

# 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.

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## Revision History

| Date    | Revision | Description  | Checked By |
|---------|----------|--|------------|
| 3/10/17 | A        | Initial Release. Revised based on PSFEM6XXXGSXXX_D with new PN's performance, block diagram, TBW, power consumption. Add VPFEM6030GZCDMTL. Add Industrial Temperature PN's |            |
| 3/13/17 | B        | Add VPFEM6030GZCDMTL.  |            |
| 3/21/17 | C        | Add Industrial Temperature PN's. Revise note 2 on Extended SMART Attribute Actual Data table. Add 8GB and 16GB info. Add section on Flash Management                       |            |
| 5/18/17 | D        | Add PN's VPFEM5008GZCWMTL and VPFEM5016GZCDMTL. Remove I.T. from page1   |            |
|         |          |  |            |
|         |          |  |            |

## Legal Information

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

| Part Number      | Length (mm) | Interface | Application | User Capacity (GB) | Temperature (C) | NAND         |
|------------------|-------------|-----------|-------------|--------------------|-----------------|--------------|
| VPFEM5008GZCWMTL | 80          | SATA 6GB  | Client      | 8                  | 0 to 70         | TSB 15nm MLC |
| VPFEM5016GZCDMTL | 80          | SATA 6GB  | Client      | 16                 | 0 to 70         | TSB 15nm MLC |
| VPFEM5032GZCDMTL | 80          | SATA 6GB  | Client      | 32                 | 0 to 70         | TSB 15nm MLC |
| VPFEM5060GZCDMTL | 80          | SATA 6GB  | Client      | 60                 | 0 to 70         | TSB 15nm MLC |
| VPFEM5256GZCAMTL | 80          | SATA 6GB  | Client      | 256                | 0 to 70         | TSB 15nm MLC |
| VPFEM5008GZIWMTL | 80          | SATA 6GB  | Client      | 8                  | -40 to +85      | TSB 15nm MLC |
| VPFEM5016GZIDMTL | 80          | SATA 6GB  | Client      | 16                 | -40 to +85      | TSB 15nm MLC |
| VPFEM5032GZIDMTL | 80          | SATA 6GB  | Client      | 32                 | -40 to +85      | TSB 15nm MLC |
| VPFEM5064GZIDMTL | 80          | SATA 6GB  | Client      | 64                 | -40 to +85      | TSB 15nm MLC |
| VPFEM5128GZIBMTL | 80          | SATA 6GB  | Client      | 128                | -40 to +85      | TSB 15nm MLC |
| VPFEM5256GZIAMTL | 80          | SATA 6GB  | Client      | 256                | -40 to +85      | TSB 15nm MLC |
| VPFEM5512GZIZMTL | 80          | SATA 6GB  | Client      | 512                | -40 to +85      | TSB 15nm MLC |

**Notes:**

- Refer to Product Specifications for Capacity and LBA count
- Lower case "x" is the NAND device code

**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.

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## 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

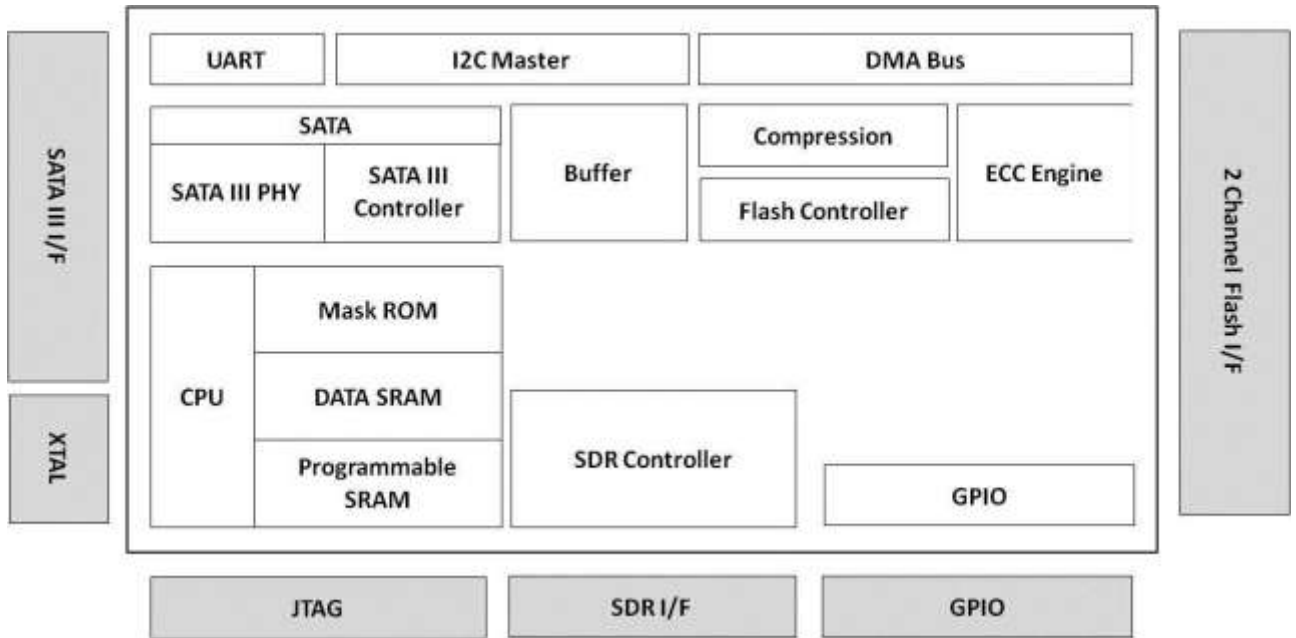
The SSD delivers the following features:

