RoHS Compliant

PCIe Gen 3x4 - U.2 - Flash Drive Series

Datasheet for PCIe Gen 3x4 – U.2 3D TLC BICS5 NAND based Flash Drive

February 23, 2023

Revision 1.1

This Specification Describes the Features and Capabilities of the Standard and Industrial Temperature PCI Express Flash Drives

Please Contact Fortasa Memory Systems Sales for any Custom Features Required For Your Specific Application

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Features:

- **PCIe Interface**
    - Compliant with NVMe 1.3
    - Compatible with PCIe Gen 3 x 4 interface
    - PCI Express Base 3.1
- **Temperature ranges**
    - Operation:
        Standard Temperature: 0°C to 70°C
        Industrial Temperature: -40°C to 85°C
    - Storage: -55°C to 100°C
- **Capacity**
    960GB, 1920GB, 3840GB, 7680GB
- **NAND flash type: BiCS5 3D TLC**
- **MTBF (hours):** >3,000,000
- **Performance**
    - Interface burst read/write: 4 GB/sec
    - Sustained Performance
        - Read: up to 3405 MB/sec
        - Write: up to 1100MB/sec
        - Random read 4K: up to 687,000 IOPS
        - Random write 4K: up to 254,000 IOPS
- **Connector Type**
    - 2.5" – U.2 - (SFF-8639)
- **Form factor**
    - 2.5 inch (100.00 x 69.85 x 7.00, unit: mm)
    - Net Weight: 71.5 ± 5% grams
- **Intelligent endurance design**
    - Built-in hardware LDPC (Low Density Parity Check) ECC
    - Global wear-leveling scheme together with dynamical block allocation to significantly increase the lifetime of a flash device and optimize the disk performance
    - Flash bad-block management
    - SMART Command
    - *Power Failure Management*
    - *ATA Secure Erase*
    - *Trim Command*
- **Thermal Sensor for Temperature Management**
- **Endurance in Drive Writes Per Day (DWPD)**
    - 960 GB: 0.98 DWPD
    - 1920 GB: 1.02 DWPD
    - 3840 GB: 1.86 DWPD
    - 7680 GB: 1.86 DWPD
- **Security**
    - AES 256-bit hardware encryption

- **Low power consumption (typical)**
    - Supply voltage: 12V ± 5%V
    - Active mode: 670 mA (max)
    - Idle mode: 200 mA

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1 Product Description

1.1 General Description

Fortasa's PCI Express 2.5" U.2 SSD family is a high-performance, PCI Express interface, solid state drive (SSD) designed to offer a fastest throughput storage solution on a fast PC bus.

The PCIe 2.5" drive offers capacities of up to 8 terabyte, providing full compliance with the latest PCIe Gen 3 x 4 interface specifications. It can operate at sustained access rates of up to 3400 megabytes per second, which is much faster than other solid-state or traditional HDD drives currently available on the market. **Manufactured using Industrial Temperature rated BiCS5 3D TLC NAND-flash, this SSD can work in highly demanding environment and withstand standard range of operating temperature from -40°C to +85°C.**

PCIe 2.5" SSD products offer high reliability global data wear-leveling scheme to allow uniform use of all storage blocks, increasing the lifetime of Flash media and optimizing drive performance. The PCIe 2.5" SSD also offers Self-Monitoring Analysis and Reporting Technology (S.M.A.R.T.) feature monitors the drive accesses and provides the host with vital information about drive condition to schedule maintenance and service times.

1.2 Capacity Specification

Standard capacity specification of the PCIe 2.5" Flash Drive product are shown in Table 1-1. The table lists the specific capacity and useable number of sectors for each product capacity.

Table 1-1: Capacity specifications

Capacity	Total Bytes*	Total LBA**
960GB	960,197,124,096	1,875,385,008
1920GB	1,920,383,410,176	3,750,748,848
3840GB	3,840,755,982,336	7,501,476,528
7680GB	7,681,501,126,656	15,002,931,888

*Display of total bytes varies from file systems, which means not all of the bytes can be used for storage.
**Notes: 1 GB = 1,000,000,000 bytes; 1 sector = 512 bytes.
LBA count addressed in the table above indicates total user storage capacity and will remain the same throughout the lifespan of the device. However, the total usable capacity of the SSD is most likely to be less than the total physical capacity because a small portion of the capacity is reserved for device maintenance usages.

