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.

Revision History

Date	Revision	Description	Checked By
3/27/15	X1	Initial Release from modified PSFEM4XXXGTXXX_X3 and PN table per PSG	
5/07/15	A	Add photo, update per psg. 4/29/15 Change all PN to VPxx., remove 42/60mm references. Change all PN to VPxx., remove 42/60mm references. Remove PFAIL/DATA Hardening signaling. Changed Absolute max Vin 3.6V. Reliability table changed from 72 bit per 1KB to 120 bit per 2KB page. Changed table 4-1 Signal and Power pin 58 to Reserved for MFG_CLOCK	
5/13/15	B	Revise power consumption table. IOPS per IOmeter8. Add notes to PN table	
7/30/15	C	Add 15nm PN's	
3/1/16	D	Update PN table	
9/20/16	E	Revise logo and color scheme. Remove temp sensor and SATA attribute.	
3/20/17	F	Revise note 2 on Extended SMART Attribute Actual Data table	

Legal Information

Legal Information

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Ordering Information: M.2 80mm SATA SSD Solid-State Drive

Part Number	Interface	User Capacity (GB)	NAND	Temperature (C)	NAND
VPFEM5480GTCZMTK	SATA 6GB	480	MLC	(0 to +70'c)	TSB A19nm K-die
VPFEM5480GTCZMMC	SATA 6GB	480	MLC	(0 to +70'c)	Micron 16nm L95B
VPFEM5240GTCVMTK	SATA 6GB	240	MLC	(0 to +70'c)	TSB A19nm K-die
VPFEM5240GTCAMMC	SATA 6GB	240	MLC	(0 to +70'c)	Micron 16nm L95B
VPFEM5120GTCTMTK	SATA 6GB	120	MLC	(0 to +70'c)	TSB A19nm K-die
VPFEM5120GTCBMMC	SATA 6GB	120	MLC	(0 to +70'c)	Micron 16nm L95B
VPFEM5480GTCZMTL	SATA 6GB	480	MLC	(0 to +70'c)	TSB 15nm L-die
VPFEM5240GTCAMTL	SATA 6GB	240	MLC	(0 to +70'c)	TSB 15nm L-die
VPFEM5120GTCBMTL	SATA 6GB	120	MLC	(0 to +70'c)	TSB 15nm L-die

Notes:

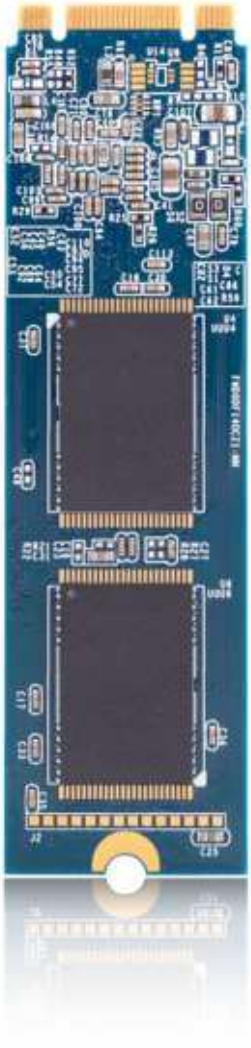
1. Usable capacity based on a level of over-provisioning applied to wear leveling, bad sectors, index tables etc.
2. Higher capacity points may be available based on customer application. Consult your local Viking FAE Engineer.
3. SSD's ship unformatted from the factory unless otherwise requested.
4. 1 GB = 1,000,000,000 Byte
5. One Sector = 512 Byte.

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Product Picture(s)



M.2 2280 FRONT



M.2 2280 BACK

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

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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.