- 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
- Compliant with ONFI 4.0 interface:
  - SDR up to mode 5
  - NV-DDR up to mode 5
  - NV-DDR2 up to mode 7
  - NV-DDR3 up to mode 8

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## 1.2 Block Diagram

Figure 1-1: High-Level Block Diagram



**Notes:**

1. Support for up to 2-channels and 2 CE in the NAND Flash interface

### 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.

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## 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   |
| 512               | 480                | 937,703,088   |
| 512               | 512                | 1,000,215,216 |

**Notes:**

- Per [www.idema.org](http://www.idema.org), LBA1-03 spec,  

$$\text{LBA counts} = (97,696,368) + (1,953,504 * (\text{Advertised Capacity in GBytes} - 50))$$
- GB capacities based on power of 10, GiB capacities are based on powers of 2

## 2.2 Performance

**Table 2-1: Maximum Sustained Read and Write Bandwidth**

| Capacity  | Flash Structure        | Performance     |        |        |        |
|-----------|------------------------|-----------------|--------|--------|--------|
|           |                        | CrystalDiskMark |        | ATTO   |        |
|           |                        | Read            | Write  | Read   | Write  |
|           |                        | (MB/s)          | (MB/s) | (MB/s) | (MB/s) |
| 8GB       | 8GBx1, TSOP, TSB 15nm  | 320             | 105    | 560    | 540    |
| 16GB      | 16GBx1, TSOP, TSB 15nm | 320             | 85     | 560    | 540    |
| 30/32GB   | 32GBx1, BGA, TSB 15nm  | 550             | 175    | 550    | 540    |
| 60/64GB   | 32GBx2, BGA, TSB 15nm  | 550             | 335    | 550    | 540    |
| 120/128GB | 64GBx2, BGA, TSB 15nm  | 550             | 465    | 550    | 540    |
| 240/256GB | 128GBx2, BGA, TSB 15nm | 550             | 465    | 550    | 540    |
| 480/512GB | 256GBx2, BGA, TSB 15nm | 550             | 470    | 550    | 540    |

**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 A15nm Toggle NAND devices
5. L95A data not currently available

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

| Capacity | Flash Type | Random Read IOPS | Random Write IOPS |
|----------|------------|------------------|-------------------|
| 8GB      | 15nm       | TBD              | TBD               |
| 16GB     | 15nm       | TBD              | TBD               |
| 32GB     | 15nm       | TBD              | TBD               |
| 64GB     | 15nm       | TBD              | TBD               |
| 128GB    | 15nm       | TBD              | TBD               |
| 256GB    | 15nm       | TBD              | TBD               |
| 512GB    | 15nm       | TBD              | TBD               |

**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. Data is based on SSD's using Toshiba A15nm NAND devices
7. 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 Flash Management

### 2.4.1 Error Correction Code (ECC)

Flash memory cells will deteriorate with use, which might generate random bit errors in the stored data. Thus, the Viking M.2 2280 applies the LDPC (Low Density Parity Check) of ECC algorithm, which can detect and correct errors occur during read process, ensure data been read correctly, as well as protect data from corruption.

### 2.4.2 Wear Leveling

NAND flash devices can only undergo a limited number of program/erase cycles, and in most cases, the flash media are not used evenly. If some areas get updated more frequently than others, the lifetime of the device would be reduced

significantly. Thus, Wear Leveling is applied to extend the lifespan of NAND flash by evenly distributing write and erase cycles across the media. Viking SSDs provides advanced Wear Leveling algorithm, which can efficiently spread out the flash usage through the whole flash media area. Moreover, by implementing both dynamic and static Wear Leveling algorithms, the life expectancy of the NAND flash is greatly improved.

