

NVMe PCIe SSD M.2 Manual

NVMe PCIe SSD is a non-volatile, solid-state storage device delivering uncompromising performance, reliability and ruggedness for environmentally challenging applications.

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 1 of 56

Revision History

Date	Revision	Description	Checked By
12/20/17	A	Initial Release	
3/22/18	A1	Revise Power Consumption, Reliability performance. per 1686A PCB no support for 960GB, and no bottom component on PCB	
5/22/18	B	Add VRFNP5400GKCCPT3 - M.2 NVMe 480GB pSLC	
7/31/18	C	Add PNs VRFNP5400GKCHWT3 VRFNP5800GKCFWT3	

Legal Information

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Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 3 of 56

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

Part Number	Interface	Application	User Capacity (GB)	Temperature (C)	NAND
VRFNP5800GKCFWT3 ¹	PCIe/NVMe	Enterprise	800 ¹	0 to +70'c)	Toshiba 3D
VRFNP5480GKCHWT3	PCIe/NVMe	Enterprise	480	0 to +70'c)	Toshiba 3D
VRFNP5400GKCHWT3	PCIe/NVMe	Enterprise	400	0 to +70'c)	Toshiba 3D
VRFNP5240GKI5WT3	PCIe/NVMe	Enterprise	240	(-40 to +85'c)	Toshiba 3D
VRFNP5240GKC5WT3	PCIe/NVMe	Enterprise	240	0 to +70'c)	Toshiba 3D
VRFNP5120GKI5WT3	PCIe/NVMe	Enterprise	120	(-40 to +85'c)	Toshiba 3D
VRFNP5120GKC5WT3	PCIe/NVMe	Enterprise	120	0 to +70'c)	Toshiba 3D
VRFNP5060GKI5WT3	PCIe/NVMe	Enterprise	60	(-40 to +85'c)	Toshiba 3D
VRFNP5060GKC5WT3	PCIe/NVMe	Enterprise	60	(-0 to +70'c)	Toshiba 3D
VRFNP5400GKCCPT3	PCIe/NVMe	Enterprise	480	(-0 to +70'c)	pSLC, Toshiba 3D

Notes:

1. Usable capacity based on a level of over-provisioning applied to wear leveling, bad sectors, index tables etc.
2. SSD's ship unformatted from the factory unless otherwise requested.
3. 1 GB = 1,000,000,000 Byte
4. One Sector = 512 Byte.
5. Lower case "x" is the NAND device code
6. The lowercase letters y and z are wildcard characters that indicate FLASH vendor and die revisions and /or for customer specific locked
7. Contact Viking for availability

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 4 of 56

Table of Contents

1	INTRODUCTION	10
1.1	Features	10
1.2	PCIE Interface	10
2	PRODUCT SPECIFICATIONS	11
2.1	Capacity and LBA count	11
2.2	Performance	11
2.2.1	Throughput	12
2.2.2	Predict & Fetch	12
2.3	Electrical Characteristics	12
2.3.1	Absolute Maximum Ratings	12
2.3.2	Supply Voltage	13
2.3.3	Power Consumption	13
2.4	Environmental Conditions	14
2.4.1	Temperature and Altitude	14
2.4.2	Shock and Vibration	14
2.4.3	Electromagnetic Immunity	15
2.5	Reliability	15
2.6	Data Security	16
2.6.1	Power Loss Protection: Flushing Mechanism	16
2.6.2	Secure Erase	16
2.6.3	Write Protect	16
2.7	Flash Management	17
2.7.1	Error Correction Code (ECC)	17
2.7.2	Wear Leveling	18
2.7.3	Bad Block Management	18
2.7.4	TRIM	18
2.7.5	SMART	19
2.7.6	Over-Provision	19
2.7.7	Firmware Upgrade	19
3	MECHANICAL INFORMATION	20
3.1	Card Edge Detail	23

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 5 of 56

3.2	M.2 SSD Weight	24
4	PIN AND SIGNAL DESCRIPTIONS	24
4.1	Signal and Power Description Tables	24
5	PCIE AND NVM EXPRESS REGISTERS	25
5.1	PCI Express Registers	25
5.1.1	PCI Register Summary	25
5.1.2	PCI Header Registers	25
5.1.3	PCI Power Management Registers	31
5.1.4	Message Signaled Interrupt Registers	32
5.1.5	MSI-X Registers	33
5.1.6	PCI Express Capability Registers	34
5.1.7	Advanced Error Reporting Registers	38
5.1.8	Device Serial Number Capability Register	43
5.1.9	Power Budgeting Extended Capability	43
5.1.10	Latency Tolerance Reporting Capability Registers	44
5.1.11	L1 Substates Capability Registers	44
5.2	NVM Express Registers	45
5.2.1	Register Summary	45
5.2.2	Controller Registers	46
6	SUPPORTED COMMAND SET	49
6.1	Admin Command Set	49
6.1.1	Identify Command	50
6.2	NVM Express I/O Command Set	55
6.3	SMART/Health Information	56
7	REFERENCES	56

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 6 of 56

Table of Tables

<i>Table 2-1: Maximum Sustained Read and Write Bandwidth</i>	11
Table 2-2: Maximum Random Read and Write Input/Output Operations per Second (IOPS)	12
<i>Table 2-3: Absolute Maximum Ratings</i>	13
<i>Table 2-4: Operating Voltage</i>	13
<i>Table 2-5: Power Consumption</i>	13
<i>Table 2-6: Temperature and Altitude Related Specifications</i>	14
<i>Table 2-7: Shock and Vibration Specifications</i>	14
<i>Table 2-8: Toshiba 3D NAND Reliability Specifications</i>	15
<i>Table 2-9: pSLC Toshiba 3D NAND Reliability Specifications</i>	15
<i>Table 3-1: M.2 SSD weight</i>	24
<i>Table 4-1: M.2 PCIe Connector Pinouts</i>	24
<i>Table 5-1: PCI Register Summary</i>	25
<i>Table 5-2: PCI Header Register Summary</i>	26
<i>Table 5-3: Identifier Register</i>	27
<i>Table 5-4: Command Register</i>	28
<i>Table 5-5: Device Status Register</i>	28
<i>Table 5-6: Revision ID Register</i>	28
<i>Table 5-7: Class Code Register</i>	28
<i>Table 5-8: Cache Line Size Register</i>	29
<i>Table 5-9: Master Latency Timer Register</i>	29
<i>Table 5-10: Header Type Register</i>	29
<i>Table 5-11: Built-in Self Test Register</i>	29
<i>Table 5-12: Memory Register Base Address Lower 32-bits (BAR0) Register</i>	29
<i>Table 5-13: Memory Register Base Address Upper 32-bits (BAR1) Register</i>	30
<i>Table 5-14: Index/Data Pair Register Base Address (BAR2) Register</i>	30
<i>Table 5-15: BAR3 Register</i>	30
<i>Table 5-16: Vendor Specific BAR4 Register</i>	30
<i>Table 5-17: Vendor Specific BAR5 Register</i>	30
<i>Table 5-18: Subsystem Identifier Register</i>	30
<i>Table 5-19: Expansion ROM Register</i>	30
<i>Table 5-20: Capabilities Pointer Register</i>	30
<i>Table 5-21: Interrupt Information Register</i>	30
<i>Table 5-22: Minimum Grant Register</i>	31
<i>Table 5-23: Maximum Latency Register</i>	31
<i>Table 5-24: PCI Power Management Capability Register Summary</i>	31
<i>Table 5-25: PCI Power Management Capability ID Register</i>	31
<i>Table 5-26: PCI Power Management Capability Register</i>	31
<i>Table 5-27: PCI Power Management Control and Status Register</i>	31
<i>Table 5-28: Message Signaled Interrupt Capability Register Summary</i>	32
<i>Table 5-29: Message Signaled Interrupt Capability ID Register</i>	32
<i>Table 5-30: Message Signaled Interrupt Control Register</i>	32
<i>Table 5-31: Message Signaled Interrupt Lower Address Register</i>	32
<i>Table 5-32: Message Signaled Interrupt Upper Address Register</i>	32
<i>Table 5-33: Message Signaled Interrupt Message Data Register</i>	32
<i>Table 5-34: Message Signaled Interrupt Masked Bits Register</i>	32
<i>Table 5-35: Message Signaled Interrupt Pending Bits Register</i>	33
<i>Table 5-36: MSI-X Capability Register Summary</i>	33
<i>Table 5-37: MSI-X Identifier Register</i>	33
<i>Table 5-38: MSI-X Control Register</i>	33

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 7 of 56

Table 5-39: MSI-X Table Offset Register	33
Table 5-40: MSI-X Pending Bit Array Offset Register	33
Table 5-41: PCI Express Capability Register Summary	34
Table 5-42: PCI Express Capability ID Register	34
Table 5-43: PCI Express Capabilities Register	34
Table 5-44: PCI Express Device Capabilities Register	34
Table 5-45: PCI Express Device Control Register	35
Table 5-46: PCI Express Device Status Register	35
Table 5-47: PCI Express Device Link Capabilities Register	35
Table 5-48: PCI Express Device Link Control Register	36
Table 5-49: PCI Express Device Link Status Register	36
Table 5-50: PCI Express Device Capabilities 2 Register	36
Table 5-51: PCI Express Device Control 2 Register	37
Table 5-52: PCI Express Device Status 2 Register	37
Table 5-53: PCI Express Link Capabilities 2 Register	37
Table 5-54: PCI Express Link Control 2 Register	37
Table 5-55: PCI Express Link Status 2 Register	37
Table 5-56: Advanced Error Reporting Capability Register Summary	38
Table 5-57: AER Capability ID Register	38
Table 5-58: AER Uncorrectable Error Status Register	38
Table 5-59: AER Uncorrectable Error Mask Register	39
Table 5-60: AER Uncorrectable Error Severity Register	39
Table 5-61: AER Correctable Error Status Register	40
Table 5-62: AER Correctable Error Mask Register	40
Table 5-63: AER Capabilities and Control Register	40
Table 5-64: AER Header Log Register	41
Table 5-65: AER TLP Prefix Log Register	41
Table 5-66: Secondary PCI Express Capability Register Summary	41
Table 5-67: Secondary PCI Express Capability ID Register	41
Table 5-68: PCI Express Link Control 3 Register	42
Table 5-69: PCI Express Lane Error Status Register	42
Table 5-70: PCI Express Lane 0 Equalization Register	42
Table 5-71: PCI Express Lane 1 Equalization Register	42
Table 5-72: PCI Express Lane 2 Equalization Register	42
Table 5-73: PCI Express Lane 3 Equalization Register	42
Table 5-74: Device Serial Number Capability Register Header	43
Table 5-75: Serial Number Register Header (offset 0x4/0x8)	43
Table 5-76: Power Budgeting Extended Capability Header	43
Table 5-77: Data Register	43
Table 5-78: Power Budget Capability Register	43
Table 5-79: LTR Extended Capability Header	44
Table 5-80: LTR Max Snoop latency Register	44
Table 5-81: LTR Max No Snoop latency Register	44
Table 5-82: L1 Substates Extended Capability Header	44
Table 5-83: L1 Substates Capability Register	44
Table 5-84: L1 Substates Control1 Register	45
Table 5-85: L1 Substates Control2 Register	45
Table 5-86: Register Summary	45
Table 5-87: Controller Capabilities	46
Table 5-88: Version	46
Table 5-89: Interrupt Mask Set	46
Table 5-90: Interrupt Mask Clear	47
Table 5-91: Controller Configuration	47

