFEh | Master Password Revision Code |
| 93 | F | 0000h | Hardware reset result. The contents of the bits (12:0) of this word shall change only during the execution of s hardware reset. |
| 94 | V | 0000h | Vendor's recommended and actual acoustic management value |
| 95 | F | 0000h | Stream Minimum Request Size |
| 96 | V | 0000h | Streaming Transfer Time – DMA |

| Word | F: Fixed V: Variable X: Both | Default Value | Description |
|---------|------------------------------------|--|---|
| 97 | V | 0000h | Streaming Access Latency – DMA and PIO |
| 98-99 | F | 0000h | Streaming Performance Granularity |
| 100-103 | V | See *4 | Maximum user LBA for 48 bit Address feature set |
| 104 | V | 0000h | Streaming Transfer Time – PIO |
| 105 | F | 0000h | Maximum number of 512-byte blocks per DATA SET MANAGEMENT command |
| 106 | F | 4000h | Physical sector size / Logical sector size |
| 107 | F | 0000h | Inter-seek delay for ISO-7779 acoustic testing in microseconds |
| 108-111 | F | 0000000000000000h | Unique ID |
| 112-115 | F | 0000000000000000h | Reserved |
| 116 | V | 0000h | Reserved |
| 117-118 | F | 00000000h | Words per logical Sector |
| 119 | F | 4014h | Supported settings |
| 120 | F | 4014h | Command set/Feature Enabled/Supported |
| 121-126 | F | 0h | Reserved |
| 127 | F | 0h | Removable Media Status Notification feature set support |
| 128 | V | 0021h | Security status |
| 129-159 | X | 0h | Vendor specific |
| 160 | F | 0h | Compact Flash Association (CFA) power mode 1 |
| 161-167 | X | 0h | Reserved for assignment by the CFA |
| 168 | F | 3h: 2.5 inch 4h: 1.8 inch 5h: < 1.8 inch | Device Nominal Form Factor |
| 169 | F | 0001h | DATA SET MANAGEMENT command is supported |
| 170-173 | F | 0h | Additional Product Identifier |
| 174-175 | | 0h | Reserve |
| 176-205 | V | 0h | Current media serial number |
| 206 | F | 0h | SCT Command Transport(|
| 207-208 | F | 0h | Reserved |
| 209 | F | 4000h | Alignment of logical blocks within a physical block |
| 210-211 | V | 0000h | Write-Read-Verify Sector Count Mode 3 (not supported) |
| 212-213 | F | 0000h | Write-Read-Verify Sector Count Mode 2 (not supported) |
| 214-216 | | 0000h | NV Cache relate (not supported) |
| 217 | F | 0001h | Non-rotating media device |
| 218 | F | 0h | Reserved |

| Word | F: Fixed V: Variable X: Both | Default Value | Description |
|---------|------------------------------------|-------------------------|--|
| 219 | F | 0h | NV Cache relate (not supported) |
| 220 | V | 0h | Write read verify feature set current mode |
| 221 | | 0h | Reserved |
| 222 | F | 107Fh | Transport major version number |
| 223 | F | 0h | Transport minor version number |
| 224-229 | | 0h | reserved |
| 230-233 | | 0h | Extend number of user addressable sectors |
| 234 | | 0001h | Minimum number of 512-byte data blocks per DOWNLOAD MICROCODE command for mode 03h |
| 235 | | 0080h | Maximum number of 512-byte data blocks per DOWNLOAD MICROCODE command for mode 03h |
| 236-254 | F | 0h | Reserved |
| 255 | X | XXA5h XX is variable | Integrity word (Checksum and Signature) |

Notes for Capacity specific Device Identification

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

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

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

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

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 30 of 36 |

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

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

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

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

5.1.2.1 Extended SMART Attributes

Table 5-4: Extended SMART Attribute Table

| SMART Attribute ID | Description |
|--------------------|--|
| 01h | Number of accumulated Uncorrectable errors (Range 0-255) Read Error Rate |
| 05h | Reallocated Sector Count |
| 09h | Power-On hours Count (Range 0-4294967295) |
| 0Ch | Drive Power Cycle Count (Number of accumulated power on/off cycles) |
| A8h | SATA PHY Error Count (only record from power on, when power off this value will clear to zero) this value include all PHY error count, ex data FIS CRC ,code error, disparity error ,command FIS CRC |
| AAh | Max Bad Block Count (will show early bad and later bad block count) |
| ADh | Erase count (average, max, erase count) |

| SMART Attribute ID | Description |
|--------------------|--|
| B1h | Wear Range delta [(most wear block – average wear block)/Max P/E cycles] x 100 |
| B5h | Program Fail Count |
| B6h | Erase Failure Block Count |
| BBh | Reported Uncorrectable Errors (ECC fail count) 4bytes 01h only 1 bytes |
| C0h | Unexpected Power Loss Count |
| C2h | N/A |
| C7h | Number of accumulated CRC Error (read/write data FIS CRC error) CRC Error Count (R CRC + W CRC) |
| DAh | Number of accumulated CRC Error (read/write data FIS CRC error) Number of CRC Errors |
| E7h | SSD life remaining |
| E8h | Read Failure Block Count |
| E9h | Lifetime Writes to Flash ((GB) |
| F1h | Lifetime Writes from Host (each G) |
| F2h | Lifetime Reads from Host (each G) |
| F3h | Total internal copy ecc error count |
| F4h | Average erase count (4bytes) |
| F5h | Max erase count (4 bytes) |
| F6h | Total Erase Count (6 bytes) |
| FAh | Read retry count |
| FBh | Do wearleveling count |
| FCh | CRC error write count |