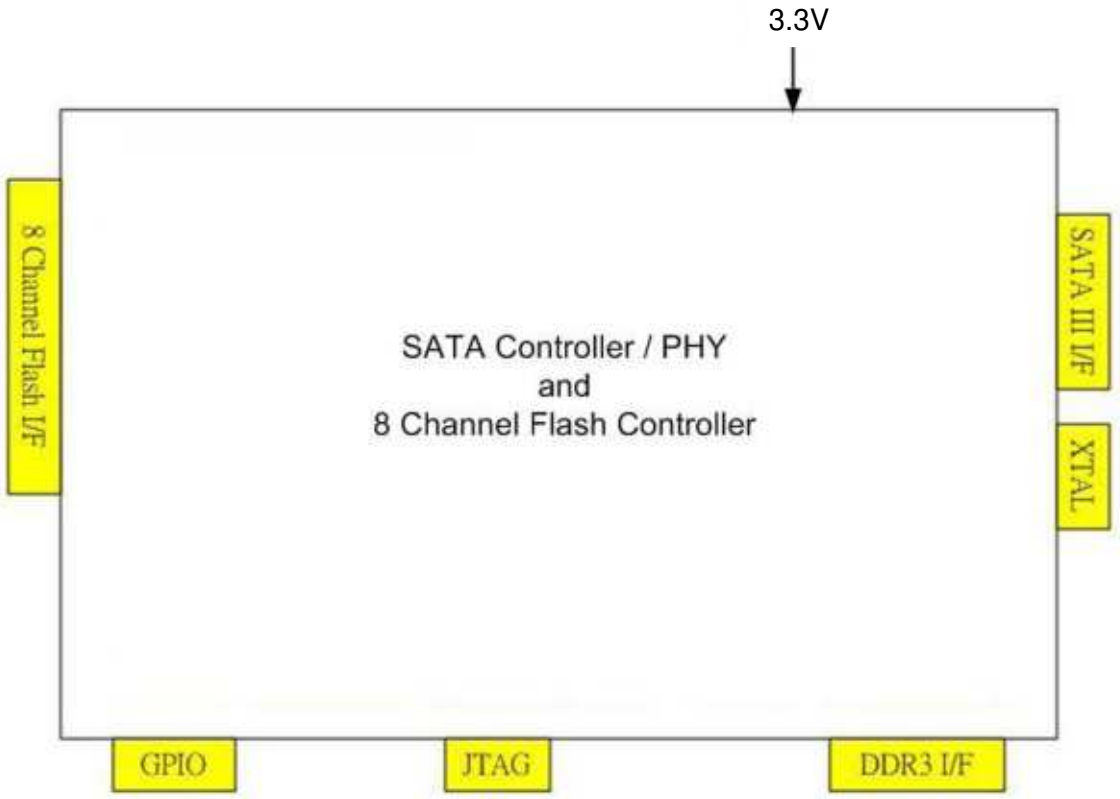
1.1 Features

The SSD delivers the following features:

- Seamless SATA Revision 3.2 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 static and dynamic wear-leveling algorithm
- Efficient error recovery
- Power hold-up circuit technology ensures no data loss resulting from an unexpected power loss and is supported for industrial temperatures
- TRIM Support
- 48-bit LBA Support

1.2 Block Diagram

Figure 1-1: High-Level Block Diagram



Notes: Support for up to 8-channels and 32 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.

2 Product Specifications

2.1 Performance

Table 2-1: Maximum Sustained Read and Write Bandwidth

Access Type	MB/s
Sequential Read, 256K	Up to 550
Sequential Write, 256K	Up to 530

Notes:
1. Performance measured using Iometer 08
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

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

Access Type	IOPS
Read, 4K	Up to 100,000
Write, 4K	Up to 90,000

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 A19nm NAND devices

2.2 Timing

Table 2-3: Timing Specifications

Type	Average Latency
Read (at 64KB)	0.14mS
Write (at 64KB)	2.12mS
Power On Ready (POR)	436mS

Notes:
1. Device measured using Drivemaster.
2. DRQ (Data Transfer Requested) bit being asserted

2.2.1 STANDBY IMMEDIATE Command

The Power-On-to-Ready time assumes a proper shutdown (power removal preceded by STANDBY IMMEDIATE command. A STANDBY IMMEDIATE before power down always performs a graceful shutdown and does not require the use of the hold-up circuit.

