Samsung NVMe TCG Opal SSC SEDs PM1723b Series

FIPS 140-2 Non-Proprietary Security Policy
Document Revision: 1.1

H/W version: MZWLL3T8HAJQ-000G6, MZWLL3T8HAJQ-00AG6
MZWLL15THMLA-00AG6

F/W version: NA01, NA03 and NA06

Revision History

Author(s)	Version	Updates
Seungjae Lee	1.0	Initial Version
Seungjae Lee	1.1	Minor changes as updated module version

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1. Introduction

Samsung Electronics Co., Ltd. ("Samsung") NVMe TCG Opal SSC SEDs PM1723b Series, herein after referred to as a "cryptographic module" or "module", SSD (Solid State Drive), satisfies all applicable FIPS 140-2 Security Level 2 requirements, supporting TCG Opal SSC based SED (Self-Encrypting Drive) features, designed to protect unauthorized access to the user data stored in its NAND Flash memories. The built-in AES HW engines in the cryptographic module's controller provide on-the-fly encryption and decryption of the user data without performance loss. The SED's nature also provides instantaneous sanitization of the user data via cryptographic erase.

Module Name	Hardware Version	Firmware Version	Drive Capacity
Samsung NVMe TCG Opal SSC SEDs PM1723b Series	MZWLL3T8HAJQ-000G6 MZWLL3T8HAJQ-00AG6	NA01, NA03, NA06	3.8TB
	MZWLL15THMLA-00AG6	NA06	15TB

<u>Exhibit 1</u> – *Versions of Samsung NVMe TCG Opal SSC SEDs PM1723b Series.*

1.1. Hardware and Physical Cryptographic Boundary

The following photographs show the cryptographic module's top and bottom views. The multiple-chip standalone cryptographic module consists of hardware and firmware components that are all enclosed in two aluminum alloy cases, which serve as the cryptographic boundary of the module. The top and bottom cases are assembled by screws and the tamper-evident labels are applied for the detection of any opening of the cases. No security relevant component can be seen within the visible spectrum through the opaque enclosure.

New firmware versions within the scope of this validation must be validated through the FIPS 140-2 CMVP. Any other firmware loaded into this module is out of the scope of this validation and requires a separate FIPS 140-2 validation.