<i>Table 5-92: Controller Status</i>	47
<i>Table 5-93: Admin Queue Attributes</i>	47
<i>Table 5-94: Admin Submission Queue Base Address</i>	48
<i>Table 5-95: Admin Completion Queue Base Address</i>	48
<i>Table 5-96: Submission Queue Tail y Doorbell</i>	48
<i>Table 5-97: Completion Queue Head y Doorbell</i>	48
<i>Table 6-1: Opcode for Admin Commands</i>	49
<i>Table 6-2: Admin Commands –NVM Command Set Specific</i>	49
<i>Table 6-3: Identify Controller Data Structure</i>	50
<i>Table 6-4: Identify Power State Descriptor Data Structure</i>	52
<i>Table 6-5: Identify Namespace Data Structure</i>	53
<i>Table 6-6: LBA Format 0 Data Structure</i>	55
<i>Table 6-7: Opcode for NVM Express I/O Commands</i>	55
<i>Table 6-8: SMART/Health Information Log</i>	56

Table of Figures

<i>Figure 3-1: Dimension Details for M.2 80mm length</i>	20
<i>Figure 3-2: Signal and Power Pins on M.2 card edge</i>	23

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 9 of 56

1 Introduction

This document describes the specification of Viking SSD which uses PCIe interface. The Viking SSD is fully consist of semiconductor device and using NAND Flash Memory which has a high reliability and a high technology in a small form factor for using a SSD and supporting Peripheral Component Interconnect Express (PCIe) 3.0 interface standard up to 4 lanes shows much faster performance than previous SSDs. It could also provide rugged features with an extreme environment with a high MTBF.

1.1 Features

The SSD delivers the following features:

- Native-PCIe SSD with 2x Core ARM Cortex processor (SM226x family)
- PCI Express Gen3: Single port X4 lanes
- Compliant with PCI Express Base Specification Rev. 3.0
- Compliant with NVM Express Specification Rev.1.2
- Static and Dynamic Wear Leveling and Bad Block Management
- RoHS / Halogen-Free Compliant
- Support up to queue depth 64K
- 8 Flash Channels with 32 CE
- Max. ECC of 2KB LDPC + RAID
- E2E + SRAM ECC
- DDR3, DDR3L or LPDDR2 DRAM cache
- Support for Toggle 3.0 or ONFi 4.0
- Optional AES-128/256 / Opal 2.0
- Max. SSD Density of 2TB
- NAND Support for 3D TLC
- Support SMART and TRIM commands
- Support 48-bit addressing mode
- Firmware update

1.2 PCIE Interface

- PCI Express Gen3: Single port X4 lanes, 8Gb/s
- Compliant with PCI Express Base Specification Rev. 3.0
- Compliant with NVM Express Specification Rev.1.2

For a list of supported commands and other specifics, refer to Chapter 5 and 6.

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 10 of 56

2 Product Specifications

2.1 Capacity and LBA count

Raw Capacity (GB)	User Capacity (GB)	LBA Count
128	120	234,441,648
256	240	468,862,128
512	400	781,422,768
512	480	937,703,088
1000	800	1,562,824,368
1000	960	1,875,385,008

Notes:

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

2.2 Performance

Table 2-1: Maximum Sustained Read and Write Bandwidth

Parameter	Unit	120/128GB	240/256GB	400/480/512GB	800/960/1024GB
Sequential Read (Max)	MB/S	1550	1650	1650	2100
Sequential Write (Max)	MB/S	530	950	1000	1000

Notes:

- Performance may vary from flash configuration and platform.
- Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.

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

Parameter	Unit	120/128GB	240/256GB	400/480/512GB	800/960/1024GB
Random Read (4K) QD=32 (Max)	IOPS	83200	89600	92160	92160
Random Write (4K) QD=32 (Max)	IOPS	89600	92160	92160	92160

Notes:

1. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology

2.2.1 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.

2.2.2 Predict & Fetch

Normally, when the Host tries to read data from a PCIe SSD, the PCIe SSD will only perform one read action after receiving one command. However, the Viking SSD applies Predict & Fetch to improve the read speed. When the host issues sequential read commands to the PCIe SSD, the PCIe 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.

2.3 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 2-3: 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 2-4: Operating Voltage

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

2.3.3 Power Consumption

Table 2-5: Power Consumption

Capacity	Idle	Active	Unit
120/128GB, 240/256GB, 480/512GB, 960/1024GB	< 2.0	< 9.0	W

2.4 Environmental Conditions

2.4.1 Temperature and Altitude

Table 2-6: Temperature and Altitude Related Specifications

Conditions	Operating	Shipping	Storage
Industrial Temperature- Case ¹	-40 to 85°C	-40 to 85°C	-40 to 85°C
Humidity (non-condensing)	90% under 40C	93% under 40C	93% under 40C

Notes:

1. Tc is measured at the surface of NAND Flash package

2.4.2 Shock and Vibration

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

Table 2-7: Shock and Vibration Specifications

Stimulus	Description
Shock(non-operating)	Estimate: 1500G (0.5ms duration x,y,z with 1/2 sine wave)
Vibration (non-operating)	Estimate: (60min /axis on 3 axes) Displacement: 1.52mm (20 ~ 80 Hz) Acceleration: 20G (80 ~ 2,000 Hz)

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 2-8: Toshiba 3D NAND Reliability Specifications

Parameter	Description	
ECC	Up to 27 bytes correctable per 512-byte sector (BCH), up to 12 9-bit symbols correctable	
MTBF	Estimate: 1,500,000 hours	
Write Endurance	Capacity	TBW ⁴
	120GB	131
	240GB	262
	400GB	438
	800GB	876
Data retention	> 90 days at NAND expiration	

Notes:

1. The reliability specification follows JEDEC standards JESD218A and JESD219A
2. Average Minimum Program/Erase cycles (MLC, 3000)
3. If available, 960GB Estimate would be 1396
- 4.1 DWPD, for 3 years

Table 2-9: pSLC Toshiba 3D NAND Reliability Specifications

Parameter	Description	
ECC	Up to 27 bytes correctable per 512-byte sector (BCH), up to 12 9-bit symbols correctable	
MTBF	Estimate: 1,500,000 hours	
Write Endurance	Capacity	TBW
	120GB	TBD
	240GB	TBD
	480GB	TBD
	960GB	N/A
Data retention	> 90 days at NAND expiration	

Notes:

1. The reliability specification follows JEDEC standards JESD218A and JESD219A

2.6 Data Security

2.6.1 Power Loss Protection: Flushing Mechanism

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 applies the GuaranteedFlush technology, which requests the controller to transfer data to the cache. DDR performs as a cache, and its sizes include 256MB, 512MB, 1024MB or 2048MB. 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 SSD applies an algorithm to reduce the amount of data resides in the cache to provide a better performance. This SmartCacheFlush technology allows incoming data to only have a “pit stop” in the cache and then move to the 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 sum, with Flush Mechanism, the SSD proves to provide the reliability required by consumer, industrial, and enterprise-level applications.

2.6.2 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 empty its storage blocks and return to its factory default settings.

2.6.3 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.

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 16 of 56

2.7 Flash Management

2.7.1 Error Correction Code (ECC)

Flash memory cells will deteriorate with use, which might generate random bit errors in the stored data. The SSD applies a BCH ECC algorithm, which can detect and correct errors occur during read process, ensure data been read correctly, as well as protect data from corruption.

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 17 of 56

2.7.2 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.

Advanced Wear Leveling algorithm, 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.

2.7.3 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 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.

2.7.4 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.

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 18 of 56

2.7.5 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.

2.7.6 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.

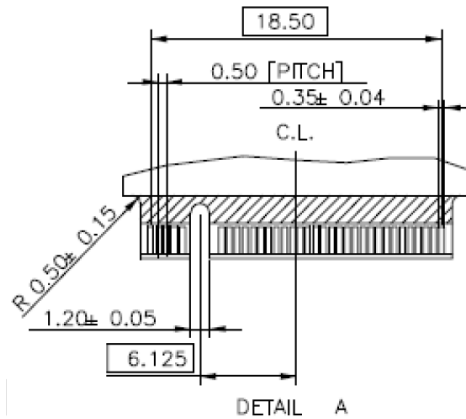
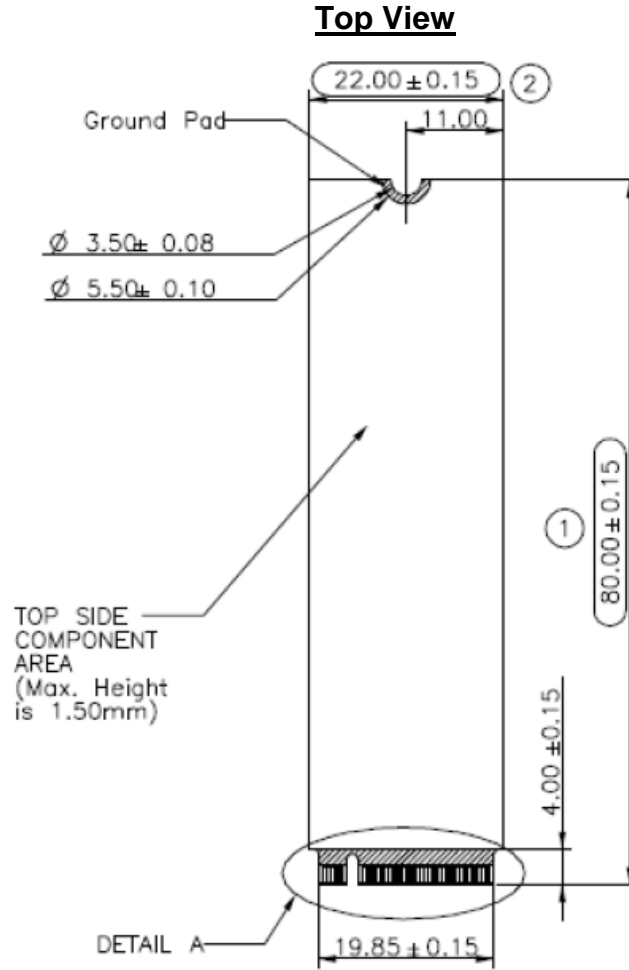
2.7.7 Firmware Upgrade

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.