### 2.4.3 Bad Block Management

Bad blocks are blocks that include one or more invalid bits, and their reliability is not guaranteed. Blocks that are identified and marked as bad by the manufacturer are referred to as “Initial Bad Blocks”. Bad blocks that are developed during the lifespan of the flash are named “Later Bad Blocks”. Viking SSDs implements an efficient bad block management algorithm to detect the factory-produced bad blocks and manages any bad blocks that appear with use. This practice further prevents data being stored into bad blocks and improves the data reliability.

### 2.4.4 TRIM

TRIM is a feature which helps improve the read/write performance and speed of solid-state drives (SSD). Unlike hard disk drives (HDD), SSDs are not able to overwrite existing data, so the available space gradually becomes smaller with each use. With the TRIM command, the operating system can inform the SSD which blocks of data are no longer in use and can be removed permanently. Thus, the SSD will perform the erase action, which prevents unused data from occupying blocks all the time.

### 2.4.5 SMART

SMART, an acronym for Self-Monitoring, Analysis and Reporting Technology, is an open standard that allows a hard disk drive to automatically detect its health and report potential failures. When a failure is recorded by SMART, users can choose to replace the drive to prevent unexpected outage or data loss. Moreover, SMART can inform users of impending failures while there is still time to perform proactive actions, such as copy data to another device.

### 2.4.6 Over-Provision

Over Provisioning refers to the inclusion of extra NAND capacity in a SSD, which is not visible and cannot be used by users. With Over Provisioning, the performance and IOPS (Input/Output Operations per Second) are improved by providing the controller additional space to manage P/E cycles, which enhances the reliability and endurance as well. Moreover, the write amplification of the SSD becomes lower when the controller writes data to the flash.

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### 2.4.7 Firmware Upgrade

Firmware can be considered as a set of instructions on how the device communicates with the host. Firmware will be upgraded when new features are added, compatibility issues are fixed, or read/write performance gets improved.

## 2.5 Low Power Management

### 2.5.1 DEVSLP Mode (Optional)

With the increasing need of aggressive power/battery life, SATA interfaces include a new feature, Device Sleep (DEVSLP) mode, which helps further reduce the power consumption of the device. DEVSLP enables the device to completely power down the device PHY and other sub-systems, making the device reach a new level of lower power operation. The DEVSLP does not specify the exact power level a device can achieve in the DEVSLP mode, but the power usage can be dropped down to 5mW or less.

### 2.5.2 DIPM/HIPM Mode

SATA interfaces contain two low power management states for power saving: Partial and Slumber modes. For Partial mode, the device has to resume to full operation within 10 microseconds, whereas the device will spend 10 milliseconds to become fully operational in the Slumber mode. SATA interfaces allow low power modes to be initiated by Host (HIPM, Host Initiated Power Management) or Device (DIPM, Device Initiated Power Management). As for HIPM, Partial or Slumber mode can be invoked directly by the software. For DIPM, the device will send requests to enter Partial or Slumber mode.

## 2.6 Power Loss Protection: Flushing Mechanism (Optional)

Power Loss Protection is a mechanism to prevent data loss during unexpected power failure. DRAM is a volatile memory and frequently used as temporary cache or buffer between the controller and the NAND flash to improve the SSD performance. However, one major concern of the DRAM is that it is not able to keep data during power failure. Accordingly, the SSD requests the controller to transfer data to the cache. SDR performs as a cache, and its size is 32MB. Only when the data is fully committed to the NAND flash will the controller send acknowledgement (ACK) to the host. Such implementation can prevent false-positive performance and the risk of power cycling issues.

Additionally, it is critical for a controller to shorten the time the in-flight data stays in the cache. Thus, the Viking SSD applies an algorithm to reduce the amount of data resides in the cache to provide a better performance. This technology allows incoming data to only have a “pit stop” in the cache and then move to the

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NAND flash at once. If the flash is jammed due to particular file sizes (such as random 4KB data), the cache will be treated as an “organizer”, consolidating incoming data into groups before written into the flash to improve write amplification. In summary, provide the reliability required by consumer, industrial, and enterprise-level applications.

## 2.7 Advanced Device Security Features

### 2.7.1 Secure Erase

Secure Erase is a standard ATA command and will write all “0xFF” to fully wipe all the data on hard drives and SSDs. When this command is issued, the SSD controller will erase its storage blocks and return to its factory default settings.