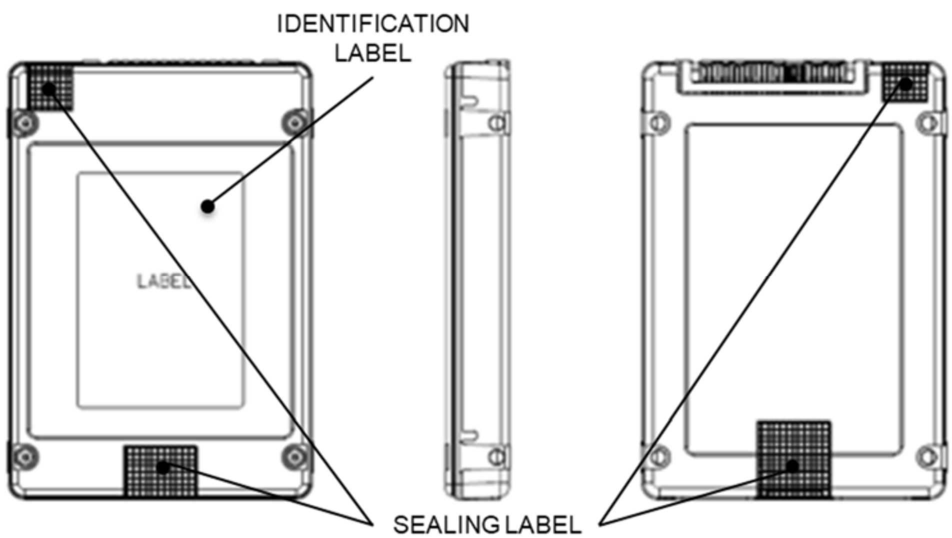
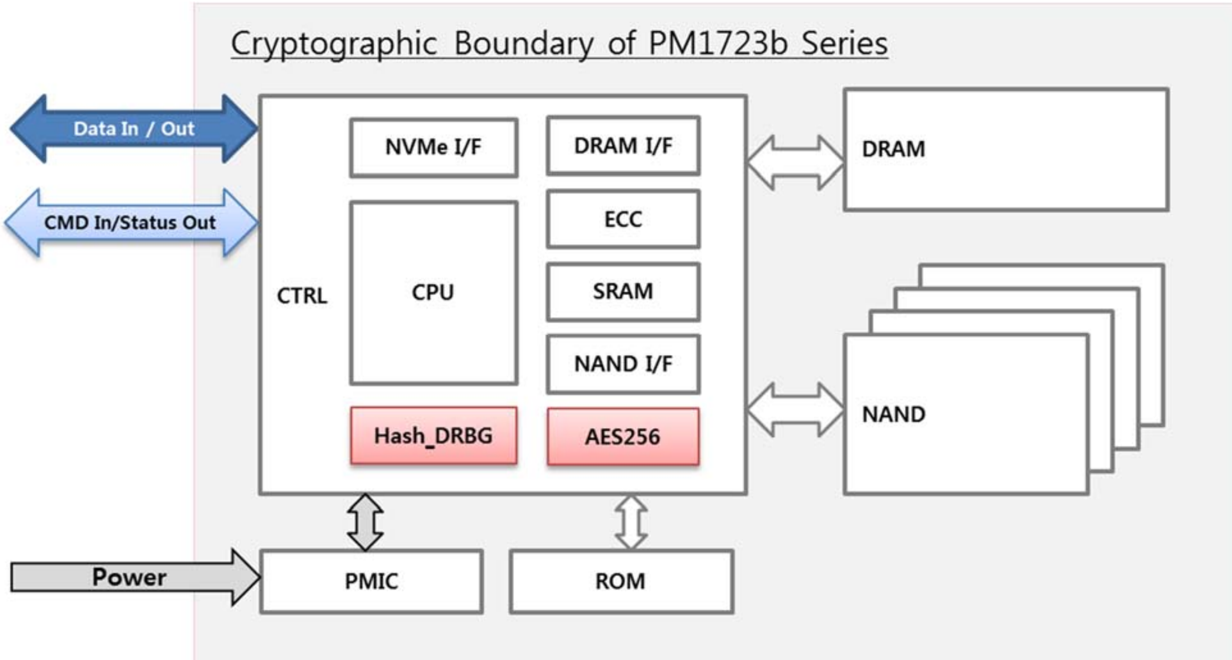


Exhibit 2 – ***Specification of the Samsung NVMe TCG Opal SSC SEDs PM1723b Series Cryptographic Boundary (From top to bottom, side).***

1.2. Firmware and Logical Cryptographic Boundary

The PM1723b series use a single chip controller with a NVMe interface on the system side and Samsung NAND flash internally. The following figure depicts the Module operational environment.



<u>Exhibit 3</u> – *Block Diagram for Samsung NVMe TCG Opal SSC SEDs PM1723b Series.*

2. Acronym

Acronym	Description
CTRL	EPiC2 Controller (SAMSUNG EPiC2 NVMe TLC/MLC SSD Controller)
NVMe I/F	Non-Volatile Memory Express Interface
CPU	Central Processing Unit (ARM-based)
DRAM I/F	Dynamic Random Access Memory Interface
ECC	Error Correcting Code
SRAM	Static Random Access Memory
NAND I/F	NAND Flash Interface
PMIC	Power Management Integrated Circuit
ROM	Read-only Memory
DRAM	Dynamic Random Access Memory
NAND	NAND Flash Memory
LBA	Logical Block Address
MEK	Media Encryption Key
MSID	Manufactured SID(Security Identifier)

Exhibit 4 – ***Acronym and Descriptions for Samsung NVMe TCG Opal SSC SEDs PM1723b Series.***

3. Security Level Specification

Security Requirements Area	**Level**
Cryptographic Module Specification	2
Cryptographic Module Ports and Interfaces	2
Roles, Services, and Authentication	2
Finite State Model	2
Physical Security	2
Operational Environment	N/A
Cryptographic Key Management	2
EMI/EMC	3
Self-tests	2
Design Assurance	2
Mitigation of Other Attacks	N/A