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 19 of 56

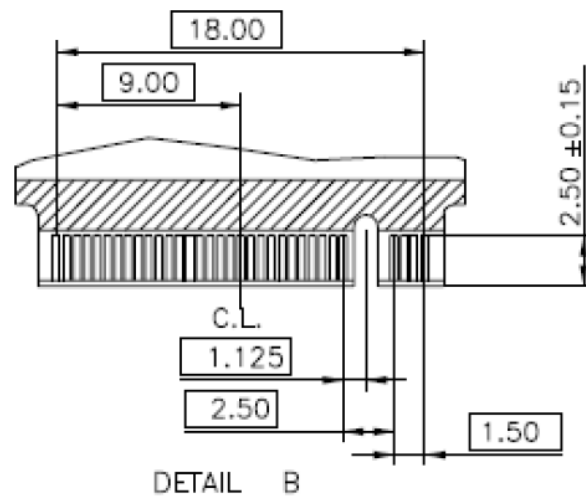
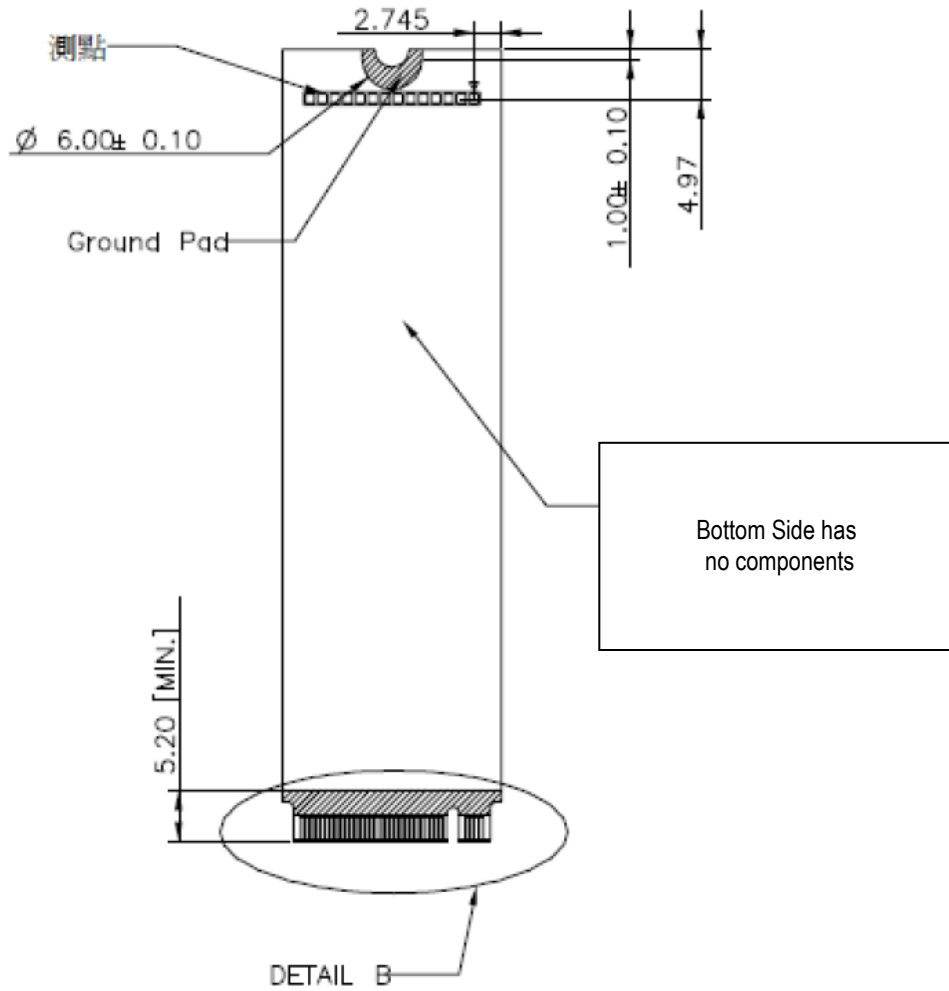
3 Mechanical Information

Figure 3-1: Dimension Details for M.2 80mm length



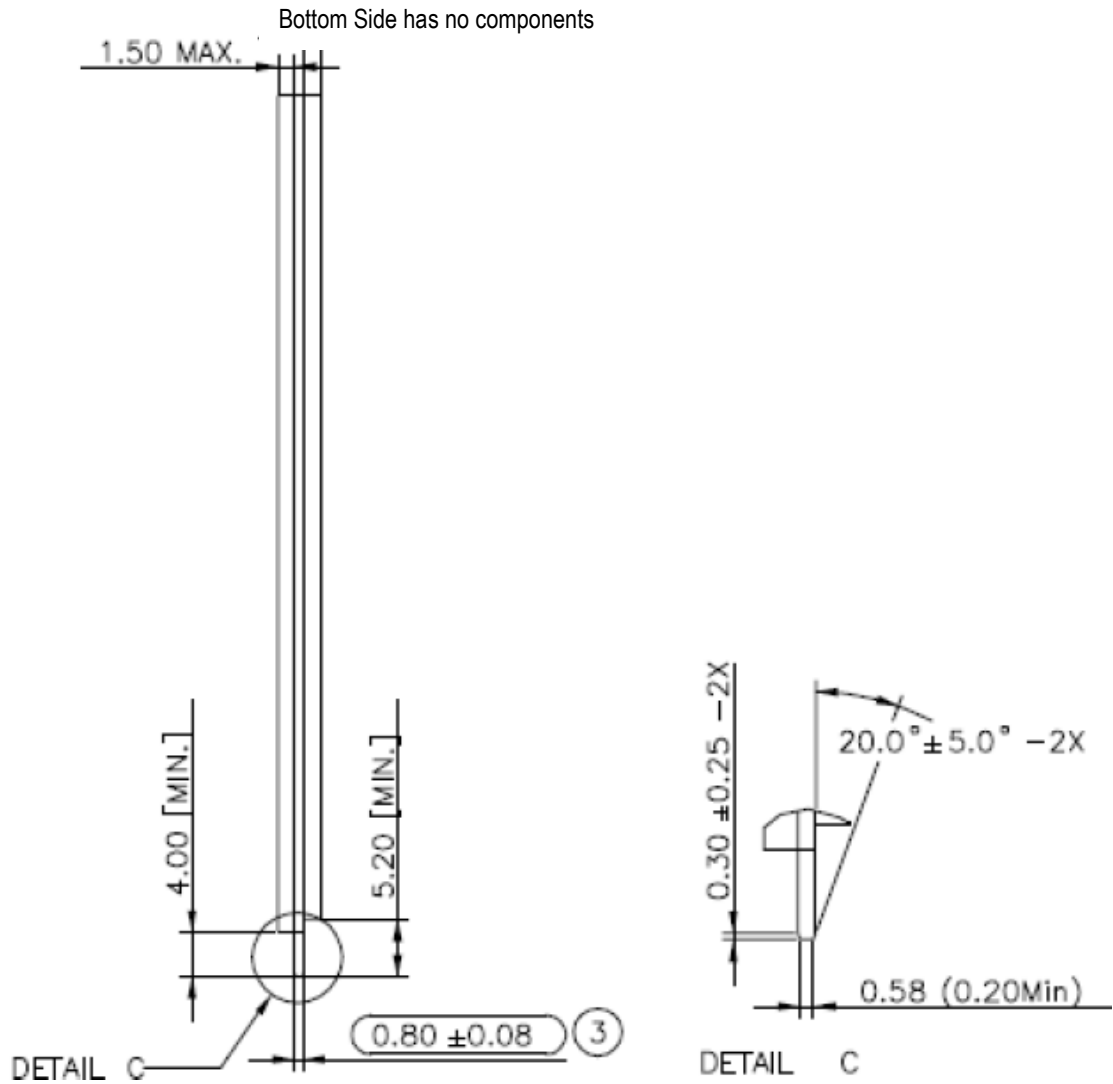
Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 20 of 56

Bottom View




Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 21 of 56

Side View



Notes:

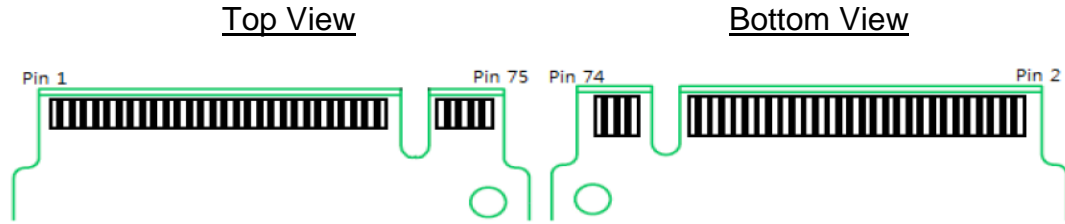
1. M.2 2280-D5-M: 80mm (L) x 22mm (W) x 3.8mm (H)
2. All dimensions are in millimeter
3. General tolerance is $\pm 0.15\text{mm}$

4. Max component height designated by 
5. No component area designated by 
6. No component (signal vias/Signal copper/Print) 
7. Check points locations at   

Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 22 of 56

3.1 Card Edge Detail

Figure 3-2: Signal and Power Pins on M.2 card edge



Manual	7/31/2018
PSFNP5xxxxKxxx	Viking Technology
Revision C	Page 23 of 56

3.2 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 PCIE Connector Pinouts

Pin #	Assignment	Description	Pin #	Assignment	Description
1	GND	Return current path	2	3.3V	3.3V source
3	GND	Return current path	4	3.3V	3.3V source
5	PETn3	PCle TX	6	N/C	N/C
7	PETp3	PCle TX	8	N/C	N/C
9	GND	Return current path	10	LED1#	Device Active Signal
11	PERn3	PCle Rx	12	3.3V	3.3V source
13	PERp3	PCle Rx	14	3.3V	3.3V source
15	GND	Return current path	16	3.3V	3.3V source
17	PETn2	PCle TX	18	3.3V	3.3V source
19	PETp2	PCle TX	20	N/C	N/C
21	GND	Return current path	22	N/C	N/C
23	PERn2	PCle Rx	24	N/C	N/C
25	PERp2	PCle Rx	26	N/C	N/C
27	GND	Return current path	28	N/C	N/C
29	PETn1	PCle TX	30	N/C	N/C
31	PETp1	PCle TX	32	N/C	N/C
33	GND	Return current path	34	N/C	N/C
35	PERn1	PCle Rx	36	N/C	N/C
37	PERp1	PCle Rx	38	N/C	N/C
39	GND	Return current path	40	N/C	N/C
41	PETn0	PCle TX	42	N/C	N/C
43	PETp0	PCle TX	44	N/C	N/C
45	GND	Return current path	46	N/C	N/C
47	PERn0	PCle Rx	48	N/C	N/C