### 2.7.2 Write Protect

When a SSD contains too many bad blocks and data are continuously written in, then the SSD might not be usable anymore. Thus, Write Protect is a mechanism to prevent data from being written in and protect the accuracy of data that are already stored in the SSD.

## 2.8 SSD Lifetime Management

### 2.8.1 Terabytes Written (TBW)

TBW (Terabytes Written) is a measurement of SSDs’ expected lifespan, which represents the amount of data written to the device. To calculate the TBW of a SSD, the following equation is applied:

$$TBW = [(NAND\ Endurance) \times (SSD\ Capacity) \times (WLE)] / WAF$$

NAND Endurance: Refers to the P/E (Program/Erase) cycle of a NAND flash.

SSD Capacity: The SSD capacity is the specific capacity in total of a SSD.

WLE: Wear Leveling Efficiency (WLE) ratio of the average #of erases on all the blocks to the erases on any block at maximum.

WAF: Write Amplification Factor (WAF) is a numerical value representing the ratio between the amount of data that a SSD controller needs to write and the amount of data that the host’s flash controller writes. A better WAF, which is near 1, guarantees better endurance and lower frequency of data written to flash memory.

### 2.8.2 Thermal Monitor (Optional)

Thermal monitors are devices for measuring temperature, and can be found in SSDs in order to issue warnings when SSDs go beyond a certain temperature. The higher temperature the thermal monitor detects, the more power the SSD consumes, causing the SSD to get aging quickly. Hence, the processing speed of a SSD should be under control to prevent temperature from exceeding a certain range. Meanwhile, the SSD can achieve power savings.

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## 2.9 An Adaptive Approach to Performance Tuning

### 2.9.1 Throughput

Based on the available space of the disk, the SSD will regulate the read/write speed and manage the performance of throughput. When there still remains a lot of space, the firmware will continuously perform read/write action. There is still no need to implement garbage collection to allocate and release memory, which will accelerate the read/write processing to improve the performance. Contrarily, when the space is going to be used up, the SSD will slow down the read/write processing, and implement garbage collection to release memory. Hence, read/write performance will become slower.

### 2.9.2 Predict & Fetch

Normally, when the host tries to read data from the SSD, the SSD will only perform one read action after receiving one command. However, the SSD applies “Predict & Fetch” to improve the read speed. When the host issues sequential read commands to the SSD, the SSD will automatically expect that the following will also be read commands. Thus, before receiving the next command, flash has already prepared the data. Accordingly, this accelerates the data processing time, and the host does not need to wait so long to receive data.

### 2.9.3 Compression

Write data to the NAND Flash costs time. To improve the write speed performance, the SSD launches a compression technique. Whether a file could be compressed or not depending on the file type, for file types have redundancy data pattern, through our embedded encode engine, we could reduce the amount of data that is actually written to the Flash. Comparing to the SSD without the compression, write efficiency is raised and the SSD endurance is also improved since Flash could be benefit from less data written for a longer SSD lifetime.

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## 2.10 Electrical Characteristics

### 2.10.1 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    |

### 2.10.2 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    |

### 2.10.3 Power Consumption

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

**Table 2-7: Typical Power Consumption at 3.3V**

| Capacity  | Flash Structure        | Power Consumption |               |                |
|-----------|------------------------|-------------------|---------------|----------------|
|           |                        | Read<br>(mW)      | Write<br>(mW) | DevsIp<br>(mW) |
| 8GB       | 8GBx1, TSOP, TSB 15nm  | 830               | 765           | 4.9            |
| 16GB      | 16GBx1, TSOP, TSB 15nm | 895               | 805           | 4.9            |
| 30/32GB   | 32GBx1, BGA, TSB 15nm  | 1,190             | 1,280         | 4.9            |
| 60/64GB   | 32GBx2, BGA, TSB 15nm  | 1,190             | 1,295         | 4.9            |
| 120/128GB | 64GBx2, BGA, TSB 15nm  | 1,170             | 1,525         | 4.9            |
| 240/256GB | 128GBx2, BGA, TSB 15nm | 1,250             | 1,555         | 4.9            |
| 480/512GB | 256GBx2, BGA, TSB 15nm | 1,455             | 1,675         | 4.9            |

