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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
3/10/17	A	Initial Release. Revised based on PSFEM6XXXGSXXX_D with new PN's performance, block diagram, TBW, power consumption. Add VPFEM6030GZCDMTL. Add Industrial Temperature PN's	
3/13/17	B	Add VPFEM6030GZCDMTL.	
3/21/17	C	Add Industrial Temperature PN's. Revise note 2 on Extended SMART Attribute Actual Data table. Add 8GB and 16GB info. Add section on Flash Management	
5/18/17	D	Add PN's VPFEM5008GZCWMTL and VPFEM5016GZCDMTL. Remove I.T. from page1. Add 8GB LBA	
7/24/17	E	Add IOPS and MB/s performance based on IOMETER06	

Legal Information

viking TECHNOLOGY

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

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

Notes:
- Refer to Product Specifications for Capacity and LBA count
- Lower case “x” is the NAND device code

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

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1 Introduction

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

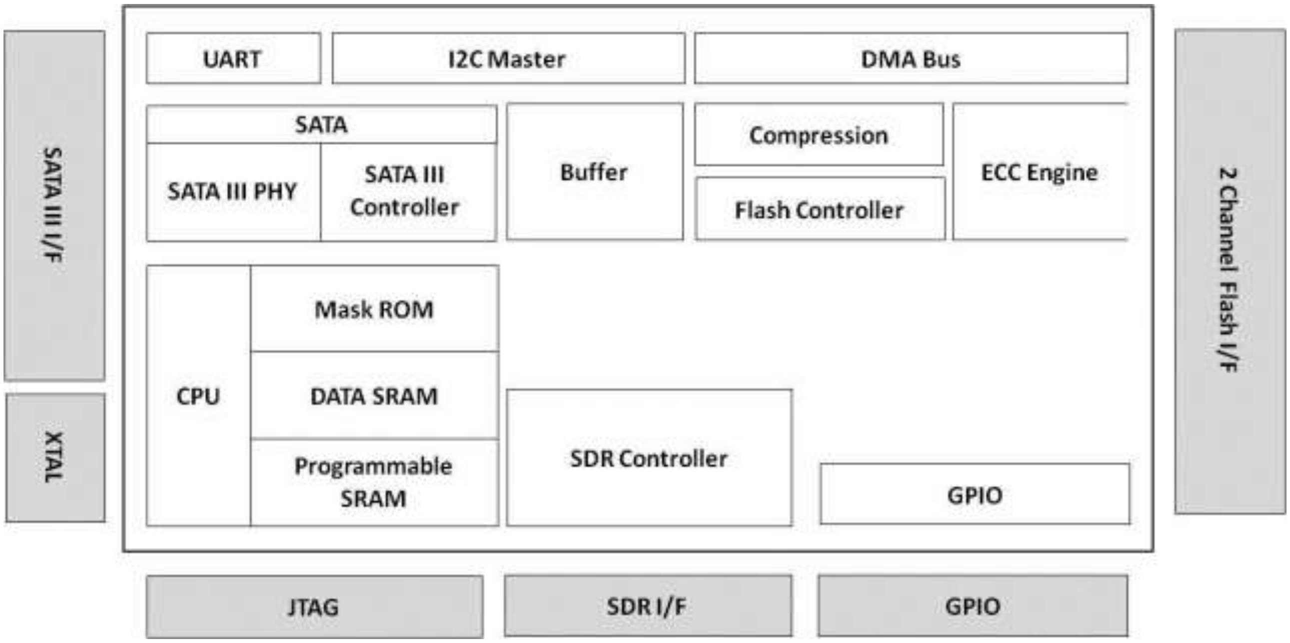
1.1 Features

The SSD delivers the following features:

- Offers seamless SATA Revision 3.0 interface support for SATA up to 6Gb/s
- Low overall SSD power consumption
- Supports Native Command Queuing (NCQ) to 32 commands
- Compatible with all major SLC and MLC flash technologies
- S.M.A.R.T.
- Superior wear-leveling algorithm
- Efficient error recovery
- Compliant with ONFI 4.0 interface:
  - SDR up to mode 5
  - NV-DDR up to mode 5
  - NV-DDR2 up to mode 7
  - NV-DDR3 up to mode 8