Notes:

1. Dummy is null and not used

Table 5-5: Extended SMART Attribute Actual Data

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
|-----|------|------|---------------|---------------|----------------------|---|-----------|---|--------------------|----|----|-----------|
| ID | Flag | Flag | Value | Worse | DATA | | | | | | | Threshold |
| 01h | 0Bh | 00h | 64h | 64h | 0 | 0 | ECC error | 0 | 0 | 0 | 0 | 32h |
| 05h | 13h | 00h | 64h | 64h | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32h |
| 09h | 12h | 00h | 64h | 64h | Power on hour | | 0 | 0 | 0 | 0 | 0 | 00h |
| 0Ch | 12h | 00h | 64h | 64h | Power on/off cycles | | | | 0 | 0 | 0 | 00h |
| A8h | 12h | 00h | 64h | 64h | SATA PHY error count | | | | 0 | 0 | 0 | 00h |
| AAh | 03h | 00h | Note 1 | Note 1 | Early bad block NO | | 0 | 0 | Later bad block NO | | 0 | 0Ah |

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
|-----|------|------|-------|-------|---------------------------------------|------------------------------------|-----|---|---|-----|-----|-----------|
| ID | Flag | Flag | Value | Worse | DATA | | | | | | | Threshold |
| ADh | 12h | 00h | 64h | 64h | Max erase count (MAX 65535) | Average erase count (MAX 65535) | 0 0 | | | 0 | 00h | |
| B1h | 00h | 00h | 00h | 00h | The value | | | 0 | 0 | 0 | 00h | |
| B5h | 12h | 00h | 00h | 00h | Total program bad blocks count | | | 0 | 0 | 0 | 00h | |
| B6h | 32h | 00h | 00h | 00h | Total erase bad blocks count | | | 0 | 0 | 0 | 00h | |
| BBh | 03h | 00h | 00h | 00h | Total ECC error count | | | 0 | 0 | 0 | 00h | |
| C0h | 12h | 00h | 64h | 64h | number of accidental power loss count | | | 0 | 0 | 0 | 00h | |
| C2h | N/A | N/A | N/A | N/A | N/A | N/A | N/A | | | N/A | N/A | |
| C7h | 12h | 00h | 64h | 64h | CRC Error Count (R CRC + W CRC) | | | 0 | 0 | 0 | 00h | |
| DAh | 0Bh | 00h | 64h | 64h | Number of CRC Error | | | 0 | 0 | 0 | 32h | |
| E7h | 13h | 00h | 64h | 64h | % SSD life remaining (Note 2) | | | 0 | 0 | 0 | 00h | |
| E8h | 0Bh | 00h | 64h | 64h | Total Read bad Block Count | | | 0 | 0 | 0 | 00h | |
| E9h | 0Bh | 00h | 64h | 64h | Flash write 64GB each count | | | 0 | 0 | 0 | 00h | |
| F1h | 32h | 00h | 00h | 00h | Host write 64GB count | | | 0 | 0 | 0 | 00h | |
| F2h | 32h | 00h | 00h | 00h | Host read 64GB count) | | | 0 | 0 | 0 | 00h | |
| F3h | 02h | 00h | 64h | 64h | Total internal copy ecc error count | | | 0 | 0 | 0 | 00h | |
| F4h | 02h | 00h | 64h | 64h | Total Average erase count | | | 0 | 0 | 0 | 00h | |
| F5h | 02h | 00h | 64h | 64h | Max erase count | | | 0 | 0 | 0 | 00h | |
| F6h | 02h | 00h | 64h | 64h | Total Erase Count | | | | | 0 | 00h | |
| FAh | 02h | 00h | 64h | 64h | Read retry Count | | | | | 0 | 00h | |
| FBh | 02h | 00h | 64h | 64h | Cool down Count | | | | | 0 | 00h | |
| FCh | 02h | 00h | 64h | 64h | CRC write Count | | | | | 0 | 00h | |

Note 1 Formula:

MABN: Maximum acceptable bad block number

CBBN: Current bad block number

Value = ((MABN – CBBN)/ (MABN)) x 100

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

Note 2 Formula:

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

5.1.2.2 Off-line Mode

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

| | |
|----------------|-------------------|
| Manual | 9/20/2016 |
| PSFEM4xxxGSxxx | Viking Technology |
| Revision G | Page 34 of 36 |

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

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

5.2 SATA Commands

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

5.2.1 Native Command Queuing (NCQ)

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

- READ FPDMA QUEUED
- WRITE FPDMA QUEUED

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

6 References

- Serial ATA Specification, Revision 3
- PCI Express M.2 Specification, Revision 1.0

7 Glossary

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

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