Please contact factory for any non-listed Flash Drive capacity or custom CHS requirement.

1.3 Performance Specification

Performances of the PCIe 2.5" Flash Drive are listed in Tables 1-2.

Table 1-2: Performance specifications

Performance \ Capacity	960GB	1920GB	3840GB	7680GB
Sustained read (MB/s)	3405	3345	3245	3295
Sustained write (MB/s)	745	1100	965	910
Random Read IOPS (4K)	271,000	535,000	687,000	636,000
Random Write IOPS (4K)	180,000	254,000	221,000	207,000

Note:
- Results may differ from various flash configurations or host system setting.
- Sequential read/write is based on CrystalDiskMark 8.0.4 with file size 1,000MB.
- Random read/write is measured using IOMeter with Queue Depth 128.

1.4 Pin Assignments

Pin assignment of the PCIe 2.5" is shown in Figure 1-2 and described in Table 1-3.

Figure 1-2: PCIe 2.5" pin assignment
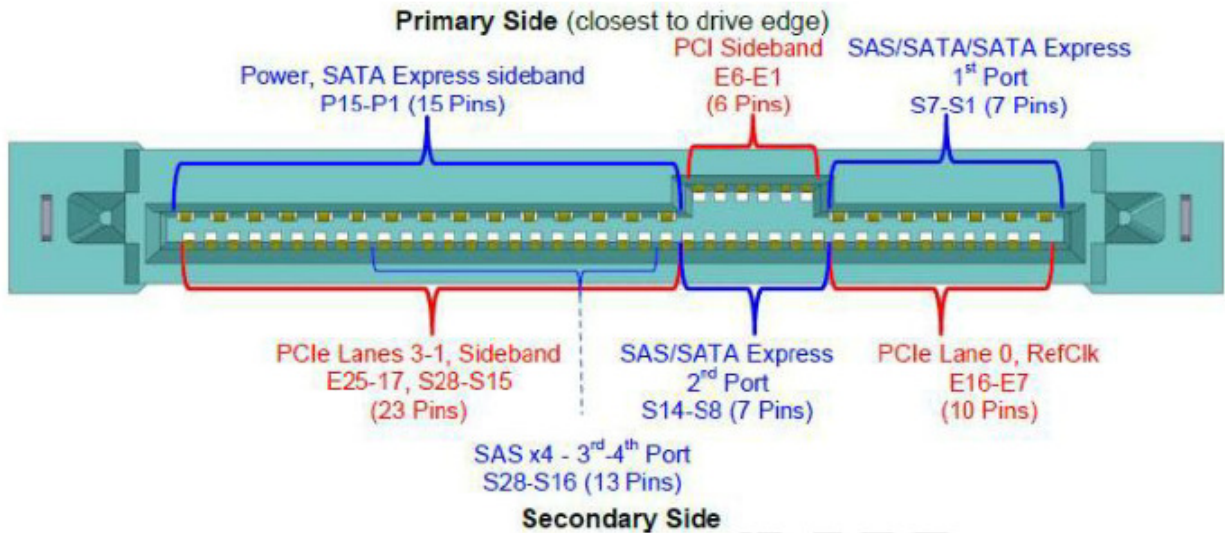
Pin Number	Name	Type	Description
P1	WAKE#	Input	No connector
P2	-	-	No connector
P3	CLKREQ#	Bi-Dir	Clock request
P4	IfDet#	Input	Interface Type Detect
P5	Ground	Ground	Ground
P6	Ground	Ground	Ground
P7	-	-	No connector
P8	-	-	No connector
P9	-	-	No connector
P10	PRSNT#	Input	Presence detect
P11	Activity	Input	-
P12	Ground	Ground	Ground