1.2 Block Diagram

Figure 1-1: High-Level Block Diagram



Notes:

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

1.3 SATA Interface

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

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

2 Product Specifications

2.1 Capacity and LBA count

Raw Capacity (GB)	User Capacity (GB)	LBA Count
8	8	15,649,200
16	14	27,370,224
16	16	31,277,232
32	30	58,626,288
32	32	62,533,296
64	60	117,231,408
64	64	125,045,424
128	120	234,441,648
128	128	250,069,680
256	240	468,862,128
256	256	500,118,192
512	480	937,703,088
512	512	1,000,215,216

Notes:

1. Per www.idema.org, LBA1-03 spec,
   LBA counts = (97,696,368) + (1,953,504 * (Advertised Capacity in GBytes – 50))
2. GB capacities based on power of 10, GiB capacities are based on powers of 2

2.2 Performance

Table 2-1: Maximum Sustained Read and Write Bandwidth

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

Notes:
1. Performance measured using CrystalDiskMark.
2. Performance may vary from flash configuration, SDR configuration, and platform.
3. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.
4. Data is based on SSD's using Toshiba A15nm Toggle NAND devices
5. L95A data not currently available

Table 2-2: Sequential Read and Write Bandwidth (Iometer 06)

Capacity	Flash Type	Read MB/s (256K)	Write MB/s (256K)
8GB	15nm	537[1]	366[1]
16GB	15nm	537[1]	366[1]
32GB	15nm	537[1]	366[1]
64GB	15nm	537[1]	366[1]
128GB	15nm	537[1]	366[1]
256GB	15nm	537	366
512GB	15nm	537[1]	366[1]

Notes:
1. Estimated Performance measured using Iometer 06 with queue depth set to 32.
2. Write Cache enabled with DDR cache.
3. Tested with VPFEM5256GZIAMTL (Toshiba MLC L die)

Table 2-3: Random Read/ Write Input/Output Operations per Second (IOPS) (Iometer 06)

Capacity	Flash Type	Random Read IOPS (4K)	Random Write IOPS (4K)
8GB	15nm	14200[1]	1100[1]
16GB	15nm	14200[1]	1100[1]
32GB	15nm	14200[1]	1100[1]
64GB	15nm	14200[1]	1100[1]
128GB	15nm	14200[1]	1100[1]
256GB	15nm	14200	1100
512GB	15nm	14200[1]	1100[1]

Notes:

1. Estimated Performance measured using Iometer 06 with queue depth set to 32.
2. Write Cache enabled with DDR cache.
3. Tested with VPFEM5256GZIAMTL (Toshiba MLC L die)
4. 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).
5. Performance may vary by NAND type and host.
6. Refer to Application Note AN0006 for Viking SSD Benchmarking Methodology.
7. Data is based on SSD's using Toshiba A15nm NAND devices
8. L95A data not currently available

2.3 Timing

Table 2-4: Timing Specifications

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

Notes:

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

2.3.1 STANDBY IMMEDIATE Command

The Power-On-to-Ready time assumes a proper shutdown (power removal preceded by STANDBY IMMEDIATE command. A STANDBY IMMEDIATE before power down always performs a graceful shutdown and does not require the use of the hold-up circuit. Note that SMART attribute 174 "Unexpected Power Loss" records the number of non-graceful power cycle events.

Table 2-5: STANDBY IMMEDIATE Timing

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

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

2.4 Flash Management

2.4.1 Error Correction Code (ECC)

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

2.4.2 Wear Leveling

NAND flash devices can only undergo a limited number of program/erase cycles, and in most cases, the flash media are not used evenly. If some areas get updated more frequently than others, the lifetime of the device would be reduced significantly. Thus, Wear Leveling is applied to extend the lifespan of NAND flash by evenly distributing write and erase cycles across the media.
Viking SSDs provides advanced Wear Leveling algorithm, which can efficiently spread out the flash usage through the whole flash media area. Moreover, by implementing both dynamic and static Wear Leveling algorithms, the life expectancy of the NAND flash is greatly improved.