Pin #	Assignment	Description	Pin #	Assignment	Description
49	PERp0	PCIe Rx	50	PERST#	PCIe Reset
51	GND	Return current path	52	CLKREQ#	PCIe Device Clock Request
53	REFCLKN	PCIe Reference Clock	54	PEWake#	N/C
55	REFCLKP	PCIe Reference Clock	56	N/C	N/C
57	GND	Return current path	58	N/C	N/C
67	N/C	N/C	68	SUSCLK	32.768 kHz clk input by host
69	PEDET	N/C	70	3.3V	3.3V source
71	GND	Return current path	72	3.3V	3.3V source
73	GND	Return current path	74	3.3V	3.3V source
75	GND	Return current path			

Note

- Pin 59 through 66 are reserved for the module key

5 PCIe and NVM Express Registers

5.1 PCI Express Registers

5.1.1 PCI Register Summary

Table 5-1: PCI Register Summary

Start Address	End Address	Name	Type
00h	3Fh	PCI Header	PCI Capability
40h	47h	PCI Power Management Capability	PCI Capability
50h	67h	MSI Capability	PCI Capability
70h	A3h	PCI Express Capability	PCI Capability
B0h	BBh	MSI-X Capability	PCI Capability
100h	12Bh	Advanced Error Reporting Capability	PCI Capability
148h	157h	Device Serial No Capability	PCI Capability
158h	167h	Power Budgeting Capability	PCI Capability
168h	17Bh	Secondary PCI Express Header	PCI Capability
188h	18Fh	Latency Tolerance Reporting (LTR)	PCI Capability
190h	19Fh	L1 Substates Capability Register	PCI Capability

5.1.2 PCI Header Registers

Table 5-2: PCI Header Register Summary

Start Address	End Address	Symbol	Description
00h	03h	ID	Identifiers
04h	05h	CMD	Command Register
06h	07h	STS	Device Status
08h	08h	RID	Revision ID
09h	0Bh	CC	Class Codes
0Ch	0Ch	CLS	Cache Line Size
0Dh	0Dh	MLT	Master Latency Timer
0Eh	0Eh	HTYPE	Header Type
0Fh	0Fh	BIST	Built in Self Test
10h	13h	MLBAR (BAR0)	Memory Register Base Address (lower 32-bit)
14h	17h	MUBAR (BAR1)	Memory Register Base Address (upper 32-bit)
18h	1Bh	IDBAR (BAR2)	Index/Data Pair Register Base Address
1Ch	1Fh	BAR3	Reserved
20h	23h	BAR4	Reserved
24h	27h	BAR5	Reserved
28h	2Bh	CCPTR	CardBus CIS Pointer
2Ch	2Fh	SS	Subsystem Identifiers
30h	33h	EROM	Expansion ROM Base Address
34h	34h	CAP	Capabilities Pointer
35h	3Bh	R	Reserved
3Ch	3Dh	INTR	Interrupt Information
3Eh	3Eh	MGNT	Minimum Grant
3Fh	3Fh	MLAT	Maximum Latency

Table 5-3: Identifier Register

Bits	Type	Default Value	Description
31:16	RO	tbd	Device ID
0:15	RO	tbd	Vendor ID

Table 5-4: Command Register

Bits	Type	Default Value	Description
15:11	RO	0	Reserved
10	RW	0	Interrupt Disable
9	RO	0	Fast Back-to-Back Enable (N/A)
8	RW	0	SERR# Enable (N/A)
7	RO	0	Zero value
6	RW	0	Parity Error Response Enable
5	RO	0	VGA Palette Snooping Enable (N/A)
4	RO	0	Memory Write and Invalidate Enable (N/A)
3	RO	0	Special Cycle Enable (N/A)
2	RW	0	Bus Master Enable
1	RW	0	Memory Space Enable
0	RW	0	I/O Space Enable

Table 5-5: Device Status Register

Bits	Type	Default Value	Description
15	RW1C	0	Detected Parity Error
14	RW1C	0	N/A
13	RW1C	0	Received Master Abort
12	RW1C	0	Received Target Abort
11	RW1C	0	Signaled Target Abort
10:9	RO	0	N/A
8	RW1C	0	Master Data Parity Error Detected
7	RO	0	N/A
6	RO	0	Reserved
5	RO	0	N/A
4	RO	tbd	Capabilities List
3	RO	0	INTx Status
2:0	RO	0	Reserved

Table 5-6: Revision ID Register

Bits	Type	Default Value	Description
7:00	RO	tbd	Controller Hardware Revision ID

Table 5-7: Class Code Register

Bits	Type	Default Value	Description
23:16	RO	tbd	Base Class Code
15:08	RO	tbd	Sub Class Code
7:00	RO	tbd	Programming Interface

Table 5-8: Cache Line Size Register

Bits	Type	Default Value	Description
7:0	RW	0h	N/A

Table 5-9: Master Latency Timer Register

Bits	Type	Default Value	Description
7:00	RO	0	N/A

Table 5-10: Header Type Register

Bits	Type	Default Value	Description
7:00	RO	0	N/A

Table 5-11: Built-in Self Test Register

Bits	Type	Default Value	Description
7:00	RO	0	N/A

Table 5-12: Memory Register Base Address Lower 32-bits (BAR0) Register

Bits	Type	Default Value	Description
31:04	RW	0	Base Address
3	RO	0	Pre-Fetchable
2:1	RO	tbd	Address Type (64-bit)
0	RO	0	Memory Space Indicator (MEMSI)

Table 5-13: Memory Register Base Address Upper 32-bits (BAR1) Register

Bits	Type	Default Value	Description
31:0	RO	0	Base Address

Table 5-14: Index/Data Pair Register Base Address (BAR2) Register

Bits	Type	Default Value	Description
31:0	RO	0	Base Address

Table 5-15: BAR3 Register

Bits	Type	Default Value	Description
31:0	RO	0	Base Address

Table 5-16: Vendor Specific BAR4 Register

Bits	Type	Default Value	Description
31:0	RO	0	Base Address

Table 5-17: Vendor Specific BAR5 Register

Bits	Type	Default Value	Description
31:0	RO	0	Base Address

Table 5-18: Subsystem Identifier Register

Bits	Type	Default Value	Description
31:16	RO	tbd	Subsystem ID
15:0	RO	tbd	Subsystem Vendor ID

Table 5-19: Expansion ROM Register

Bits	Type	Default Value	Description
31:11	RW	0	Expansion ROM Base Address
10:1	RO	0	Reserved
0	RW	0	Expansion ROM Enable/Disable

Table 5-20: Capabilities Pointer Register

Bits	Type	Default Value	Description
7:0	RO	tbd	Capability Pointer (Points to PCI Power Management Capability Offset)

Table 5-21: Interrupt Information Register

Bits	Type	Default Value	Description
15:8	RO	tbd	Interrupt Pin
7:0	RW	tbd	Interrupt Line

Table 5-22: Minimum Grant Register

Bits	Type	Default Value	Description
31:0	RO	0	Base Address

Table 5-23: Maximum Latency Register

Bits	Type	Default Value	Description
31:0	RO	0	Base Address

5.1.3 PCI Power Management Registers

Table 5-24: PCI Power Management Capability Register Summary

Start Address	End Address	Symbol	Description
40h	40h	PID	PCI Power Management Capability ID
41h	41h	Next cap ptr	Next cap ptr
42h	43h	PMC	PC Power Management Capabilities
44h	45h	PMCS	PCI Power Management Control and Status
46h	46h	PMCSR_BSE	PMCSR_BSE Bridge Extensions
47h	47h	Data	Data

Table 5-25: PCI Power Management Capability ID Register

Bits	Type	Default Value	Description
15:08	RO	tbd	Next Capability
7:00	RO	tbd	Capability ID

Table 5-26: PCI Power Management Capability Register

Bits	Type	Default Value	Description
15:11	RO	0	N/A
10	RO	0	D2 Support
9	RO	0	D1 Support
8:6	RO	0	N/A
5	RO	0	Device Specific Initialization
4	RO	0	Reserved
3	RO	0	PME Clock
2:0	RO	tbd	Version (Support for revision 1.2)

Table 5-27: PCI Power Management Control and Status Register

Bits	Type	Default Value	Description
31:24	RO	0	data register
23	RO	0	Bus power/Clock enable
22	RO	0	B2, B3 support
21:16	RsvdP	0	Reserved
15	RW1CS	0	PME Status
14:13	RO	0	N/A
12:09	RO	0	N/A
8	RWS	0	PME Enable
7:04	RsvdP	0	Reserved
3	RO	tbd	No Soft Reset
2	RsvdP	0	Reserved
1:00	RW	0	Power State

5.1.4 Message Signaled Interrupt Registers

Table 5-28: Message Signaled Interrupt Capability Register Summary

Start Address	End Address	Symbol	Description
50h	51h	MID	Message Signaled Interrupt Capability ID
52h	53h	MC	Message Signaled Interrupt Message Control
54h	57h	MA	Message Signaled Interrupt Message Address
58h	5Bh	MUA	Message Signaled Interrupt Upper Address
5Ch	5Dh	MD	Message Signaled Interrupt Message Data
60h	63h	MMASK	Message Signaled Interrupt Mask Bits
64h	67h	MPEND	Message Signaled Interrupt Pending Bits

Table 5-29: Message Signaled Interrupt Capability ID Register

Bits	Type	Default Value	Description
15:08	RO	tbd	Next Capability
7:0	RO	tbd	Capability ID

Table 5-30: Message Signaled Interrupt Control Register

Bits	Type	Default Value	Description
15:9	RsvdP	0	Reserved
8	RO	0	Per Vector Masking Capable
7	RO	tbd	64-bit Address Capable
6:4	RW	0h	Multiple Message Enable
3:1	RO	tbd	Multiple Message Capable
0	RW	0h	MSI Enable

Table 5-31: Message Signaled Interrupt Lower Address Register

Bits	Type	Default Value	Description
31:2	RW	0	Address
1:0	RO	0	Reserved

Table 5-32: Message Signaled Interrupt Upper Address Register

Bits	Type	Default Value	Description
31:0	RW	0	Upper Address

Table 5-33: Message Signaled Interrupt Message Data Register

Bits	Type	Default Value	Description
16:31	RsvdP	0	Reserved
0:15	RO	0	Data

Table 5-34: Message Signaled Interrupt Masked Bits Register

Bits	Type	Default Value	Description
31:0	RW	0	Mask Bits

Table 5-35: Message Signaled Interrupt Pending Bits Register

Bits	Type	Default Value	Description
31:0	RO	0	Pending Bits

5.1.5 MSI-X Registers

Table 5-36: MSI-X Capability Register Summary

Start Address	End Address	Symbol	Description
B0h	B1h	MXID	MSI-X Capability ID
B2h	B3h	MXC	MSI-X Message Control
B4h	B7h	MTAB	MSI-X Table Offset and Table BIR
B8h	BBh	MPBA	MSI-X PBA Offset and PBA BIR