Table 2-4: STANDBY IMMEDIATE Timing

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

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

2.3 Electrical Characteristics

2.3.1 Absolute Maximum Ratings

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

Table 2-5: Absolute Maximum Ratings

Description	Min	Max	Unit
Maximum Voltage Range for Vin	-0.2	3.6	V
Maximum Temperature Range	-40	85	c

2.3.2 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

2.3.3 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: TSBA19	Read()	Write	Idle	Partial	Slumber
128GB	8GBx1Diex16CE	2.224	3.446	0.505	0.0911	0.0911
256GB	8GBx1Diex32CE	2.21	4.31	0.566	0.0695	0.068
512GB	8GBx2Diex32CE	2.335	4.431	0.632	0.0824	0.0798
1TB	16GBx2Diex32CE	2.481	4.234	0.651	0.1014	0.1009

Capacity	Flash: M L95B	Read()	Write	Idle	Partial	Slumber
128GB	16GBx1Diex8CE	2.193	2.524	0.625	0.1158	0.0716
256GB	16GBx1Diex16CE	2.161	3,624	0,571	0.0675	0,0659
512GB	16GBx2Diex16CE	2.39	3.971	0.567	0.1199	0.0968

Notes:

1. The average value of power consumption is achieved based on 100% conversion efficiency.
2. The measured power voltage is 5V.
3. Samples were built of Toshiba A19nm Toggle MLC NAND flash and measured under ambient temperature.
4. Sequential R/W is measured while testing 400MB sequential R/W 5 times by CrystalDiskMark.
5. Power Consumption may differ according to flash configuration and platform.

2.4 Environmental Conditions

2.4.1 Temperature and Altitude

Table 2-8: Temperature and Altitude Related Specifications

Conditions	Operating	Shipping	Storage
Commercial Temperature- Ambient	0 to 70°C	-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

2.4.2 Shock and Vibration

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

Table 2-9: Shock and Vibration Specifications

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

2.4.3 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.

2.5 Reliability

Table 2-10: Reliability Specifications

Parameter	Description					
ECC	120 bit per 2KB page					
Read Endurance	Unlimited					
Write Endurance	**32GB**	**64GB**	**128GB**	**256GB**	**512GB**	**1024GB**
	79 TBW	158 TBW	317 TBW	635 TBW	1272 TBW	2548 TBW
Data retention	> 90 days at NAND expiration					

2.6 Data Security

2.6.1 Encryption

The SSD drive is a self-encrypting drive (SED), with a bulk data encryption feature that provides automatic hardware-based data security and enhanced secure erase capability.

A self-encrypting drives, scrambles data using a data encryption key as it is written to the drive and then descrambles it with the key as it is retrieved. This gives the user the highest level of data protection available and provides a fast

erase simply by deleting the encryption key, eliminating the need for time consuming data-overwrite. Data on the drive is instantly rendered unreadable.

The SSD supports AES-256 encryption and ATA Secure Erase features to protect sensitive data.

The SSD drives support the following security features:

- AES 256 on the fly support.
- RSA 512/1024/2048
- SHA 160/256/512
- TCG OPAL SSC V1.0

2.6.2 Quick Erase

Quick Erase has been designed to remove data under prompt and urgent situation and is triggered by sending an ATA Command.

Input Info of Executing Quick Erase Command

Register	7	6	5	4	3	2	1	0
Features	01h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing Quick Erase Command

Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.
ERR shall be cleared to zero.

2.6.3 Military Secure Erase / Sanitization/ Purge Routines

Many government and military organizations such as NIST/NSA define their own standard and procedures for performing a Military Secure Erase which overwrite different patterns to sanitize the flash media. Some of the more common military or government purge routines are defined in the following table and the data security features of the drive comply with Department of Defense (DoD) and US military data security standards.

Table 2-11: Military Secure Erase / Sanitize Routines

Standard	Action	SSD Code[1]
NSA/CSS 9-12	Erase and overwrite all locations with a known unclassified pattern. Verify the overwrite procedure by randomly rereading the overwritten information to confirm that only the known pattern can be recovered.	Note 1
NSA/CSS 130-2	Erase the media and overwrite with random data 2 times, then erase and overwrite with a character	Note 1
DoD5220.22-M	Erase the media and overwrite with single character, then erase again	Note 1
NISPOMSUP Chap 8, Sect.8-501	Erase the media and overwrite with single character, then erase again and overwrite with single character, then erase again and overwrite with random character then erase again	Note 1
USA Army 380-19	Erase the media and overwrite with random data, erase and overwrite with a character, then erase and overwrite with complement of the character	Note 1
Navy NAVSO P-5239-26	Erase the media and overwrite with random data, then erase again	Note 1
Air Force AFSSI 5020	Erase the media and overwrite with pattern, repeat 3 times	Note 1
Air Force AFSSI 8580	TBD	Note 1

Notes:
1. Enabled using ATA commands

2.6.3.1 AFSSI 5020

Pattern:
1) To erase the whole disk.
2) To fill the whole disk with random data.