2.4.3 Bad Block Management

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

2.4.4 TRIM

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

2.4.5 SMART

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

2.4.6 Over-Provision

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

2.4.7 Firmware Upgrade

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

2.5 Low Power Management

2.5.1 DEVSLP Mode (Optional)

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

2.5.2 DIPM/HIPM Mode

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

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

Power Loss Protection is a mechanism to prevent data loss during unexpected power failure. DRAM is a volatile memory and frequently used as temporary cache or buffer between the controller and the NAND flash to improve the SSD performance. However, one major concern of the DRAM is that it is not able to keep data during power failure. Accordingly, the SSD requests the controller to transfer data to the cache. SDR performs as a cache, and its size is 32MB. Only when the data is fully committed to the NAND flash will the controller send acknowledgement (ACK) to the host. Such implementation can prevent false-positive performance and the risk of power cycling issues.
Additionally, it is critical for a controller to shorten the time the in-flight data stays in the cache. Thus, the Viking SSD applies an algorithm to reduce the amount of data resides in the cache to provide a better performance. This technology allows incoming data to only have a “pit stop” in the cache and then move to the NAND flash at once. If the flash is jammed due to particular file sizes (such as random 4KB data), the cache will be treated as an “organizer”, consolidating incoming data into groups before written into the flash to improve write amplification. In summary, provide the reliability required by consumer, industrial, and enterprise-level applications.

2.7 Advanced Device Security Features

2.7.1 Secure Erase

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

2.7.2 Write Protect

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

2.8 SSD Lifetime Management

2.8.1 Terabytes Written (TBW)

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

TBW = [(NAND Endurance) x (SSD Capacity) x (WLE)] / WAF

NAND Endurance: Refers to the P/E (Program/Erase) cycle of a NAND flash.
SSD Capacity: The SSD capacity is the specific capacity in total of a SSD.
WLE: Wear Leveling Efficiency (WLE) ratio of the average #of erases on all the blocks to the erases on any block at maximum.
WAF: Write Amplification Factor (WAF) is a numerical value representing the ratio between the amount of data that a SSD controller needs to write and the amount of data that the host's flash controller writes. A better WAF, which is near 1, guarantees better endurance and lower frequency of data written to flash memory.

2.8.2 Thermal Monitor (Optional)

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

2.9 An Adaptive Approach to Performance Tuning

2.9.1 Throughput

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

2.9.2 Predict & Fetch

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

2.9.3 Compression

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

2.10 Electrical Characteristics

2.10.1 Absolute Maximum Ratings

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

Table 2-6: Absolute Maximum Ratings

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

2.10.2 Supply Voltage

The operating voltage is 3.3V

Table 2-7: Operating Voltage

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

2.10.3 Power Consumption

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

Table 2-8: Typical Power Consumption at 3.3V

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

Notes:

1. Measured using Toshiba A15 Toggle MLC NAND

2.11 Environmental Conditions

2.11.1 Temperature and Altitude

Table 2-9: Temperature and Altitude Related Specifications

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

2.11.2 Shock and Vibration

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

Table 2-10: Shock and Vibration Specifications

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

2.11.3 Electromagnetic Immunity

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

2.12 Reliability

Table 2-11: Reliability Specifications

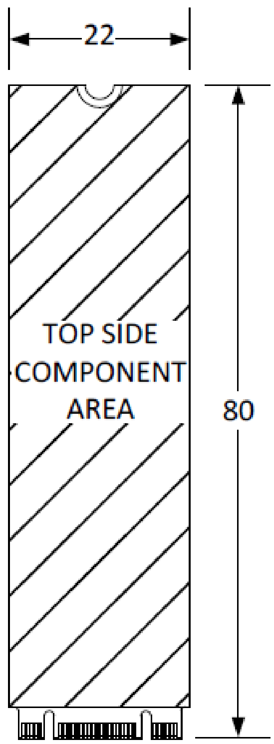
Parameter	Description						
MTBF	Over 2,000,000 hours						
ECC	72-bit per 1KByte						
Read Endurance	Unlimited						
Write Endurance	**8GB**	**16GB**	**32GB**	**64GB**	**128GB**	**256GB**	**512GB**
	12 TBW	23 TBW	45 TBW	90 TBW	181 TBW	262 TBW	544 TBW
Data retention	> 90 days at NAND expiration						