Table 5-37: MSI-X Identifier Register

Bits	Type	Default Value	Description
15:8	RO	00h	Next Capability
7:0	RO	tbd	Capability ID

Table 5-38: MSI-X Control Register

Bits	Type	Default Value	Description
15	RW	0	MSI-X Enable
14	RW	0	Function Mask
13:11	RsvdP	0	Reserved
10:0	RO	tbd	Table Size

Table 5-39: MSI-X Table Offset Register

Bits	Type	Default Value	Description
31:3	RO	tbd	Table Offset
2:0	RO	0	Table BIR

Table 5-40: MSI-X Pending Bit Array Offset Register

Bits	Type	Default Value	Description
31:3	RO	tbd	Pending Bit Array Offset
2:0	RO	0	Pending Bit Array BIR

5.1.6 PCI Express Capability Registers

Table 5-41: PCI Express Capability Register Summary

Start Address	End Address	Symbol	Description
70h	71h	PXID	PCI Express Capability ID
72h	73h	PXCAP	PCI Express Capabilities
74h	77h	PXDCAP	PCI Express Device Capabilities
78h	79h	PXDC	PCI Express Device Control
7Ah	7Bh	PXDS	PCI Express Device Status
7Ch	7Fh	PXLCAP	PCI Express Link Capabilities
80h	81h	PXLC	PCI Express Link Control
82h	83h	PXLS	PCI Express Link Status
94h	97h	PXDCAP2	PCI Express Device Capabilities 2
98h	99h	PXDC2	PCI Express Device Control 2
9Ah	9Bh	PXDS2	PCI Express Device Status 2
9Ch	9Fh	PXLCAP2	PCI Express Link Capabilities 2
A0h	A1h	PXLC2	PCI Express Link Control 2
A2h	A3h	PXLS2	PCI Express Link Status 2

Table 5-42: PCI Express Capability ID Register

Bits	Type	Default Value	Description
15:8	RO	tbd	Next Pointer (MSI-X Capability)
7:0	RO	tbd	Capability ID

Table 5-43: PCI Express Capabilities Register

Bits	Type	Default Value	Description
15:14	RsvdP	0	Reserved
13:9	RO	0	Interrupt Message Number
8	HwInit	0	N/A
7:4	RO	0	Device/Port Type
3:0	RO	tbd	Capability Version

Table 5-44: PCI Express Device Capabilities Register

Bits	Type	Default Value	Description
31:29	RsvdP	0	Reserved
28	RO	tbd	Function Level Reset Capability
27:26	RO	0	Captured Slot Power Limit Scale
25:18	RO	0	Captured Slot Power Limit Value
17:16	RO	0	Reserved
15	RO	tbd	Role-based Error Reporting
14:12	RO	0	Reserved
11:9	RO	tbd	Endpoint L1 Acceptable Latency
8:6	RO	tbd	Endpoint L0 Acceptable Latency
5	RO	0	Extended Tag Field Supported
4:3	RO	0	Phantom Functions Supported
2:0	RO	0	Max Payload Size Supported (128 byte payload)

Table 5-45: PCI Express Device Control Register

Bits	Type	Default Value	Description
15	RW	0	Initiate Function Level Reset
14:12	RW	tbd	Max Read Request Size
11	RW	tbd	Enable No Snoop
10	RWS	0	Aux Power PM Enable (N/A)
9	RW	0	Phantom Functions Enable (N/A)
8	RW	0	Extended Tag Enable
7:5	RW	0	Max Payload Size
4	RW	tbd	Enable Relaxed Ordering (N/A)
3	RW	0	Unsupported Request Reporting Enable
2	RW	0	Fatal Error Reporting Enable
1	RW	0	Non-Fatal Error Reporting Enable
0	RW	0	Correctable Error Reporting Enable

Table 5-46: PCI Express Device Status Register

Bits	Type	Default Value	Description
15:06	RsvdP	0	Reserved
5	RO	0	Transactions Pending
4	RO	tbd	Aux Power Detected
3	RW1C	0	Unsupported Request Detected
2	RW1C	0	Fatal Error Detected
1	RW1C	0	Non-Fatal Error Detected
0	RW1C	0	Correctable Error Detected

Table 5-47: PCI Express Device Link Capabilities Register

Bits	Type	Default Value	Description
31:24	Hwlnit	0 (Port 0)	Port Number
23	RsvdP	0	Reserved
22	Hwlnit	tbd	ASPM Optionality Compliance
21	RO	0	Link Bandwidth Notification Capability (N/A)
20	RO	0	Data Link Layer Link Active Reporting Capable (N/A)
19	RO	0	Surprise Down Error Reporting Capable (N/A)
18	RO	tbd	Clock Power Management
17:15	RO	tbd	L1 Exit Latency
14:12	RO	tbd	L0s Exit Latency
11:10	RO	0	Active State Power Management Support
9:4	RO	4h (x4 link)	Maximum Link Width
3:0	RO	3h	Supported Link Speeds

Table 5-48: PCI Express Device Link Control Register

Bits	Type	Default Value	Description
15:12	RsvdP	0	Reserved
11	RsvdP	0	Link Autonomous Bandwidth Interrupt Enable
10	RsvdP	0	Link Bandwidth Management Interrupt Enable
9	RsvdP	0	Hardware Autonomous Width Disable
8	RW	0	Enable Clock Power Management (N/A)
7	RW	0	Extended Sync
6	RW	0	Common Clock Configuration
5	RsvdP	0	Retrain Link
4	RsvdP	0	Link Disable
3	Root Ports (RO) End Points & Bridges (RW) Switch Ports (RO)	0	Read Completion Boundary (N/A)
2	RsvdP	0	Reserved
1:00	RW1C	0	Active State Power Management Control

Table 5-49: PCI Express Device Link Status Register

Bits	Type	Default Value	Description
15	RW1C	0h	Link Autonomous Bandwidth Status
14	RW1C	0	Link Bandwidth Management Status
13	RO	0	Data Link Layer Link Active
12	Hwlnit	tbd	Slot Clock Configuration
11	RO	0	Link Training (1: Link training in progress;0: No link training in progress) (Non-standard)
10	RO	0	Reserved
9:4	RO	tbd	Negotiated Link Width
3:0	RO	tbd	Current Link Speed

Table 5-50: PCI Express Device Capabilities 2 Register

Bits	Type	Default Value	Description
31:24	RsvdP	0	Reserved
23:22	Hwlnit	0	Max End-End TLP Prefixes (N/A)
21	Hwlnit	0	End-End TLP Prefix Supported (N/A)
20	RO	0	Extended Format Field Supported (N/A)
19:18	Hwlnit	0	OBFF Supported (N/A)
17:14	RO	0	Reserved
13:12	RO	0	TPH Completer Supported (N/A)
11	RO	tbd	Latency Tolerance Reporting Supported (N/A)
10	Hwlnit	0	No RO-enabled PR-PR Passing (N/A)
9	RO	0	128-bit CAS Completer Supported (N/A)
8	RO	0	64-bit Atomic Op Completer Supported (N/A)
7	RO	0	32-bit Atomic Op Completer Supported (N/A)
6	RO	0	Atomic Op Routing Supported (N/A)
5	RO	0	ARI Forwarding Supported (N/A)
4	RO	tbd	Completion Timeout Disable Supported
3:0	Hwlnit	0	Completion Timeout Ranges Supported (50us to 200ms)

Table 5-51: PCI Express Device Control 2 Register

Bits	Type	Default Value	Description
15	RsvdP	0	End-to-end TLP Prefix Blocking (N/A)
14:13	RW/RsvdP	0	OBFF Enable (N/A)
12:11	RsvdP	0	Reserved
10	RW/RsvdP	0	Latency Tolerance Reporting Mechanism Enable (N/A)
9	RW	0	IDO Completion Enable
8	RW	0	IDO Request Enable
7	RW	0	AtomicOp Egress Blocking
6	RW	0	AtomicOp Requester Enable
5	RW	0	ARI Forwarding Enable
4	RW	0	Completion Timeout Disable
3:0	RW	0	Completion Timeout Value (0h - 50 μ s; 1h - 100 μ s; 2h - 2 ms; 5h - 50 ms; 6h - 200 ms; others - reserved)

Table 5-52: PCI Express Device Status 2 Register

Bits	Type	Default Value	Description
15:0	RsvdZ	0	Reserved

Table 5-53: PCI Express Link Capabilities 2 Register

Bits	Type	Default Value	Description
31:9	RsvdP	0	Reserved
8	RO	0	Cross-Link Supported (N/A)
7:1	RO	tbd	Supported Link Speeds 001b: 2.5 GT/s (Gen 1) 010b: 5.0 GT/s (Gen 2) 100b: 8 GT/s (Gen 3)
0	RsvdP	0	Reserved

Table 5-54: PCI Express Link Control 2 Register

Bits	Type	Default Value	Description
15:12	RWS/RsvdP	0	Compliance De-emphasis
11	RWS/RsvdP	0	Compliance SOS
10	RWS/RsvdP	0	Enter Modified Compliance
9:7	RWS/RsvdP	0	Transmit Margin
6	HwInit	0	Select De-Emphasis
5	RWS/RsvdP	0	Hardware Autonomous Speed Disable
4	RWS/RsvdP	0	Enter Compliance
3:0	RWS/RsvdP	tbd	Target Link Speed 1h: 2.5 GT/s (Gen 1) 2h: 5.0 GT/s (Gen 2) 3h: 8 GT/s (Gen 3)

Table 5-55: PCI Express Link Status 2 Register

Bits	Type	Default Value	Description
15:6	RsvdP	0	Reserved
5	RW1CS	0	Link Equalization Request
4	ROS	0	Equalization Phase 3 Successful
3	ROS	0	Equalization Phase 2 Successful
2	ROS	0	Equalization Phase 1 Successful
1	ROS	0	Equalization Complete
0	RO	tbd	Current De-Emphasis

5.1.7 Advanced Error Reporting Registers

Table 5-56: Advanced Error Reporting Capability Register Summary

Start Address	End Address	Symbol	Description
100h	103h	AERID	AER Capability ID
104h	107h	AERUCES	AER Uncorrectable Error Status
108h	10Bh	AERUCEM	AER Uncorrectable Error Mask
10Ch	10Fh	AERUCESEV	AER Uncorrectable Error Severity
110h	113h	AERCES	AER Correctable Error Status
114h	117h	AERCEM	AER Correctable Error Mask
118h	11Bh	AERCC	AER Advanced Error Capabilities and Control
11Ch	12Bh	AERHL	AER Header Log