Pin Number	Name	Type	Description
P13	+12V Precharge	Power	+12V Precharge power for SFF-8639 module
P14	+12V	Power	+12V power for SFF-8639 module
P15	+12V	Power	+12V power for SFF-8639 module
S1	Ground	Ground	Ground
S2	-	-	No connector
S3	-	-	No connector
S4	Ground	Ground	Ground
S5	-	-	No connector
S6	-	-	No connector
S7	Ground	Ground	Ground
S8	Ground	Ground	Ground
S9	-	-	No connector
S10	-	-	No connector
S11	Ground	Ground	Ground
S12	-	-	No connector
S13	-	-	No connector
S14	Ground	Ground	Ground
S15	Reserved	-	Reserved for Fortasa use only
S16	Ground	Ground	Ground
S17	PETp1	Diff-Pair	Transmitter differential pair, Lane 1
S18	PETn1	Diff-Pair	Transmitter differential pair, Lane 1
S19	Ground	Ground	Ground
S20	PERn1	Diff-Pair	Receiver differential pair, Lane 1

Pin Number	Name	Type	Description
S21	PERp1	Diff-Pair	Receiver differential pair, Lane 1
S22	Ground	Ground	Ground
S23	PETp2	Diff-Pair	Transmitter differential pair, Lane 2
S24	PETn2	Diff-Pair	Transmitter differential pair, Lane 2
S25	Ground	Ground	Ground
S26	PERn2	Diff-Pair	Receiver differential pair, Lane 2
S27	PERp2	Diff-Pair	Receiver differential pair, Lane 2
S28	Ground	Ground	Ground
E1	REFCLKB+	Diff-Pair	Reference clock (differential pair) for second X2 port
E2	REFCLKB-	Diff-Pair	Reference clock (differential pair) for second X2 port
E3	+3.3 Vaux	Power	3.3 V auxiliary power
E4	PERSTB#	Output	Fundamental reset for second X2 port
E5	PERST#	Output	Fundamental reset (if dual-port enabled, first X2 port)
E6	Reserved	-	Reserved for Fortasa Use Only
E7	REFCLK+	Diff-Pair	Reference clock (if dual-port enabled, first X2 port)
E8	REFCLK-	Diff-Pair	Reference clock (if dual-port enabled, first X2 port)
E9	Ground	Ground	Ground
E10	PETp0	Diff-Pair	Transmitter differential pair, Lane 0
E11	PETn0	Diff-Pair	Transmitter differential pair, Lane 0
E12	Ground	Ground	Ground
E13	PERn0	Diff-Pair	Receiver differential pair, Lane 0

Pin Number	Name	Type	Description
E14	PERp0	Diff-Pair	Receiver differential pair, Lane 0
E15	Ground	Ground	Ground
E16	Reserved	-	No connector
E17	PETp3	Diff-Pair	Transmitter differential pair, Lane 3
E18	PETn3	Diff-Pair	Transmitter differential pair, Lane 3
E19	Ground	Ground	Ground
E20	PERn3	Diff-Pair	Receiver differential pair, Lane 3
E21	PERp3	Diff-Pair	Receiver differential pair, Lane 3
E22	Ground	Ground	Ground
E23	SMCLK	Bi-Dir	No connector
E24	SMDAT	Bi-Dir	No connector
E25	DualPortEn#	Output	No connector

Table 1-3: Pin Assignment Description

2. Software Interface

2.1 Command Set

Table 2-1 summarizes the PCIe 2.5" command set.

Table 2-1 Admin Commands

Opcode	Command Description
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 Features
0Ah	Get Features
0Ch	Asynchronous Event Request
10h	Firmware Activate
11h	Firmware Image Download
14h	Device Self Test

Table 2-2 Admin Commands – NVM Command Set Specific

Opcode	Command Description
80h	Format NVM
81h	Security Send
82h	Security Receive

Table 2-3 NVM Commands

Opcode	Command Description
00h	Flush
01h	Write
02h	Read
05h	Compare
08h	Write Zeroes
09h	Dataset Management

3. Flash Management

3.1 Error Correction/Detection

The PCIe 2.5" implements a hardware LDPC (Low Density Parity Check) ECC algorithm.