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

3 Mechanical Information

3.1 Dimensions

Figure 3-1: Dimensions

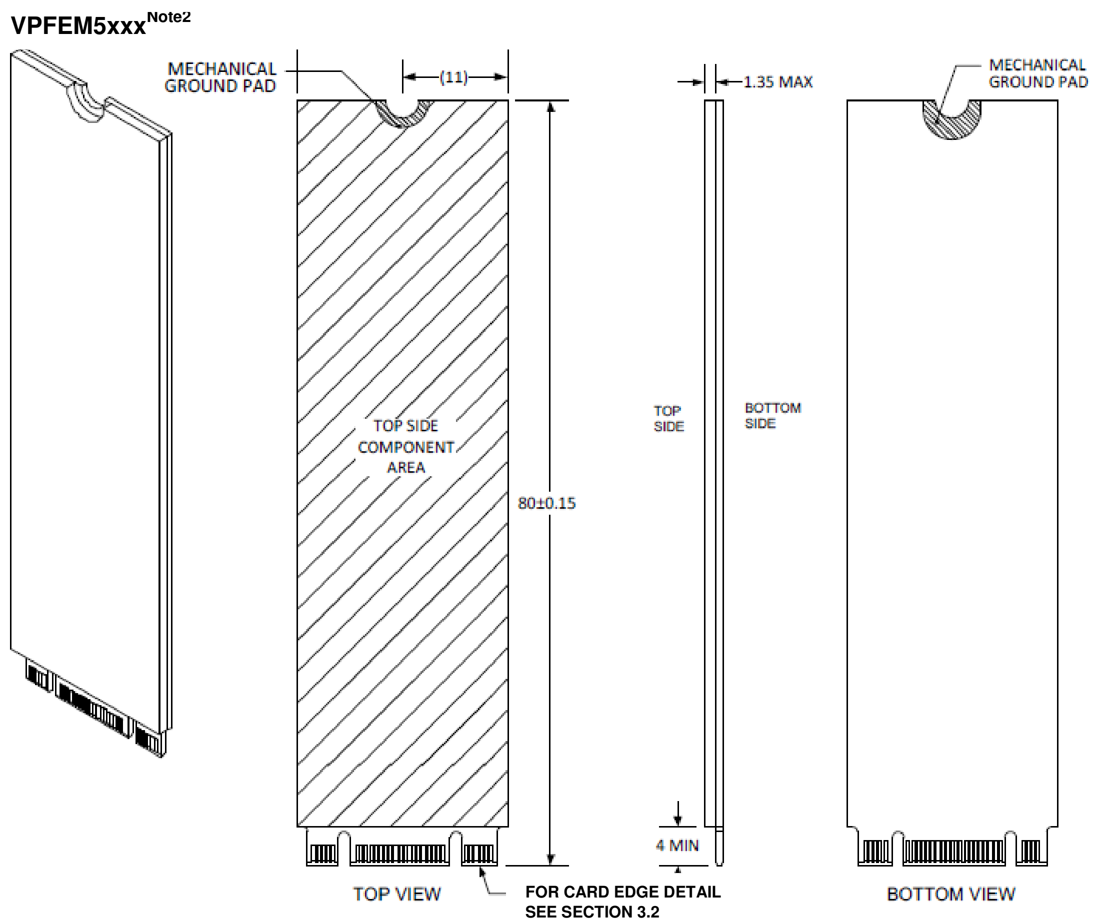