Exhibit 5 – ***Security Level Table.***

4. Cryptographic Functionality

4.1. Approve algorithms

The cryptographic module supports the following Approved algorithms for secure data storage:

CAVP Cert.	Algorithm	Standard	Mode / Method	Key Lengths, Curves or Moduli	Use
5007	AES	FIPS 197 SP 800-38E	XTS	256-bit	Data Encryption / Decryption *Note1
Vendor Affirmed	CKG	SP800-133			Cryptographic Key Generation
1845	DRBG	SP 800-90A Revision 1	Hash_ DRBG (SHA-256)		Deterministic Random Bit Generation
1288	ECDSA	FIPS 186-4	SigVer	P-224	Digital Signature Verification
4072	SHS	FIPS 180-4	SHA-256		Message Digest

Exhibit 6 - ***Samsung NVMe TCG Opal SSC SEDs PM1723b Series Approved Algorithms.***

Note1: AES-ECB is the pre-requisite for AES-XTS; AES-ECB alone is NOT supported by the cryptographic module in FIPS Mode.
Note2: This module supports AES-XTS which is only approved for storage applications.

4.2. Non-Approved Algorithm

The cryptographic module supports the following non-Approved but allowed algorithms:

Algorithm	Use
NDRNG	Non-deterministic Random Number Generator (only used for generating seed materials for the Approved DRBG) NDRNG provides a minimum of 256 bits of entropy for DRBG seed

Exhibit 7 - ***Samsung NVMe TCG Opal SSC SEDs PM1723b Series Non-Approved but allowed algorithms.***

4.3. Critical Security Parameters

The cryptographic module contains the following Keys and CSPs:

CSPs	Generation, Storage and Zeroization Methods
DRBG Internal State	Generation: SP 800-90A HASH_DRBG (SHA-256) Storage: Plaintext in SRAM Zeroization: via "Initialization", "Erase an LBA Range's Data", "Change the Password" and "Zeroize" service
DRBG Seed	Generation: NDRNG Storage: Plaintext in DRAM Zeroization: via "Initialization", "Erase an LBA Range's Data", "Change the Password" and "Zeroize" service
DRBG Entropy Input String	Generation: NDRNG Storage: Plaintext in DRAM Zeroization: via "Initialization", "Erase an LBA Range's Data", "Change the Password" and "Zeroize" service
CO Password	Generation: N/A Storage: Plaintext in Flash Memory and used in SRAM Zeroization: via "Initialization", "Change the Password" and "Zeroize" service
User Password	Generation: N/A Storage: Plaintext in Flash Memory and used in SRAM Zeroization: via "Initialization" service, "Erase an LBA Range's Data" and "Zeroize" service
MEK	Generation: SP 800-90A HASH_DRBG (SHA-256) As per SP 800-133 Section 7.1, key generation is performed as per the "Direct Generation: of Symmetric Keys" which is an Approved key generation method Key Type: AES-XTS 256 Storage: Plaintext in Flash Memory and used in SRAM Zeroization: via "Initialization", "Lock an LBA Range", "Erase an LBA Range's Data" and "Zeroize" service

Exhibit 8*– CSPs and details on Generation, Storage and Zeroization Methods.*

Note3: The values of V and C are the "secret values" of the internal state.
NOTE4: In accordance with FIPS 140-2 IG D.12, the cryptographic module performs Cryptographic Key Generation (CKG) as per SP 800-133 (Vendor Affirmed). The resulting generated symmetric key is the unmodified output from SP 800-90A DRBG.

4.4. Public Security Parameters

Public Keys	Generation, Storage and Zeroization Methods
FW Verification Key (ECDSA Public Key)	Generation: N/A Key Type: ECDSA P-224 Storage: Plaintext in Flash Memory and used in SRAM Zeroization: N/A

Exhibit 9 – ***Public Keys and details on Generation, Storage and Zeroization Methods***

5. Physical Ports and Logical Interfaces

Physical Port	Logical Interface
NVMe Connector	Data Input/Output Control Input Status Output Power Input

<u>Exhibit 10</u> – ***Specification of the Samsung NVMe TCG Opal SSC SEDs PM1723b Series Cryptographic Module Physical Ports and Logical Interfaces.***