Input Info of Executing AFSSI 5020 Command

Register	7	6	5	4	3	2	1	0
Features	02h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing AFSSI 5020 Command

Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.
ERR shall be cleared to zero.

2.6.3.2 DOD 5220.22-M

Pattern:
1) To fill the whole disk with fixed character pattern of 0x55.
2) To erase the whole disk.

Input Info of Executing DoD 5220.22-M Command

Register	7	6	5	4	3	2	1	0
Features	03h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing DoD 5220.22-M Command

Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.
ERR shall be cleared to zero.

2.6.3.3 USA NAVY NAVSO P-5239-26

Pattern:
1) To erase the whole disk.
2) To fill the whole disk with random data.
3) To erase the whole disk again.

Input Info of Executing USA Navy NAVSO P-5239-26 Command

Register	7	6	5	4	3	2	1	0
Features	04h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing USA Navy NAVSO P-5239-26 Command

Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.
ERR shall be cleared to zero.

2.6.3.4 NSAMANUAL 130-2

Pattern:
1) To erase the whole disk.
2) To fill the whole disk with random data.
3) To fill the whole disk with random data one more time.
4) To erase the whole disk again.
5) To fill the whole disk with fixed character pattern of 0x55.

Input Info of Executing NSA Manual 130-2 Command

Register	7	6	5	4	3	2	1	0
Features	05h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing NSA Manual 130-2 Command

Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.

ERR shall be cleared to zero.

2.6.3.5 USA-ARMY 380-19

Pattern:
1) To erase the whole disk.
2) To fill the whole disk with random data.
3) To fill the whole disk with fixed character pattern of 0x55.
4) To fill the whole disk with fixed character pattern of 0xAA.

Input Info of Executing USA-Army 380-19 Command

Register	7	6	5	4	3	2	1	0
Features	06h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing USA-Army 380-19 Command

Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.
ERR shall be cleared to zero.

2.6.3.6 NISPOMSUP CHAP 8, SECT. 8-501

Pattern:
1) To fill the whole disk with fixed character pattern of 0x55.
2) To fill the whole disk with fixed character pattern of 0xAA.
3) To fill the whole disk with random data.

Input Info of Executing NISPOMSUP chap 8, Sect. 8-501 Command

Register	7	6	5	4	3	2	1	0
Features	07h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing NISPOMSUP chap 8, Sect. 8-501 Command

Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.
ERR shall be cleared to zero.

2.6.3.7 NSA/CSS 9-12

Pattern:
1) To fill the whole disk with fixed character pattern of 0x55.

Input Info of Executing NSA/CSS 9-12 Command

Register	7	6	5	4	3	2	1	0
Features	08h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing NSA/CSS 9-12 Command

Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.
ERR shall be cleared to zero.

2.6.3.8 AFSSI 8580

Pattern:
1) To fill the whole disk with fixed character pattern of 0x55.
2) To fill the whole disk with fixed character pattern of 0xAA.
3) To fill the whole disk with random data.