VPFEM5xxx Note2

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

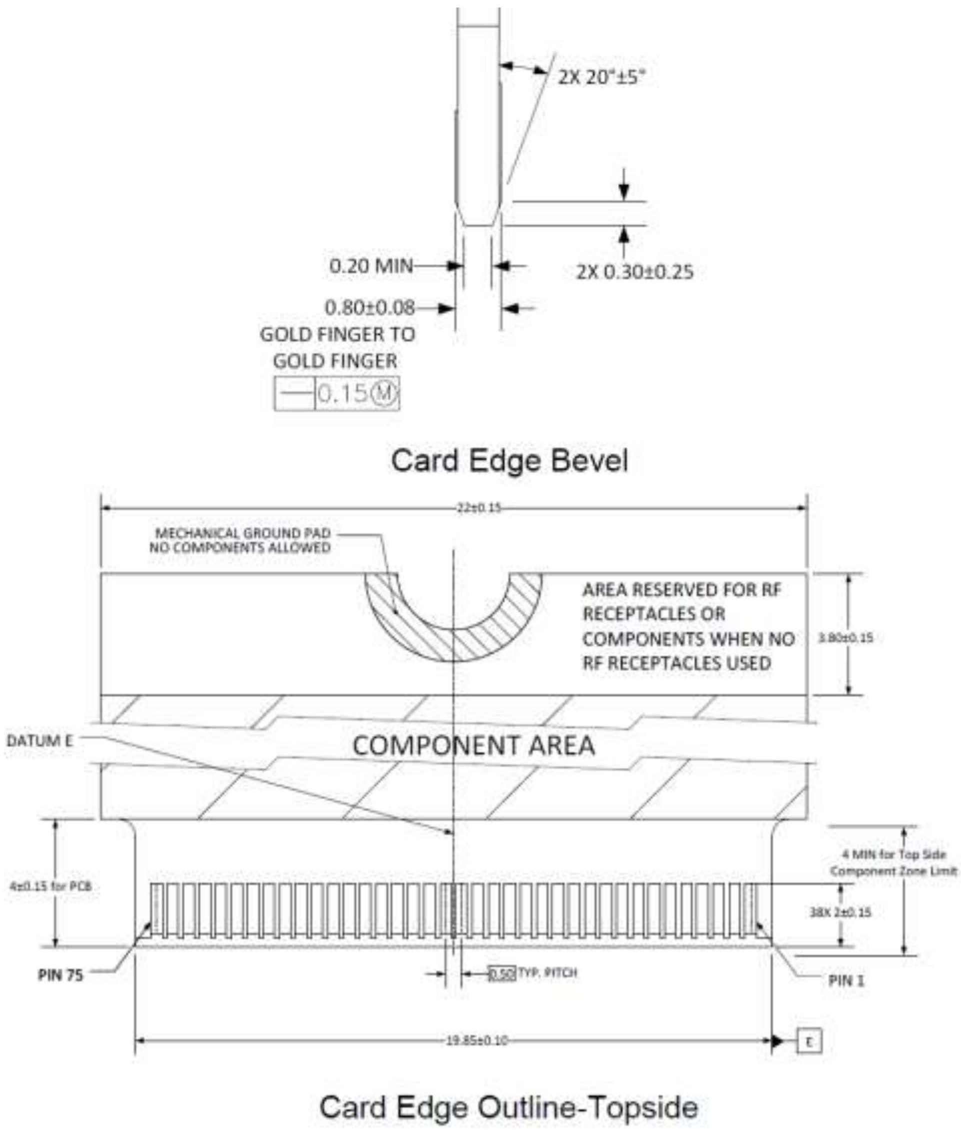
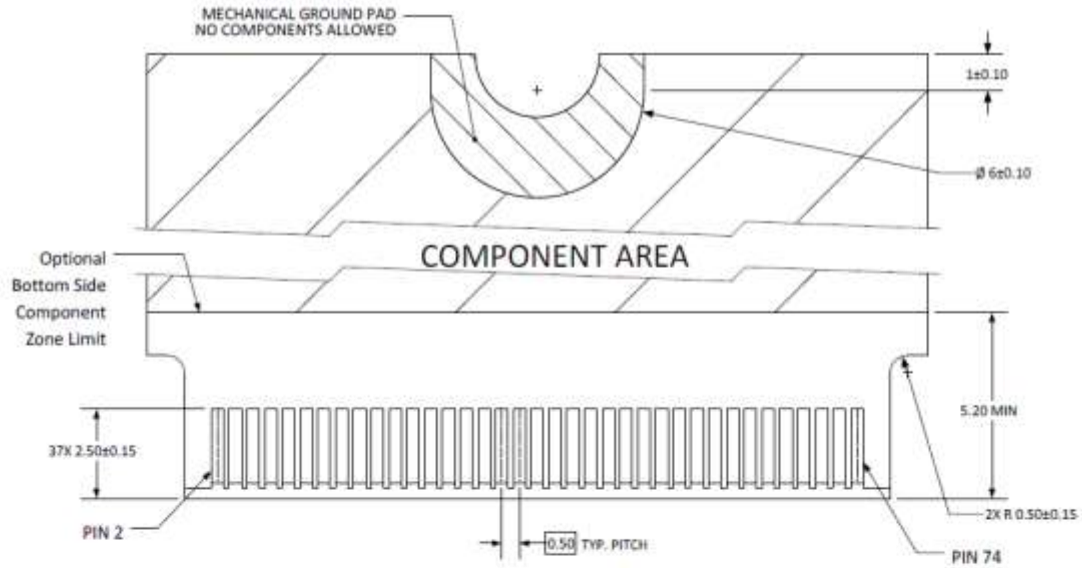