Table 5-57: AER Capability ID Register

Bits	Type	Default Value	Description
31:20:00	RO	tbd	Next Pointer (Points to Secondary PCI Express Extended Capability Header Offset)
19:16	RO	tbd	Capability Version
15:00	RO	tbd	Capability ID

Table 5-58: AER Uncorrectable Error Status Register

Bits	Type	Default Value	Description
31:26	RsvdZ	0	Reserved
25	RsvdZ	0	TLP Prefix Blocked Error Status (N/A)
24	RsvdZ	0	Atomic Op Egress Blocked Status (N/A)
23	RsvdZ	0	Reserved
22	RW1CS	0	Uncorrectable Internal Error Status
21	RsvdZ	0	Reserved
20	RW1CS	0	Unsupported Request Error Status
19	RW1CS	0	ECRC Error Status
18	RW1CS	0	Malformed TLP Status
17	RW1CS	0	Receiver Overflow Status (N/A)
16	RW1CS	0	Unexpected Completion Status
15	RW1CS	0	Completer Abort Status
14	RW1CS	0	Completion Timeout Status
13	RW1CS	0	Flow Control Protocol Error Status (N/A)
12	RW1CS	0	Poisoned TLP Status
11:6	RsvdZ	0	Reserved
5	RsvdZ	0	Reserved
4	RW1CS	0	Data Link Protocol Error Status
3:1	RsvdP		Reserved
0	Undefined	0	Undefined

Table 5-59: AER Uncorrectable Error Mask Register

Bits	Type	Default Value	Description
31:26	RsvdZ	0	Reserved
25	RsvdZ	0	TLP Prefix Blocked Error Mask (N/A)
24	RsvdZ	0	Atomic Op Egress Blocked Mask (N/A)
23	RsvdZ	0	MC Blocked TLP Mask (N/A)
22	RWS	tbd	Uncorrectable Internal Error Mask
21	RsvdZ	0	ACS Violation Mask (N/A)
20	RWS	0	Unsupported Request Error Mask
19	RWS	0	ECRC Error Mask
18	RWS	0	Malformed TLP Mask
17	RWS	0	Receiver Overflow Mask (N/A)
16	RWS	0	Unexpected Completion Mask
15	RWS	0	Completer Abort Mask
14	RWS	0	Completion Timeout Mask
13	RWS	0	Flow Control Protocol Error Mask (N/A)
12	RWS	0	Poisoned TLP Mask
11:6	RsvdP	0	Reserved
5	RsvdZ	0	Reserved
4	RWS	0	Data Link Protocol Error Mask
3:1	RsvdP	0	Reserved
0	Undefined	0	Undefined

Table 5-60: AER Uncorrectable Error Severity Register

Bits	Type	Default Value	Description
31:26	RsvdP	0	Reserved
25	RsvdP	0	TLP Prefix Blocked Error Mask (N/A)
24	RsvdP	0	Atomic Op Egress Blocked Mask (N/A)
23	RsvdP	0	Reserved
22	RWS	tbd	Uncorrectable Internal Error Mask
21	RsvdP	0	Reserved
20	RWS	0	Unsupported Request Error Mask
19	RWS	0	ECRC Error Mask
18	RWS	tbd	Malformed TLP Mask
17	RWS	tbd	Receiver Overflow Mask (N/A)
16	RWS	0	Unexpected Completion Mask
15	RWS	0	Completer Abort Mask
14	RWS	0	Completion Timeout Mask
13	RWS	tbd	Flow Control Protocol Error Mask (N/A)
12	RWS	0	Poisoned TLP Mask
11:6	RsvdP	0	Reserved
5	RsvdP	tbd	Reserved
4	RWS	tbd	Data Link Protocol Error Mask
3:1	RsvdP	0	Reserved
0	Undefined	0	Undefined

Table 5-61: AER Correctable Error Status Register

Bits	Type	Default Value	Description
31:16	RsvdZ	0	Reserved
15	RsvdZ	0	Reserved
14	RW1CS	0	Corrected Internal Error Status (N/A)
13	RW1CS	0	Advisory Non-Fatal Error Status
12	RW1CS	0	Replay Timer Timeout Status
11:9	RsvdZ	0	Reserved
8	RW1CS	0	Replay Number Rollover Status
7	RW1CS	0	Bad DLLP Status
6	RW1CS	0	Bad TLP Status
5:1	RsvdZ	0	Reserved
0	RW1CS	0	Received Error Status

Table 5-62: AER Correctable Error Mask Register

Bits	Type	Default Value	Description
31:16	RsvdP	0	Reserved
15	RsvdP	0	Reserved
14	RWS	tbd	Corrected Internal Error Mask (N/A)
13	RWS	tbd	Advisory Non-Fatal Error Mask
12	RWS	0	Replay Timer Timeout Mask
11:9	RsvdP	0	Reserved
8	RWS	0	Replay Number Rollover Mask
7	RWS	0	Bad DLLP Mask
6	RWS	0	Bad TLP Mask
5:1	RsvdP	0	Reserved
0	RW	0	Received Error Mask

Table 5-63: AER Capabilities and Control Register

Bits	Type	Default Value	Description
31:12	RsvdP	0	Reserved
11	RsvdP	0	TLP Prefix Log Present (N/A)
10	RsvdP	0	Reserved
9	RsvdP	0	Reserved
8	RWS	0	ECRC Check Enable
7	RO	tbd	ECRC Check Capable
6	RWS	0	ECRC Generation Enable
5	RO	tbd	ECRC Generation Capable
4:0	ROS	0	First Error Pointer

Table 5-64: AER Header Log Register

Bits	Type	Default Value	Description
0	ROS	0	Header Byte 3
1	ROS	0	Header Byte 2
2	ROS	0	Header Byte 1
3	ROS	0	Header Byte 0
4	ROS	0	Header Byte 7
5	ROS	0	Header Byte 6
6	ROS	0	Header Byte 5
7	ROS	0	Header Byte 4
8	ROS	0	Header Byte 11
9	ROS	0	Header Byte 10
10	ROS	0	Header Byte 9
11	ROS	0	Header Byte 8
12	ROS	0	Header Byte 15
13	ROS	0	Header Byte 14
14	ROS	0	Header Byte 13
15	ROS	0	Header Byte 12

Table 5-65: AER TLP Prefix Log Register

Bits	Type	Default Value	Description
0	RO	0	First TLP Prefix Log Byte 3 (N/A)
1	RO	0	First TLP Prefix Log Byte 2 (N/A)
2	RO	0	First TLP Prefix Log Byte 1 (N/A)
3	RO	0	First TLP Prefix Log Byte 0 (N/A)
4	RO	0	Second TLP Prefix Log Byte 7 (N/A)
5	RO	0	Second TLP Prefix Log Byte 6 (N/A)
6	RO	0	Second TLP Prefix Log Byte 5 (N/A)
7	RO	0	Second TLP Prefix Log Byte 4 (N/A)
8	RO	0	Third TLP Prefix Log Byte 11 (N/A)
9	RO	0	Third TLP Prefix Log Byte 10 (N/A)
10	RO	0	Third TLP Prefix Log Byte 9 (N/A)
11	RO	0	Third TLP Prefix Log Byte 8 (N/A)
12	RO	0	Fourth TLP Prefix Log Byte 15 (N/A)
13	RO	0	Fourth TLP Prefix Log Byte 14 (N/A)
14	RO	0	Fourth TLP Prefix Log Byte 13 (N/A)
15	RO	0	Fourth TLP Prefix Log Byte 12 (N/A)

Table 5-66: Secondary PCI Express Capability Register Summary

Start Address	End Address	Symbol	Description
168h	16Bh	SPXID	Secondary PCI Express Capability
16Ch	16Fh	PXLC3	PCI Express Link Control 3
170h	173h	PXLE	PCI Express Lane Error Status
174h	175h	PXL0EC	PCI Express Lane 0 Equalization Control
176h	177h	PXL1EC	PCI Express Lane 1 Equalization Control
178h	179h	PXL2EC	PCI Express Lane 2 Equalization Control
17Ah	17Bh	PXL3EC	PCI Express Lane 3 Equalization Control

Table 5-67: Secondary PCI Express Capability ID Register

Bits	Type	Default Value	Description
31:20	RO	tbd	Next Pointer (Viking Vendor Specific Capability)
19:16	RO	tbd	Capability Version
15:0	RO	tbd	Capability ID (Secondary PCI Express Extended capability)

Table 5-68: PCI Express Link Control 3 Register

Bits	Type	Default Value	Description
31:2	Rsvdp	0	Reserved
1	Rsvdp	0	Link Equalization Request Interrupt Enable (N/A)
0	Rsvdp	0	Perform Equalization (N/A)

Table 5-69: PCI Express Lane Error Status Register

Bits	Type	Default Value	Description
31:4	Rsvdp	0	Reserved
3:0	RW1CS	0	Lane Error Status Bits

Table 5-70: PCI Express Lane 0 Equalization Register

Bits	Type	Default Value	Description
15	RsvdP	0	Reserved
14:12	Hwlnit/RO	tbd	Upstream Port Receiver Preset Hint
11:8	Hwlnit/RO	tbd	Upstream Port Transmitter Preset
7	RsvdP	0	Reserved
6:4	Hwlnit/RsvdP	0	Downstream Port Receiver Preset Hint (N/A)
3:0	Hwlnit/RsvdP	0	Downstream Port Transmitter Preset (N/A)

Table 5-71: PCI Express Lane 1 Equalization Register

Bits	Type	Default Value	Description
15	RsvdP	0	Reserved
14:12	Hwlnit/RO	tbd	Upstream Port Receiver Preset Hint
11:8	Hwlnit/RO	tbd	Upstream Port Transmitter Preset
7	RsvdP	0	Reserved
6:4	Hwlnit/RsvdP	0	Downstream Port Receiver Preset Hint (N/A)
3:0	Hwlnit/RsvdP	0	Downstream Port Transmitter Preset (N/A)

Table 5-72: PCI Express Lane 2 Equalization Register

Bits	Type	Default Value	Description
15	RsvdP	0	Reserved
14:12	Hwlnit/RO	tbd	Upstream Port Receiver Preset Hint
11:8	Hwlnit/RO	tbd	Upstream Port Transmitter Preset
7	RsvdP	0	Reserved
6:4	Hwlnit/RsvdP	0	Downstream Port Receiver Preset Hint (N/A)
3:0	Hwlnit/RsvdP	0	Downstream Port Transmitter Preset (N/A)