Input Info of Executing AFSSI 8580 Command

Register	7	6	5	4	3	2	1	0
Features	09h							
Sector Count	2Fh							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	A0h							
Command	6Fh							

Normal Output Info of Executing AFSSI 8580 Command

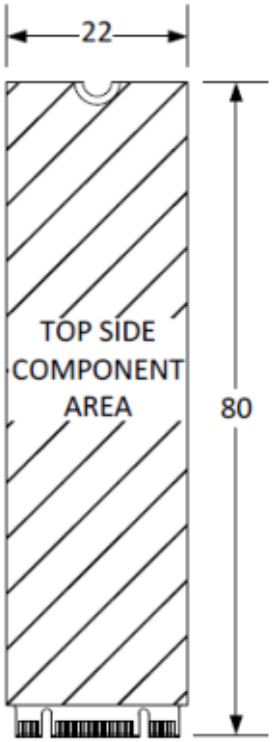
Register	7	6	5	4	3	2	1	0
Features	na							
Sector Count	na							
Sector Number	na							
Cylinder High	na							
Cylinder Low	na							
Device/Head	obs	na	obs	DEV	na	na	na	na
Command	BSY	DRDY	DF	na	DRQ	na	na	ERR

Device/Head Register:
DEV shall indicate the selected device.
Status Register:
BSY shall be cleared to zero indicating command completion.
DRDY shall be set to one.
DF (Device Fault) shall be cleared to zero.
DRQ shall be cleared to zero.
ERR shall be cleared to zero.

3 Mechanical Information

3.1 Dimensions

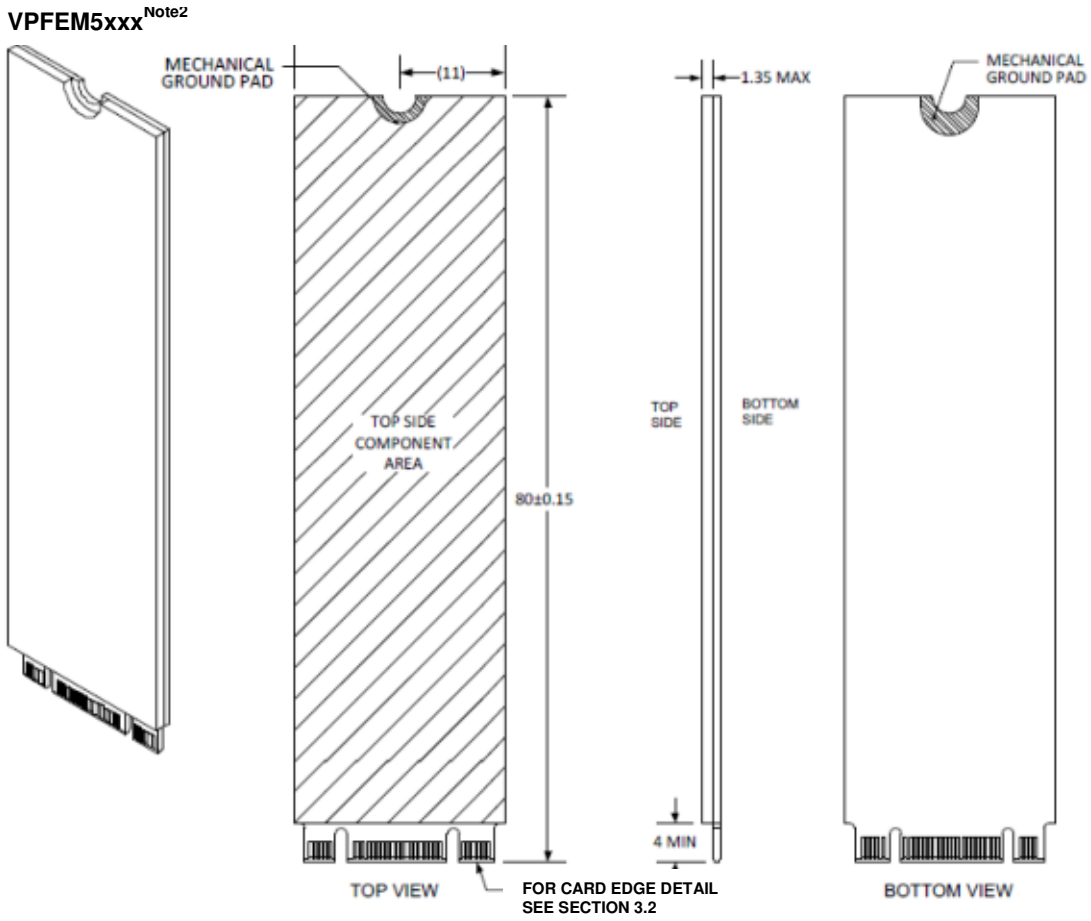
Figure 3-1: Dimensions



VPFEM5xxx [Note2]

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”.