6. Roles, Services and Authentication

6.1. Roles

The following table defines the roles, type of authentication, and associated authenticated data types supported by the cryptographic module:

Role	Authentication Data
CO Role	Password
User Role	Password
FW Loader	ECDSA

<u>Exhibit 11</u> - *Roles and Required Identification and Authentication (FIPS 140-2 Table C1).*

6.2. Authentication

The authentication mechanism allows a minimum 6-byte length or longer (32-byte) Password, where each byte can be any of 0x00 to 0xFF, for every Cryptographic Officer and User role supported by the module, which means a single random attempt can succeed with the probability of $1/2^{48}$ or lower.

Each Password authentication attempt takes at least 10ms and the number of attempts is limited to TryLimit, a configurable parameter which is set to 1024 in manufacturing time. Since the module takes at least 4 seconds to be ready after power-on and 1024 authentication failures require a power-cycle, it would take a total of 14,240ms ((10ms *1024) + 4000ms) for every 1024th authentication attempt. Therefore, the number of attempts possible in a minute period is limited to only 4400 attempts (60000ms== (10ms*1024 attempts + 4000ms) *4 + (10ms * 304 attempts)).

Therefore, the probability of multiple random attempts to succeed in one minute is 4400 / 2^{48}, which is much less than the FIPS 140-2 requirement 1/100,000.

The authentication mechanism for FW Loader role is ECDSA P-224 with SHA256 digital signature verification, which means a single random attempt, can succeed with the probability of $1/2^{112}$.

Each ECDSA Signature Verification authentication attempt takes at least 600ms. Since the module takes at least 4 seconds to be ready after power-on. It would take a total of 4600ms for every FW download attempt. This enforces the maximum number of attempts to be no more than 13 attempts (60000ms/4600ms) in a minute period. Therefore, the probability of multiple random attempts to succeed in one minute is $13/2^{112}$, which is much less than the FIPS 140-2 requirement 1/100,000.

Authentication Mechanism	Strength of Mechanism
Password (Min: 6 bytes, Max: 32 bytes) Authentication	- Probability of $1/2^{48}$ in a single random attempt - Probability of $4400/2^{48}$ in multiple random attempts in a minute
ECDSA Signature Verification	- Probability of $1/2^{112}$ in a single

	random attempt - Probability of $13/2^{112}$ in multiple random attempts in a minute

Exhibit 12 - ***Strengths of Authentication Mechanisms (FIPS 140-2 Table C2).***

6.3. Services

6.3.1. Authenticated Services

The following table lists roles, services, cryptographic keys, CSPs and Public Keys and the types of access that are available to each of the authorized roles via the corresponding services:

* Type(s) of Access indicated using "O" marker.
* R: READ; W: WRITE; G: GENERATE; Z: ZEROIZE

Role	Service	Cryptographic Keys, CSPs and Public Keys	Security Function	Type(s) of Access			
				R	W	G	Z
Cryptographic Officer	Initialization	DRBG Internal State	Hash_ DRBG (SHA-256)	O		O	O
		DRBG Seed		O		O	O
		DRBG Entropy Input String		O		O	O
		CO Password			O		O
		MEK				O	O
	Drive Extended Status	N/A	N/A	N/A			
	Admin/User Authority Enable/Disable	N/A	N/A	N/A			
	Lock an LBA Range	MEK	N/A				O
	Unlock an LBA Range	MEK	AES-XTS	O			
	Configure an LBA Range	N/A	N/A	N/A			
	Erase an LBA Range's Data	DRBG Internal State	Hash_ DRBG (SHA-256)	O		O	O
		DRBG Seed		O		O	O
		DRBG Entropy Input String		O		O	O
		MEK				O	O
	Change the Password.	CO Password	N/A		O		O
User	Unlock an LBA Range	MEK	AES-XTS	O			
	Set User Password	User Password	N/A		O		
	Lock an LBA Range	MEK	N/A				O
	Configure an LBA Range	N/A	N/A	N/A			
FW Loader	Update the firmware	FW Verification Key	ECDSA, SHA-256	O			

Exhibit 13 – ***Services Authorized for Roles, Access Rights within Services (FIPS 140-2 Table C3, Table C4).***