3.2 Wear Leveling

All NAND flash devices are limited by a finite number of write cycles. Under a standard file system, frequent file table updates are mandatory. As a painful side effect of OS file overhead, some areas of flash address space wear out faster than others. As these certain sections get a substantially higher write occurrence the whole Flash Drive can wear out very quickly. This uneven wear would significantly reduce the lifetime of the whole device, even if majority of the Flash sectors are far from the write cycle limit. Fortasa's PCIe 2.5" Flash Drive products offer advanced data wear leveling which distributes Flash writes evenly across the Flash Drive memory space. By utilizing this advanced wear leveling feature, the lifetime of the media can be significantly extended.

3.3 Power Failure Management

The Low Power Detection on the Flash controller initiates cached data saving before the power supply to the device drops too low for operation. This feature prevents the device from system crash and ensures data integrity during an unexpected brownout. This feature makes sure that there are no catastrophic failures of the Flash Drive due to system power glitches.

3.4 NVMe Secure Erase

NVMe Secure Erase is an NVMe drive sanitize command currently embedded in most of the storage drives. Defined in NVMe specifications, NVMe Secure Erase is part of Format NVM command that allows storage drives to erase all user data areas. The erase process usually runs on the firmware level as most of the NVMe-based storage media currently in the market are built-in with this command. NVMe Secure Erase can securely wipe out the user data in the drive and protects it from malicious attack.

3.5 S.M.A.R.T. Technology

S.M.A.R.T. is an acronym for Self-Monitoring, Analysis and Reporting Technology, an open standard allowing disk drives to automatically monitor their own health and report potential problems. It protects the user from unscheduled downtime by monitoring and storing critical drive performance and calibration parameters. Ideally, this should allow taking proactive actions to prevent impending drive failure.

SMART Attributes (Log Identifier 02h)

Bytes Index	Bytes	Description
[0]	1	Critical Warning
[2:1]	2	Composite Temperature
[3]	1	Available Spare
[4]	1	Available Spare Threshold
[5]	1	Percentage Used
[31:6]	26	Reserved
[47:32]	16	Data Units Read
[63:48]	16	Data Units Written
[79:64]	16	Host Read Commands
[95:80]	16	Host Write Commands
[111:96]	16	Controller Busy Time
[127:112]	16	Power Cycles
[143:128]	16	Power On Hours
[159:144]	16	Unsafe Shutdowns
[175:160]	16	Media and Data Integrity Errors
[191:176]	16	Number of Error Information Log Entries
[195:192]	4	Warning Composite Temperature Time
[199:196]	4	Critical Composite Temperature Time
[201:200]	2	Temperature Sensor 1 (Current Temperature)
[203:202]	2	Temperature Sensor 2 (N/A)
[205:204]	2	Temperature Sensor 3 (N/A)
[207:206]	2	Temperature Sensor 4 (N/A)
[209:208]	2	Temperature Sensor 5 (N/A)
[211:210]	2	Temperature Sensor 6 (N/A)
[213:212]	2	Temperature Sensor 7 (N/A)
[215:214]	2	Temperature Sensor 8 (N/A)
[511:216]	296	Reserved

SMART Attributes (Log Identifier C0h)

Bytes Index	Bytes	Description
[0-255]	256	Reserved
[256-257]	2	SSD Protect Mode
[258-261]	4	ECC Fail Count
[262-273]	12	Reserved
[274-277]	4	Total Later Black Count
[278-281]	4	Maximum Erase Count
[282-285]	4	Average Erase Count
[286-289]	4	Program Fail Count
[290-293]	4	Erase Fail Count
[294-301]	8	Flash Write Sector
[302-511]	210	Reserved

3.6 TRIM Command Support

Over time the performance of SSD degrades as user continually writes and erases data. The ATA-TRIM command "formats" the SSD to optimize the drive performance. A TRIM enabled SSD running an OS with TRIM support will stay closer to its peak performance without much performance variance.

3.7 Thermal Sensor

The PCIe 2.5" SSD contains a Thermal Sensor that measures module temperature. The drive temperature can be obtained by polling SMART Command attribute ID 200h. When the device temperature reaches a pre-set temperature threshold, the drive performance will be reduced to limit the power draw and prevent the module from overheating.