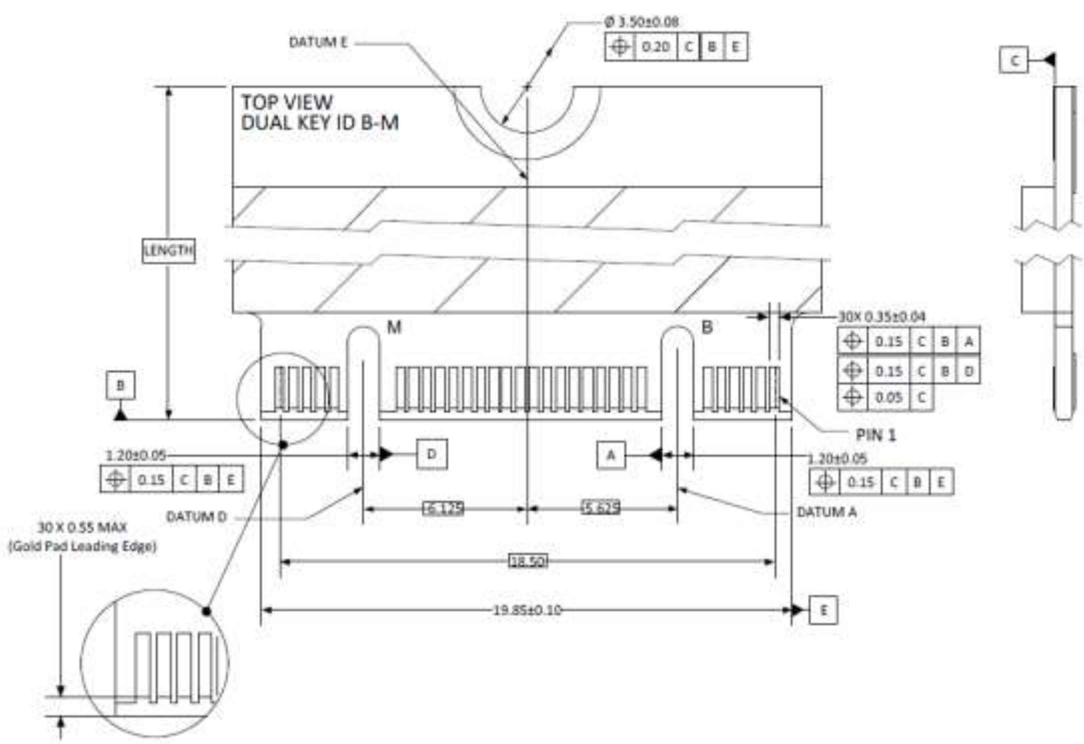


Figure 3-4: Dimension Details for M.2 connector and notch



Card Edge Outline-Backside



Key notch detail