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

3.2 Card Edge Detail

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

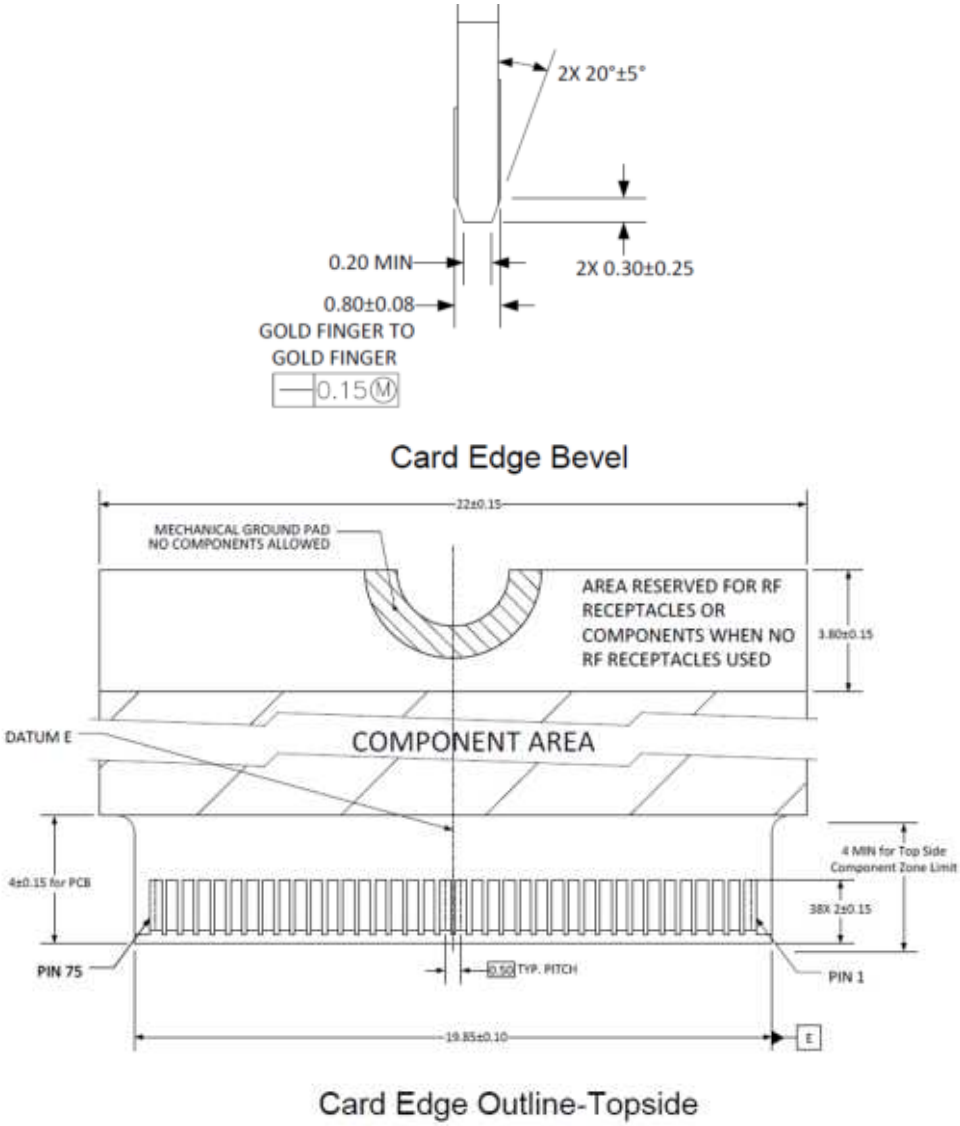
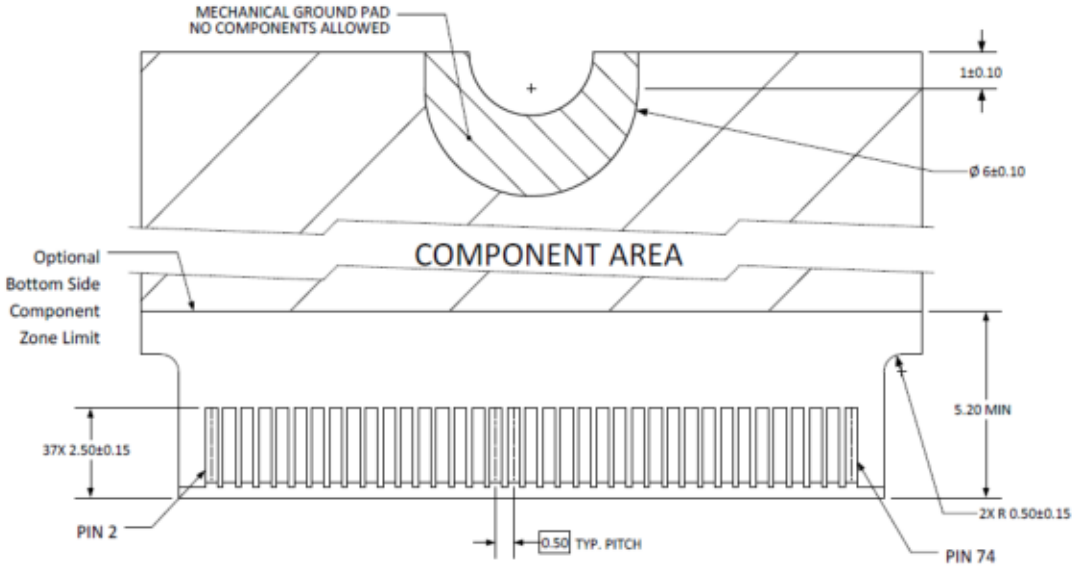
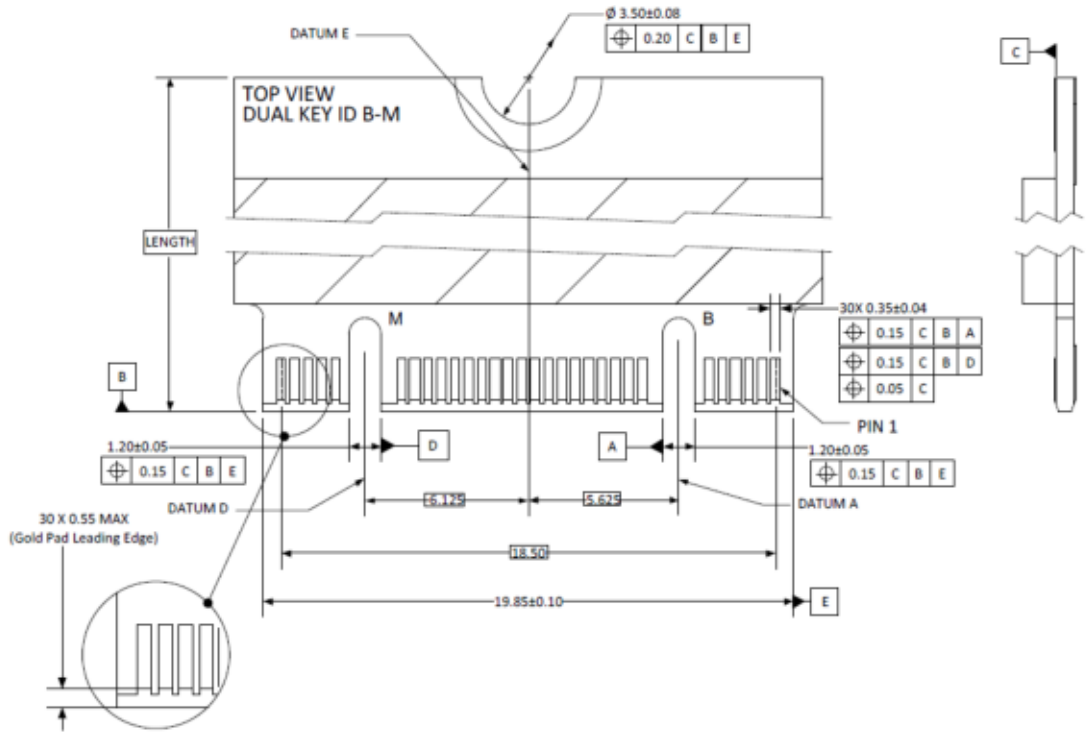