**Notes:**

1. Measured using Toshiba A15 Toggle MLC NAND

## 2.11 Environmental Conditions

### 2.11.1 Temperature and Altitude

**Table 2-8: Temperature and Altitude Related Specifications**

| Conditions                      | Operating     | Shipping      | Storage       |
|---------------------------------|---------------|---------------|---------------|
| Commercial Temperature- Ambient | 0 to 70°C     | -40 to 85°C   | -40 to 85°C   |
| Industrial Temperature- Ambient | -40 to 85°C   | -40 to 85°C   | -40 to 85°C   |
| Humidity (non-condensing)       | 95% under 55C | 93% under 40C | 93% under 40C |

### 2.11.2 Shock and Vibration

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

**Table 2-9: Shock and Vibration Specifications**

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

### 2.11.3 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.

## 2.12 Reliability

**Table 2-10: Reliability Specifications**

| Parameter       | Description                  |             |             |             |              |              |              |
|-----------------|------------------------------|-------------|-------------|-------------|--------------|--------------|--------------|
| MTBF            | Over 2,000,000 hours         |             |             |             |              |              |              |
| ECC             | 72-bit per 1KByte            |             |             |             |              |              |              |
| Read Endurance  | Unlimited                    |             |             |             |              |              |              |
| Write Endurance | <b>8GB</b>                   | <b>16GB</b> | <b>32GB</b> | <b>64GB</b> | <b>128GB</b> | <b>256GB</b> | <b>512GB</b> |
|                 | 12 TBW                       | 23 TBW      | 45 TBW      | 90 TBW      | 181 TBW      | 262 TBW      | 544 TBW      |
| Data retention  | > 90 days at NAND expiration |             |             |             |              |              |              |

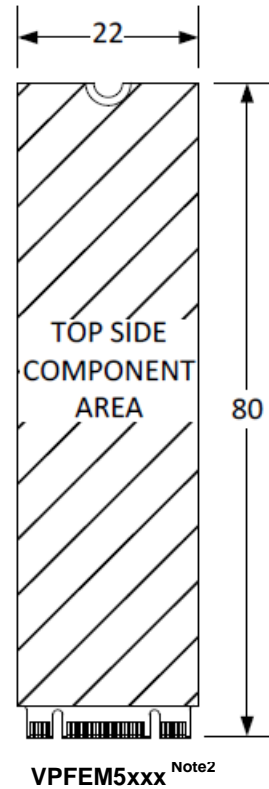
**NOTES:**

1. Tested to JEDEC219A client endurance workloads using Toshiba 15nm Toggle MLC NAND.
2. TBW may differ according to flash configuration and platform.
3. The endurance of SSD could be estimated based on user behavior, NAND endurance cycles, and write amplification factor. It is not guaranteed by flash vendor
4.  $TBW = (GB \text{ capacity} \times DWPD \times 365 \times \text{years}) / 1000$