3.8 Thermal Throttling

Thermal throttling can monitor the temperature of the SSD equipped with a built-in thermal sensor via S.M.A.R.T. commands. This method can ensure the temperature of the device stays within temperature limits by drive throttling, i.e. reducing the speed of the drive when the device temperature reaches the threshold level, so as to prevent overheating, guarantee data reliability, and prolong product lifespan. When the temperature exceeds the maximum threshold level, thermal throttling will be triggered to reduce device performance to prevent hardware components from being damaged. Performance is only permitted to drop to the extent necessary for recovering a stable temperature to cool down the device's temperature. Once the temperature decreases to the minimum threshold value, transfer speeds will rise back to its optimum performance level.

4. Environmental Specifications

4.1 Environments

Environmental specification of the PCIe 2.5" Flash Drive series follows the MIL-STD-810F standard as shown in Table 4-1.

Table 4-1: Environmental specifications

Environment		Specification
Temperature	Operation	0°C to 70°C (Standard); -40°C to 85°C (Industrial)
	Storage	-40°C to 100°C
Vibration		Operating - 7.69 GRMS, 20~2000 Hz/random (compliant with MIL-STD-810G)
		Non-Operating - 4.02 GRMS, 15~2000 Hz/random (compliant with MIL-STD-810G)
Shock		Operating - Acceleration, 50(G)/11(ms)/half sine (compliant with MIL-STD-202G)
		Non-Operating - Acceleration, 1500(G)/0.5(ms)/half sine (compliant with MIL-STD-883K)

4.2 Mean Time Between Failures (MTBF)

Mean Time Between Failures (MTBF) is predicted based on reliability data for the individual components in the The PCIe 2.5" drive. Based on provided component data, PCIe 2.5" Flash Drive is rated at more than 3,000,000 hours.

Notes about the MTBF:
> The MTBF is predicated and calculated based on "Telcordia Technologies Special Report, SR-332, Issue 2" method.

4.3 Certification and Compliance

The PCIe 2.5" complies with the following standards:
- CE
- UKCA
- FCC
- RoHS

4.4 Endurance

The endurance of a storage device is predicted by a JEDEC approved test methodology. The data, reported in Drive Writes Per Day (DWPD), is based on several factors related to device architecture and product usage, such as the amount of data written into the drive, block management conditions, and daily workload for the drive. Please contact Fortasa Sales to learn more about the DWPD analysis and calculations.

Capacity	Drive Writes Per Day
960GB	0.98
1920GB	1.02
3840GB	1.86
7680GB	1.86

Note:

- This estimation complies with JEDEC random enterprise workload.
- Flash vendor guaranteed 3D NAND TLC P/E cycle: 3K
- WAF may vary from capacity, flash configurations and writing behavior on each platform.
- 1 Terabyte = 1,024GB
- DWPD (Drive Writes Per Day) is calculated based on the number of times that user overwrites the entire capacity of an SSD per day of its lifetime during the warranty period. (3D NAND TLC warranty: 3 years)

5. Electrical Specification

5.1 Operating Voltage

Caution: **Absolute Maximum Stress Ratings –** Applied conditions greater than those listed under "Absolute Maximum Stress Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these conditions or conditions greater than those defined in the operational sections of this data sheet is not implied. Exposure to absolute maximum stress rating conditions may affect device reliability.

Table 5-1: Operating range

Range	Ambient Temperature	Voltage Range
Standard	0°C to +70°C	12V ±5%
Industrial	-40°C to +85°C	

5.2 Power Consumption

Tables 5-2 lists the PCIe 2.5" power consumption.