Figure 3-4: Dimension Details for M.2 connector and notch



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
80 mm	< 8	Grams

4 Pin and Signal Descriptions

4.1 Signal and Power Description Tables

Table 4-1: M.2 SATA Connector Pinouts

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	Reserved for MFG_CLOCK	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

Pin	Description	Description	Pin
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)	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

Description	Op Code	Description	Op Code
Flush cache Ext	EAh	Set features	EFh
Identify device	ECh	Set Max Address	F9h
Idle	E3h	Set Max Address Ext	37h
Idle immediate	E1h	Set multiple mode	C6h
Initialize drive parameters	91h	Sleep	E6h
Read buffer	E4h	Smart	B0h
Read DMA (w/o retry)	C9h	Standby	E2h
Read DMA (w/retry)	C8h	Standby immediate	E0h
Read DMA Ext	25h	Write buffer	E8h
Read FPDMA QUEUED	60h	Write DMA (w/o retry)	CBh
Read Log Ext	2Fh	Write DMA (w/retry)	CAh
Read multiple	C4h	Write DMA Ext	35h
Read multiple Ext	29h	Write DMA FUA Ext	3Dh
Read native max address	F8h	Write FPDMA QUEUED	61h
Read native max Ext	27h	Write Log Ext	3Fh
Read sector(s) (w/o retry)	21h	Write multiple	C5h
Read sector(s) (w/retry)	20h	Write multiple Ext	39h
Read sector(s) Ext	24h	Write multiple FUA Ext	CEh
Read Verify Ext	42h	Write sector(s) (w/o retry)	31h
Read verify sector(s) (w/o retry)	41h	Write sector(s) (w/retry)	30h
Read verify sector(s) (w/retry)	40h	Write sector(s) Ext	34h
Recalibrate	10h	Write uncorrectable	45h

5.1.1 48-Bit Address Command Set

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

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

5.1.2 ATA General Feature Command Set

SSD supports the ATA General Feature command set consisting of:

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

5.1.3 Device Configuration Overlay Command Set

SSD supports the Device Configuration Overlay command set consisting of:

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

5.1.4 General Purpose Log Command Set

SSD supports the General Purpose Log command set consisting of:

- Read Log Ext
- Write Log Ext

5.1.5 Host Protected Area Command Set

SSD supports the Host Protected Area command set consisting of:

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

- Set Max Unlock (optional)

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	000000000h	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 (Word 1/Word 54)	*2 (Word 57-58)	*3 (Word 60-61)	*4 (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	FFFFFFFh	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.

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 PE, MLC PE) * 100 (percentage)
Micron L95B or Toshiba 15nm MLC PE is 3000
SLC PE is 100000

5.1.2.2 Off-line Mode

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

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

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

5.2 SATA Commands

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

5.2.1 Native Command Queuing (NCQ)

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

- READ FPDMA QUEUED
- WRITE FPDMA QUEUED

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

6 References

- Serial ATA Specification, Revision 3
- 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 $1x10^9$ bytes
HDD	Hard Disk Drive
Hot Plug	A term used to describe the removal or insertion of a SATA storage drive when the system is powered on.
IOPS	Input output operations per second
LBA	Logical Block Address
MB	Mega-bytes defined as $1x10^6$ bytes
MLC	Multi-Level Cell
MTBF	Mean Time Between Failures
NCQ	Native Command Queuing. The ability of the SATA hard drive to queue and re-order commands to maximize execution efficiency.
NOP	No Operation
OS	Operating System
Port	The point at which a SATA drive physically connects to the SATA controller.
RMS	Root Mean Squared
RPM	Revolutions Per Minute
SAS	Serial Attached SCSI
SATA	Serial ATA
SFF	Small Form Factor
SLC	Single Level Cell
S.M.A.R.T.	Self-Monitoring, Analysis and Reporting Technology: an open standard for developing hard drives and software systems that automatically monitors a hard drive's health and reports potential problems.
SSD	Solid-State Drive