### 3 Mechanical Information

#### 3.1 Dimensions

Figure 3-1: Dimensions

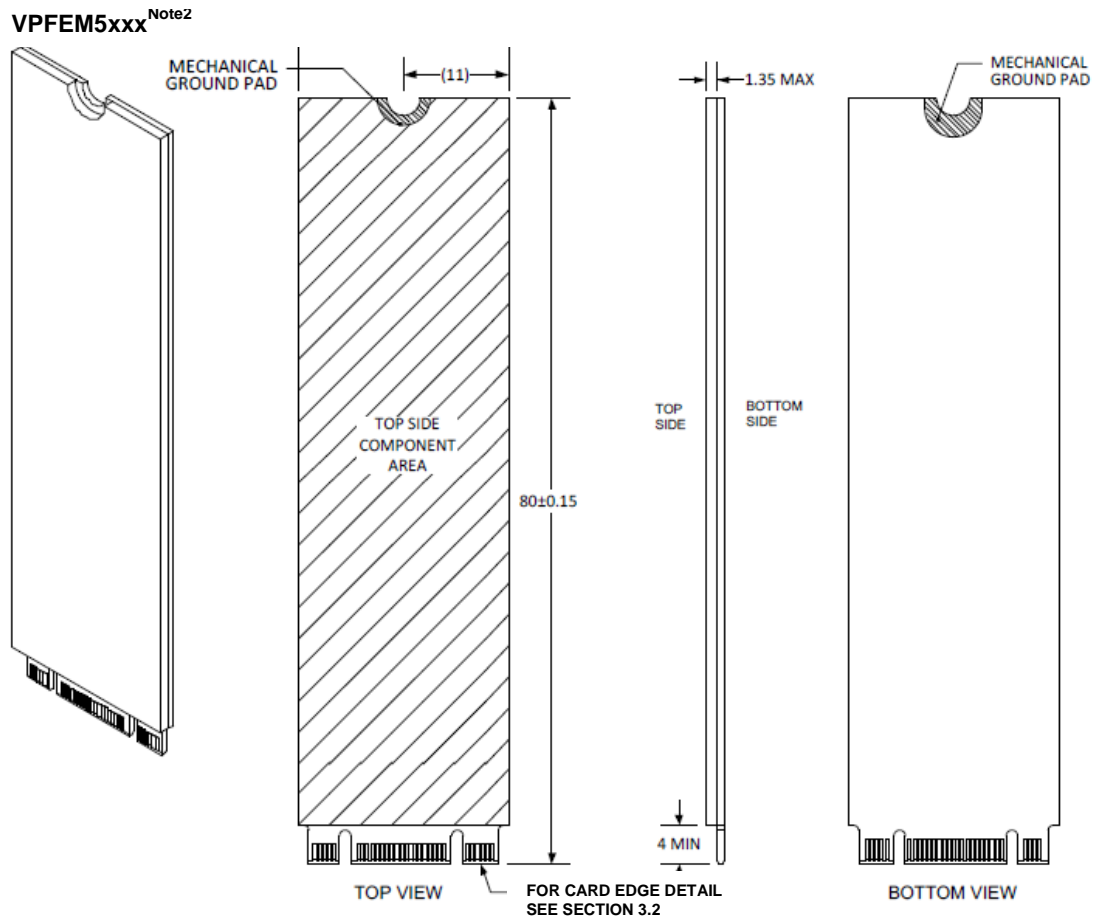


**Notes:**

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

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**Figure 3-2: Dimension Details for M.2 80mm length**