Table 5-73: PCI Express Lane 3 Equalization Register

Bits	Type	Default Value	Description
15	RsvdP	0	Reserved
14:12	Hwlnit/RO	tbd	Upstream Port Receiver Preset Hint
11:8	Hwlnit/RO	tbd	Upstream Port Transmitter Preset
7	RsvdP	0	Reserved
6:4	Hwlnit/RsvdP	0	Downstream Port Receiver Preset Hint (N/A)
3:0	Hwlnit/RsvdP	0	Downstream Port Transmitter Preset (N/A)

5.1.8 Device Serial Number Capability Register

Table 5-74: Device Serial Number Capability Register Header

Bits	Type	Default Value	Description
31:20	RO	tbd	Next Capability Offset
19:16	RO	tbd	Capability Version
15:0	RO	tbd	PCI Express Extended Capability ID

Table 5-75: Serial Number Register Header (offset 0x4/0x8)

Bits	Type	Default Value	Description
31:0	RO	parameter	Serial Number register (1st dword)

5.1.9 Power Budgeting Extended Capability

Table 5-76: Power Budgeting Extended Capability Header

Bits	Type	Default Value	Description
31:20	RO	tbd	Next Capability Offset
19:16	RO	tbd	Capability Version
15:0	RO	tbd	PCI Express Extended Capability ID

Table 5-77: Data Register

Bits	Type	Default Value	Description
31:21	RsvdP	0	Reserved
20:18	RO	0	Power Rail
17:15	RO	0	Type
14:13	RO	0	PM State
12:10	RO	0	PM Sub State
9:8	RO	0	Data Scale
7:0	RO	0	Base Power

Table 5-78: Power Budget Capability Register

Bits	Type	Default Value	Description
7:1	RsvdP	0	Reserved
0	Hwlnit	0	System Allocated

5.1.10 Latency Tolerance Reporting Capability Registers

Table 5-79: LTR Extended Capability Header

Bits	Type	Default Value	Description
31:20	RO	tbd	Next Capability Offset
19:16	RO	tbd	Capability Version
15:0	RO	tbd	PCI Express Extended Capability ID

Table 5-80: LTR Max Snoop latency Register

Bits	Type	Default Value	Description
15:13	RsvdP	0	Reserved
12:10	RW	0	Max Snoop latency Scale
9:0	RW	0	Max Snoop latency Value

Table 5-81: LTR Max No Snoop latency Register

Bits	Type	Default Value	Description
15:13	RsvdP	0	Reserved
12:10	RW	0	Max No Snoop latency Scale
9:0	RW	0	Max No Snoop latency Value

5.1.11 L1 Substates Capability Registers

Table 5-82: L1 Substates Extended Capability Header

Bits	Type	Default Value	Description
31:20	RO	0	Next Capability Offset
19:16	RO	tbd	Capability Version
15:0	RO	tbd	PCI Express Extended Capability ID

Table 5-83: L1 Substates Capability Register

Bits	Type	Default Value	Description
31:24	RsvdP	0	Reserved
23:19	Hwlnit	tbd	Port Power on value
18	RsvdP	0	Reserved
17:16	Hwlnit	0	Port T_Power_on scale
15:8	Hwlnit	tbd	Port Common_mode_restore_time
7:5	RsvdP	0	Reserved
4	Hwlnit	0	L1 PM Substates Supported
3	Hwlnit	0	ASPM PM L1.1 Supported
2	Hwlnit	0	ASPM PM L1.2 Supported
1	Hwlnit	0	PCI PM L1.1 Supported
0	Hwlnit	0	PCI PM L1.2 Supported

Table 5-84: L1 Substates Control1 Register

Bits	Type	Default Value	Description
31:29	RW	0	LTR L1.2 Threshold Scale
28:26	RsvdP	0	Reserved
25:16	RW	0	LTR L1.2 Threshold value
15:8	RsvdP	0	Common_mode_restore_time
7:4	RsvdP	0	Reserved
3	RW	0	ASPM PM L1.1 Supported
2	RW	0	ASPM PM L1.2 Supported
1	RW	0	PCI PM L1.1 Supported
0	RW	0	PCI PM L1.2 Supported

Table 5-85: L1 Substates Control2 Register

Bits	Type	Default Value	Description
31:8	RsvdP	0	Reserved
7:3	RW	tbd	T_POWER_ON Value
2	RsvdP	0	Reserved
1:0	RW	0	T_POWER_ON Scale

5.2 NVM Express Registers

5.2.1 Register Summary

Table 5-86: Register Summary

Start Address	End Address	Symbol	Description
00h	07h	CAP	Controller Capabilities
08h	0Bh	VS	Version
0Ch	0Fh	INTMS	Interrupt Mask Set
10h	13h	INTMC	Interrupt Mask Clear
14h	17h	CC	Controller Configuration
18h	1Bh	Reserved	Reserved
1Ch	1Fh	CSTS	Controller Status
20h	23h	Reserved	Reserved
24h	27h	AQA	Admin Queue Attributes
28h	2Fh	ASQ	Admin Submission Queue Base Address
30h	37h	ACQ	Admin Completion Queue Base Address
38h	EFFh	Reserved	Reserved
F00h	FFFh	Reserved	Command Set Specific
1000h	1003h	SQ0TDBL	Submission Queue 0 Tail Doorbell (Admin)
1000h + (1 * (4 << CAP.DSTRD))	1003h + (1 * (4 << CAP.DSTRD))	CQ0HDBL	Completion Queue 0 Head Doorbell (Admin)
1000h + (2y * (4 << CAP.DSTRD))	1003h + (2y * (4 << CAP.DSTRD))	SQyTDVL	Submission Queue y Tail Doorbell
1000h + ((2y + 1) * (4 << CAP.DSTRD))	1003h + ((2y + 1) * (4 << CAP.DSTRD))	CQyHDBL	Completion Queue y Head Doorbell

5.2.2 Controller Registers

Table 5-87: Controller Capabilities

Bits	Type	Name	Default Value	Description
63:56:00	RO		0h	Reserved
55:52:00	RO	MPSMAX	tbd	Memory Page Size Maximum (Maximum is 8KB)
51:48:00	RO	MPSMIN	0	Memory Page Size Minimum (Minimum is 4KB)
47:45:00	RO		0	Reserved
				Command Sets Supported
44:37:00	RO	CSS	tbd	1h: NVM command set
36	RO		0	Reserved
				Doorbell Stride
35:32:00	RO	DSTRD	0	0: Stride of 4 bytes
				Timeout
31:24:00	RO	TO	tbd	4h: 2 seconds
23:19	RO		0	Reserved
				Arbitration Mechanism Supported
18:17	RO	AMS	0	(Only support round robin)
16	RO	CQR	tbd	Contiguous Queues Required
				Maximum Queue Entries Supported
15:00	RO	MQES	tbd	(16384 entries supported)

Table 5-88: Version

Bits	Type	Name	Default Value	Description
31:16	RO	MJR	tbd	Major Version Number
15:0	RO	MNR	tbd	Minor Version Number

Table 5-89: Interrupt Mask Set

Bits	Type	Name	Default Value	Description
31:00	RW1S	IVMS	0	Interrupt Vector Mask Set

Table 5-90: Interrupt Mask Clear

Bits	Type	Name	Default Value	Description
31:00	RW1C	IVMC	0	Interrupt Vector Mask Clear

Table 5-91: Controller Configuration

Bits	Type	Name	Default Value	Description
31:24	RO	-	0	Reserved
23:20	RW	IOCQES	0	I/O Completion Queue Entry Size (Configured as a power of 2) (Should be set to 4 for a 16 byte entry size)
19:16	RW	IOSQES	0	I/O Submission Queue Entry Size (Configured as a power of 2) (Should be set to 6 for a 64 byte entry size)
15:14	RW	SHN	0	Shutdown Notification 0h: No notification 1h: Normal shutdown notification 2h: Abrupt shutdown notification 3h: Reserved CSTS.SHST indicates shutdown status.
13:11	RW	AMS	0	Arbitration Mechanism Selected 0h: Round Robin No other values supported.
10:7	RW	MPS	0	Memory Page Size MPS is $2^{(12+MPS)}$ Shall be within CAP.MPSMAX and CAP.MPSMIN ranges.
6:4	RW	CSS	0	Command Set Selected 0h: NVM Command Set No other values supported
3:1	RO	-	0	Reserved
0	RW	EN	0	Enable When set to 1, controller shall process commands. When cleared to 0, controller shall not process commands. This field is subject to CSTS.RDY and CAP.TO restrictions.

Table 5-92: Controller Status

Bits	Type	Name	Default Value	Description
31:4	RO	-	0	Reserved
3:2	RO	SHST	0	Shutdown Status 0h: Normal operation, no shutdown requested 1h: Shutdown processing occurring 2h: Shutdown processing complete 3h: Reserved
1	RO	CFS	0	Controller Fatal Status
0	RO	RDY	0	1h: Controller ready to process commands 0h: Controller shall not process commands.

Table 5-93: Admin Queue Attributes

Bits	Type	Name	Default Value	Description
31:28	RO	-	0	Reserved
27:16	RW	ACQS	0	Admin Completion Queue Size Max: 4096 (Value of 4095h - 0's based value)
15:12	RO	-	0	Reserved
11:0	RW	ASQS	0	Admin Submission Queue Size Max: 4096 (Value of 4095h - 0's based value)

Table 5-94: Admin Submission Queue Base Address

Bits	Type	Name	Default Value	Description
63:12	RW	ASQB	0	Admin Submission Queue Base Address
11:0	RO	-	0	Reserved

Table 5-95: Admin Completion Queue Base Address

Bits	Type	Name	Default Value	Description
63:12	RW	ACQB	0	Admin Completion Queue Base Address
11:0	RO	-	0	Reserved

Table 5-96: Submission Queue Tail y Doorbell

Bits	Type	Name	Default Value	Description
31:16	RO		0	Reserved
15:0	RW	SQT	0	Submission Queue Tail

Table 5-97: Completion Queue Head y Doorbell

Bits	Type	Name	Default Value	Description
31:16	RO		0	Reserved
15:0	RW	CQH	0	Completion Queue Head

6 Supported Command Set

6.1 Admin Command Set

Table 6-1: Opcode for Admin Commands

Opcode (Hex)	Command Name
00h	Delete I/O Submission Queue
01h	Create I/O Submission Queue
02h	Get Log Page
04h	Delete I/O Completion Queue
05h	Create I/O Completion Queue
06h	Identify
08h	Abort
09h	Set Feature
0Ah	Get Feature
0Ch	Asynchronous Event Request
10h	Firmware Activate
11h	Firmware Image Download
80h – BFh	Not used (I/O Command Set Specific)
C0h – FFh	Not used (Vendor Specific)