Table 5-2 PCIe 2.5" power consumption (typical)

Performance \ Capacity	960GB	1920GB	3840GB	7680GB
Active Mode (mA)	465	530	660	670
Idle Mode (mA)	180	195	195	200

Note:
- All values are typical and may vary depending on flash configurations or host system settings.
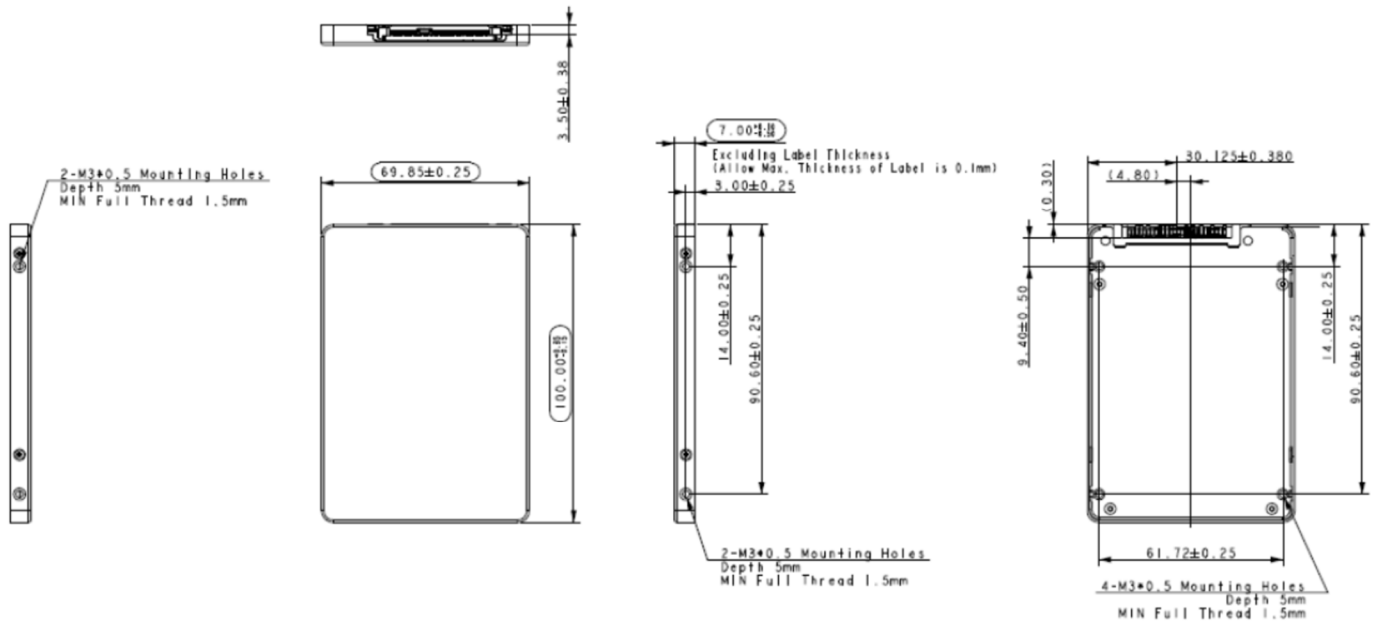- Power consumption is measured using CrystalDiskMark 8.0.4.