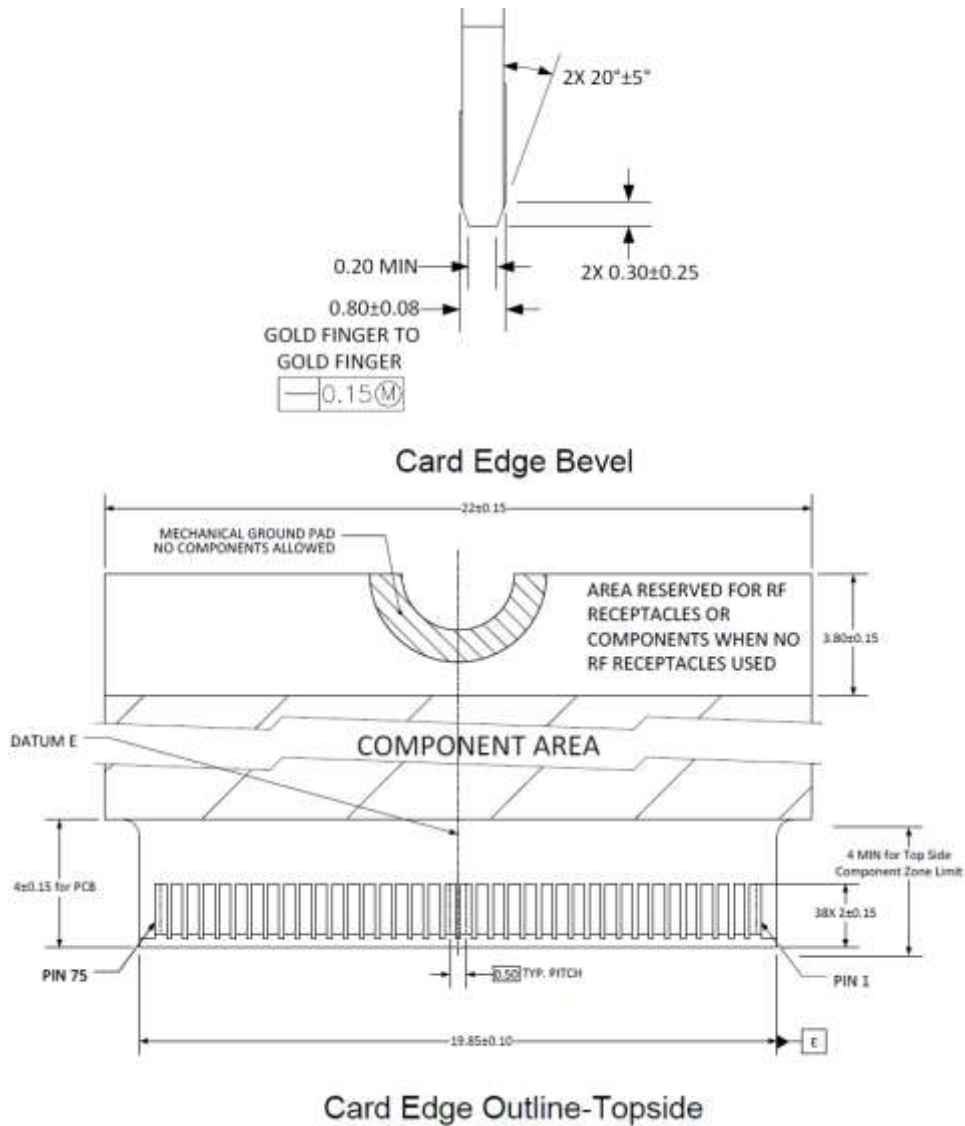
**Notes:**

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

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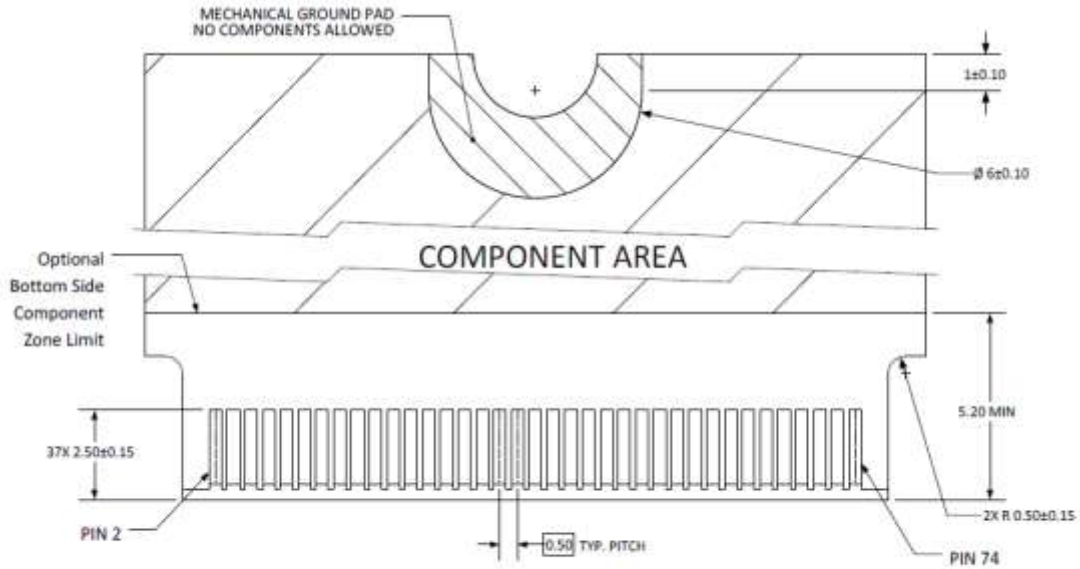
### 3.2 Card Edge Detail