Table 6-2: Admin Commands –NVM Command Set Specific

Opcode (Hex)	Command Name
80h	Format NVM
81h	Security Send
82h	Security Recieve

6.1.1 Identify Command

Table 6-3: Identify Controller Data Structure

Bytes	O/M	Default Value	Description
1:00	M	tbd	PCI Vendor ID
3:02	M	tbd	PCI Subsystem Vendor ID
23:04	M	tbd	Serial Number (ASCII), #:Variables
63:24:00	M	(see Viking PN table)	Model Number (ASCII)
71:64	M	tbd	Firmware Revision, #:Variables
72	M	tbd	Recommended Arbitration Burst
75:73	M	tbd	IEEE OUI
76	O	tbd	Controller Multi-Path I/O and Namespace Sharing Bit 2: 1h - Controller is associated with an SR-IOV Virtual Function 0h - Controller is associated with a PCI Function. Bit 1: 1h - Device has Two or More controller 0h - Device has One Controller Bit 0: 1h - Device has Two or More physical PCI Express ports 0h - Device has One PCI Express port
77	M	tbd	Maximum Data Transfer Size Bit 0: 1h - Supported (dual port – future value) 0h - Not Support (Single Port) Maximum Data Transfer Size (MDTS)
79:78	M	tbd	Controller ID (CNTLID)
255:80		tbd	Reserved
257:256	M	tbd	Optional Admin Command Support Bits 15:3 - Reserved Bit 3: 1h - Namespace Management and Namespace Attachment Commands Supported (PM953 conditionally supports the Namespace Management and Namespace Attachment command(NVMe v1.2 specification for reconfigurable overprovisioning) Bit 2: 1h – Firmware Activate/Download Supported Bit 1: 1h Format NVM Supported Bit 0: 0 Security Send and Security Receive Not Supported
258	M	tbd	Abort Command Limit (Maximum number of concurrently outstanding Abort commands) (0's based value)
259	M	tbd	Asynchronous Event Request Limit (Maximum number of concurrently outstanding Asynchronous Event Request commands) (0's based value)
260	M	tbd	Firmware Updates Bits 7:4 – Reserved Bits 3:1 – Number of firmware slots Bit 0 – 1h Slot 1 is read only
261	M	tbd	Log Page Attributes Bits 7:1 – Reserved Bit 0: 0h SMART data is global for all namespaces
262	M	tbd	Error Log Page Entries (Number of Error Information log entries stored by controller) (0's based value)
263	M	tbd	Number of Power States Support (0's based value)

Bytes	O/M	Default Value	Description
264	M	tbd	Admin Vendor Specific Command Configuration Bits 7:1 – reserved Bit 0 – Indicates Admin Vendor Specific Commands use the format defined in NVM Express 1.0c Figure 8.
265	O	tbd	Autonomous Power State Transition Attributes (APSTA)
511:266	-	-	Reserved
512	M	tbd	Submission Queue Entry Size Bits 7:4 – 6h Max SQES (64 bytes) Bits 3:0 – 6h Required SQES (64 bytes)
513	M	tbd	Completion Queue Entry Size Bits 7:4 – 4h Max SQES (16 bytes) Bits 3:0 – 4h Required SQES (16 bytes)
515:514		tbd	Reserved
519:516	M	tbd	Number of Namespaces
521:520	M	tbd	Optional NVM Command Support Bits 15:6 – Reserved Bit 5 – 1h Reservations Supported 0h Not support Reservations Bit 4 – 1h Save field in Set Feature & Select field in Get Feature Supported 0h Not support Save field in Set Feature & Select field in Get Feature Bit 3 – 1h Write Zeros Supported 0h Not support Write Zeros Bit 2 – 1h Dataset Management Supported 0h Not support Dataset Management Bit 1 – 1h Write Uncorrectable Supported 0h Not support Write Uncorrectable Bit 0 – 1h Compare Supported 0h Not support Compare
523:522	M	tbd	Fused Operation Support Bits 15:1 – Reserved Bit 0 – 0h Compare/Write Fused Operation Not Supported
524	M	tbd	Format NVM Attributes Bits 7:3 – Reserved Bit 2 – 1h Cryptographic Erase Bit 1 – 1h Secure Erase Per Namespace Bit 0 – 0h Format Per Namespace
525	M	tbd	Volatile Write Cache 0h – No VWC present
527:526	M	tbd	Atomic Write Unit Normal
529:528	M	tbd	Atomic Write Unit Power Fail (0's based value)
530	M	tbd	NVM Vendor Specific Command Configuration Bits 7:1 – reserved Bit 0 – Indicates NVM Vendor Specific Commands use the format defined in NVM Express 1.1.a
531	M	tbd	Reserved
533:532	O	tbd	ACWU
534:533	M	tbd	Reserved
539:536	O	tbd	No SGL support
703:540	-	tbd	Reserved
I/O Command Set Attributes			
2047:704	-	tbd	Reserved
Power State Descriptors			

Bytes	O/M	Default Value	Description
2079:2048	M	refer to 'Identify Power State Descriptor Data Structure'	Power State 0 Descriptor
2111:2080	O	tbd	N/A
2143:2112	O	tbd	N/A
...	-	tbd	N/A
3071:3040	O	tbd	Power State 31 Descriptor (N/A)
Vendor Specific			
4095:3072	-	-	Viking Reserved

Table 6-4: Identify Power State Descriptor Data Structure

Bits	Power State 0	Description
255:125	0h	Reserved
124:120	0h	Relative Write Latency
119:117	0h	Reserved
116:112	0h	RelativeWriteThroughput
111:109	0h	Reserved
108:104	0h	RelativeReadLatency
103:101	0h	Reserved
100:96	0h	RelativeReadThroughput
95:64	5h	Exit Latency
63:32:00	5h	(QWUVDWHQF\ ___XV__
31:26:00	0h	Reserved
25	0h	Non-Operational State
24	0h	Max Power Scale
23:16	0h	Reserved
15:00	384h	Maximum Power

Table 6-5: Identify Namespace Data Structure

Bytes	O/M	Default Value		Description
7:00	M		tbd	Namespace Size
15:88	M	120 240 480	Byte[7:0] DF94BB0h 1BF244B0h 37E436B0h	Namespace Capacity
23:16	M		-	Namespace Utilization A device may report Namespace Utilization equal to Namespace Capacity at all times if the product is not targeted for thin provisioning environments
24	M		tbd	Namespace Features Bits 7:1 Reserved Bit 0: Thin provisioning not supported
25	M		tbd	Number of LBA Formats
26	M		tbd	Formatted LBA Size Bits 7:5 – Reserved Bit 4: Metadata interleaved or separate (based on LBA format) Bit 3:0 – Indicates LBA format
27	M		tbd	Metadata Capabilities Bits 7:2 – Reserved Bit 1 – Supports Metadata as separate buffer Bit 0 – Supports Metadata as extended LBA
28	M		tbd	End-to-end Data Protection Capabilities Bits 7:5 – Reserved Bit 4 – Supports protection information as last 8 bytes of Metadata Bit 3 – Supports protection information as first 8 bytes of metadata Bit 2 – Supports Type 3 protection information Bit 1 – Supports Type 2 protection information Bit 0 – Supports Type 1 protection information
29	M		tbd	End-to-End Data Protection Type Settings Bits 7:4 – Reserved Bit 3 – 1: Protection information transferred as first 8 bytes of metadata Bit 3 – 0: Protection information transferred as last 8 bytes of metadata Bit 2:0 – 000b: Protection information disabled Bit 2:0 – 1h: Protection type 1 enabled Bit 2:0 – 2h: Protection type 2 enabled Bit 2:0 – 3h: Protection type 3 enabled
30	O		tbd	Namespace Multi-path I/O and Namespace sharing Capabilities (NMIC) Bits 7:1 - Reserved Bit 0 - 1 : Accessible by two or more controllers Bit 0 - 0 : Private namespace
31	O		tbd	Reservation Capabilities (RESCAP) Bits 7 - Reserved Bits 6 - 1: Namespace supports the Exclusive Access (All Registrants reservation type) Bit 5 - 1 : Namespace supports the Write Exclusive (All Registrants reservation type) Bit 4 - 1 : Namespace supports the Exclusive Access (Registrants only reservation type) Bit 3 - 1 : Namespace supports the Write Exclusive (Registrants only reservation type) Bit 2 - 1 : Namespace supports the Exclusive Access Reservation type Bit 1 - 1 : Namespace supports the Write Exclusive Reservation type Bit 0 - 1 : Namespace supports the Persist Through Power Loss capability
119:32	-		tbd	Reserved
127:120	M		tbd	IEEE Extended Unique Identifier(EUI64) #:Variables
131:128	M		refer to 'LBA Format 0 Data Structure'	LBA Format 0 Support
135:132	O		tbd	LBA Format 1 Support
139:136	O		tbd	LBA Format 2 Support

Bytes	O/M	Default Value	Description
143:140	O	tbd	LBA Format 3 Support
147:144	O	tbd	LBA Format 4 Support (N/A)
...			
191:188	O	tbd	LBA Format 15 Support (N/A)
383:192	-	tbd	Reserved
Vendor Specific			
4095:384		-	Viking Reserved

Table 6-6: LBA Format 0 Data Structure

Bits	Name	Default Value	Description
31:26:00		0	Reserved
25:24:00	RP	0	Relative Performance
23:16	LBADS	tbd	LBA Data Size
15:00	MS	0	Metadata Size

6.2 NVM Express I/O Command Set

Table 6-7: Opcode for NVM Express I/O Commands

Opcode (Hex)	Command Name
00h	Flush
01h	Write
02h	Read
04h	Write Uncorrectable
05h	Compare
08h	Write Zeroes
09h	Dataset Management

6.3 SMART/Health Information

Table 6-8: SMART/Health Information Log

Bytes	Default Value	Attribute Description
0	0	Critical Warning Bit 7:5 – Reserved Bit 4 – 1h: the available spare space has fallen below the threshold Bit 3 – 1h: the temperature has exceeded a critical threshold Bit 2 – 1h: the device reliability has been degraded due to significant media related errors or any internal error that degrades device reliability Bit 1 – 1h: the media has been placed in read only mode Bit 0 – 1h: the volatile memory backup device has failed. (only valid if the controller has a volatile memory backup solution)
2:01	current temp	Temperature
3	tbd	Available Spare
4	tbd	Available Spare Threshold
5	0	Percentage Used
31:06:00	-	Reserved
47:32:00	0	Data Units Read
63:48:00	0	Data Units Written
79:64	0	Host Read Commands
95:80	0	Host Write Commands
111:96	0	Controller Busy Time
127:112	0	Power Cycles
143:128	0	Power On Hours
159:144	0	8QVDIH_6KXWGRZQV
175:160	0	Media Errors
191:176	0	Number of Error Information Log Entries

7 References

- PCI Express M.2 Specification, Revision 1.0
- PCI Express Base Specification Rev. 3.0
- NVM Express Specification Rev.1.2