6. Mechanical Specifications
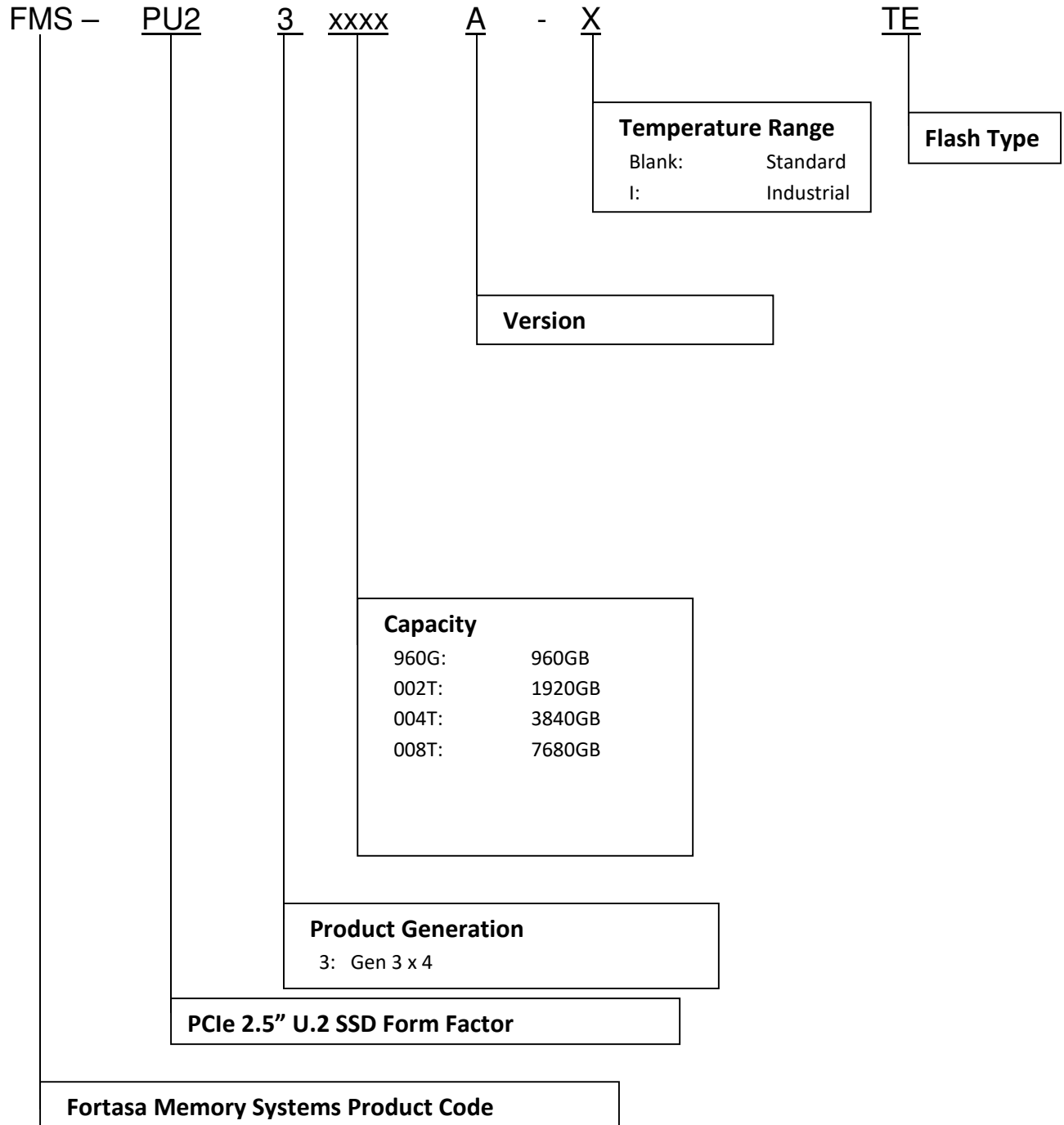
Table 6-1 – Physical Information

Parameter	Unit	960 GB	1920 GB	3840 GB	7680 GB
Length	mm	100.00 +0.35/-0.15			
Width		69.85 ± 0.25			
Height (Max.)		7.00 +0.10/-0.30			
Weight	g ± 5%	61.3	70.1	71.5	71.8

Figure 6-1 – Physical Dimensions

7. Product Ordering Information

7.1 Product Code Designations

FMS –   PU2   3   xxxx   A   -   X   TE

Temperature Range
Blank: Standard
I: Industrial

Flash Type

Version

Capacity

960G: 960GB
002T: 1920GB
004T: 3840GB
008T: 7680GB

Product Generation

3:   Gen 3 x 4

PCIe 2.5" U.2 SSD Form Factor

Fortasa Memory Systems Product Code

7.2 Valid Combinations

Capacity	Standard Temperature	Industrial Temperature
960GB	FMS-PU23960GA-TE	FMS-PU23960GA-ITE
1920GB	FMS-PU23002TA-TE	FMS-PU23002TA-ITE
3840GB	FMS-PU23004TA-TE	FMS-PU23004TA-ITE
7680GB	FMS-PU23008TA-TE	FMS-PU23008TA-ITE

Note: Valid combinations are those products in mass production or will be in mass production. Consult your Fortasa sales representative to confirm availability of valid combinations and to determine availability of new product combinations

8. Revision History

Revision	Date	Description	Comments
1.0	12/30/2022	Initial Release	
1.1	2/23/2023	Added 7860GB Capacity	