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

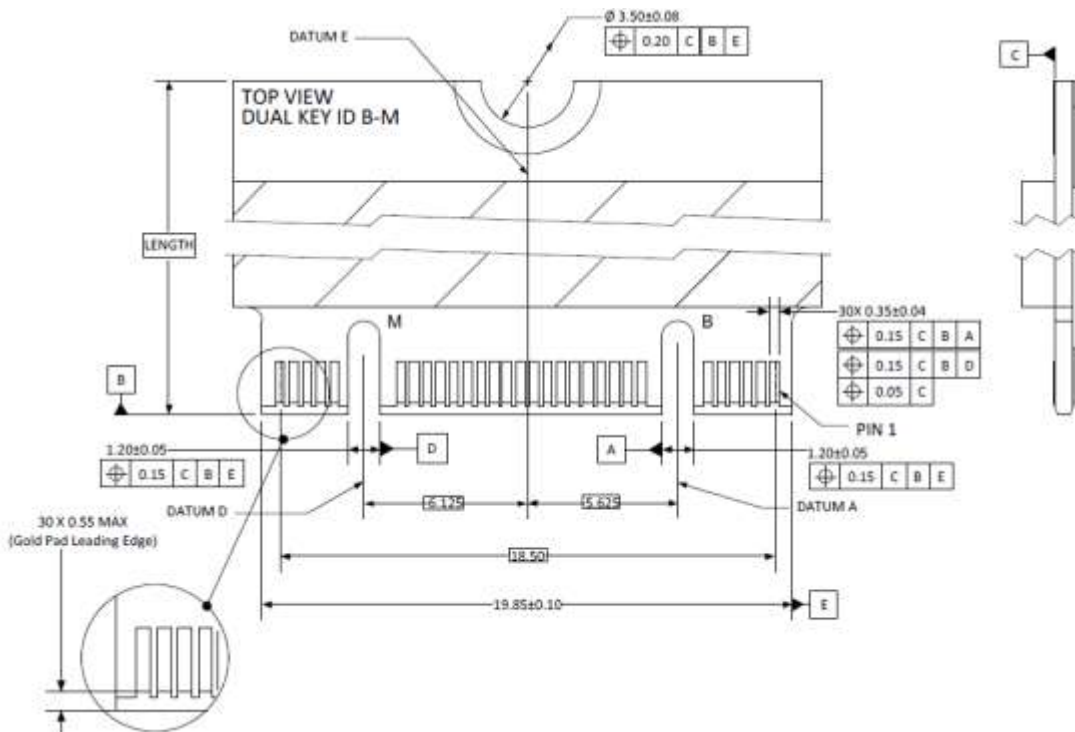


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Figure 3-4: Dimension Details for M.2 connector and notch



Card Edge Outline-Backside



Key notch detail



### 3.3 M.2 SSD Weight

Table 3-1: M.2 SSD weight

| Weight | Unit of measure |
|--------|-----------------|
| < 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) Note4  | 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  |

| Pin | Description          | Description      | Pin |
|-----|----------------------|------------------|-----|
| 26  | N/C                  | GND              | 27  |
| 24  | N/C                  | N/C              | 25  |
| 22  | N/C                  | N/C              | 23  |
| 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) Note3 | N/C              | 11  |
| 8   | N/C                  | N/C or GND Note5 | 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)
3. Status indicators via LED devices that will be provided by the system Active Low. A pulled-up LED with series current limiting resistor should allow for 9mA when On.
4. Device Sleep, Input when driven high, the host is informing the SSD to enter a low power state
5. N/C for Socket 2, and GND for Socket 3

## 4.2 Hot Plug Support

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

## 5 Command Sets

### 5.1 ATA Commands

**Table 5-1: Supported ATA Commands**

| Description            | Op Code | Description               | Op Code |
|------------------------|---------|---------------------------|---------|
| Check power mode       | E5h     | Security Disable Password | F6h     |
| Data Set management    | 06h     | Security Erase Prepare    | F3h     |
| DCO                    | B1h     | Security Erase Unit       | F4h     |
| Download Microcode PIO | 92h     | Security Freeze Lock      | F5h     |

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

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

### 5.1.6 Power Management Command Set

SSD supports the Power Management command set consisting of:

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

### 5.1.7 Security Mode Feature Set

SSD supports the Security Mode command set consisting of:

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

### 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<br>V: Variable<br>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<br>V: Variable<br>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 a 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<br>V: Variable<br>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<br>4h: 1.8 inch<br>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<br>V: Variable<br>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<br>XX is variable | Integrity word (Checksum and Signature)  |

## Notes for Capacity specific Device Identification

| Capacity<br>(GB) | *1               | *2           | *3           | *4             |
|------------------|------------------|--------------|--------------|----------------|
|                  | (Word 1/Word 54) | (Word 57-58) | (Word 60-61) | (Word 100-103) |
| 4                | 1E5Dh            | 778E3Oh      | 778E3Oh      | 778E3Oh        |
| 8                | 3CA5h            | EEC9BOh      | EEC9BOh      | EEC9BOh        |
| 16               | 3FFFh            | FBFC1Oh      | 1DD4OBOh     | 1DD4OBOh       |
| 24               | 3FFFh            | FBFC1Oh      | 2CBB7BOh     | 2CBB7BOh       |
| 32               | 3FFFh            | FBFC1Oh      | 3BA2EBOh     | 3BA2EBOh       |
| 64               | 3FFFh            | FBFC1Oh      | 774OABOh     | 774OABOh       |
| 128              | 3FFFh            | FBFC1Oh      | EE7C2BOh     | EE7C2BOh       |
| 256              | 3FFFh            | FBFC1Oh      | 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.

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### 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)<br>CRC Error Count (R CRC + W CRC) |
| DAh                | Number of accumulated CRC Error (read/write data FIS CRC error)<br>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  | <b>Note 1</b> | <b>Note 1</b> | 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<br>(MAX 65535)        | Average erase count<br>(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 PE, MLC PE) \* 100 (percentage)

Micron L95B or Toshiba 15nm MLC PE is 3000

SLC PE is 100000

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### 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.

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**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 $1 \times 10^9$ 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 $1 \times 10^6$ 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  |