6.3.2. Unauthenticated Services

The following table lists the unauthenticated services:

* Type(s) of Access indicated using “O” marker.
* R: READ; W: WRITE; G: GENERATE; Z: ZEROIZE

Unauthenticated Service	Cryptographic Keys & CSPs	Security Function	Type(s) of Access			
			R	W	G	Z
Zeroize	DRBG Internal State	Hash_DRBG (SHA-256)				O
	DRBG Seed					O
	DRBG Entropy Input String					O
	CO Password					O
	User Password					O
	MEK					O
Get Random Number	DRBG Internal State	Hash_DRBG (SHA-256)	O		O	O
	DRBG Seed		O		O	O
	DRBG Entropy Input String		O		O	O
Get MSID	N/A	N/A	N/A			
Show Status	N/A	N/A	N/A			
Self-test	N/A	N/A	N/A			

Exhibit 14 – ***Unauthenticated Service, Cryptographic Keys & CSPs and Type(s) of Access.***

7. Physical security policy

The following physical security mechanisms are implemented in a cryptographic module:

- The Module consists of production-grade components enclosed in an aluminum alloy enclosure, which is opaque within the visible spectrum. The top panel of the enclosure can be removed by unscrewing screws. However, the module is sealed with tamper-evident labels in accordance with FIPS 140-2 Level 2 Physical Security requirements so that tampering is easily detected when the top and bottom cases are detached.
- 2 tamper-evident labels are applied over both top and bottom cases of the module at the factory. The tamper-evident labels are not removed and reapplied without tamper evidence.

The following table summarizes the actions required by the Cryptographic Officer Role to ensure that physical security is maintained:

Physical Security Mechanisms	Recommended Frequency of Inspection/Test	Inspection/Test Guidance Details
Production grade cases	As often as feasible	Inspect the entire perimeter for cracks, gouges, lack of screw(s) and other signs of tampering. Remove from service if tampering found.
Tamper-evident Sealing Labels		Inspect the sealing labels for scratches, gouges, cuts and other signs of tampering. Remove from service if tampering found.

Exhibit 15 - ***Inspection/Testing of Physical Security Mechanisms (FIPS 140-2 Table C5)***

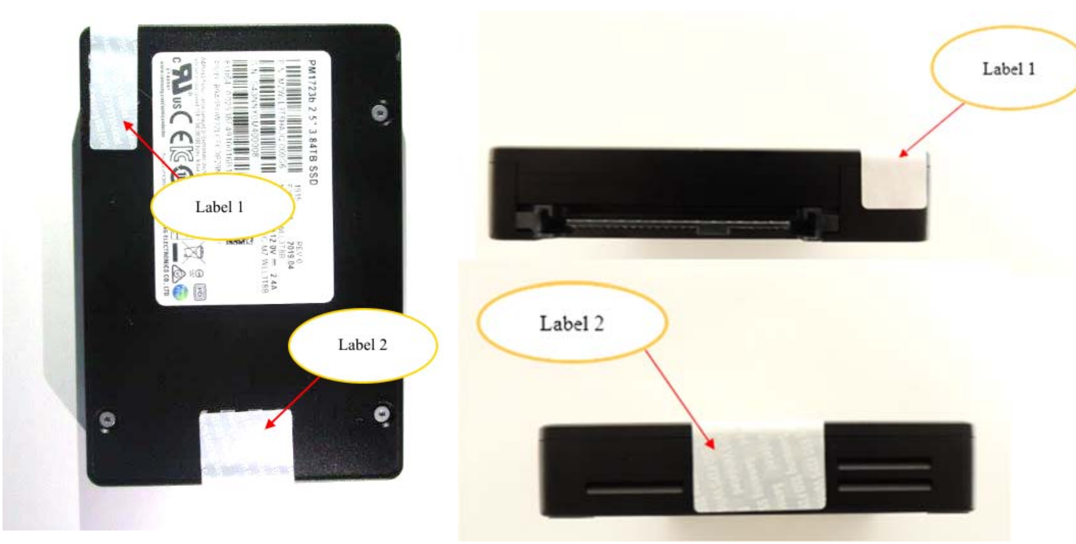
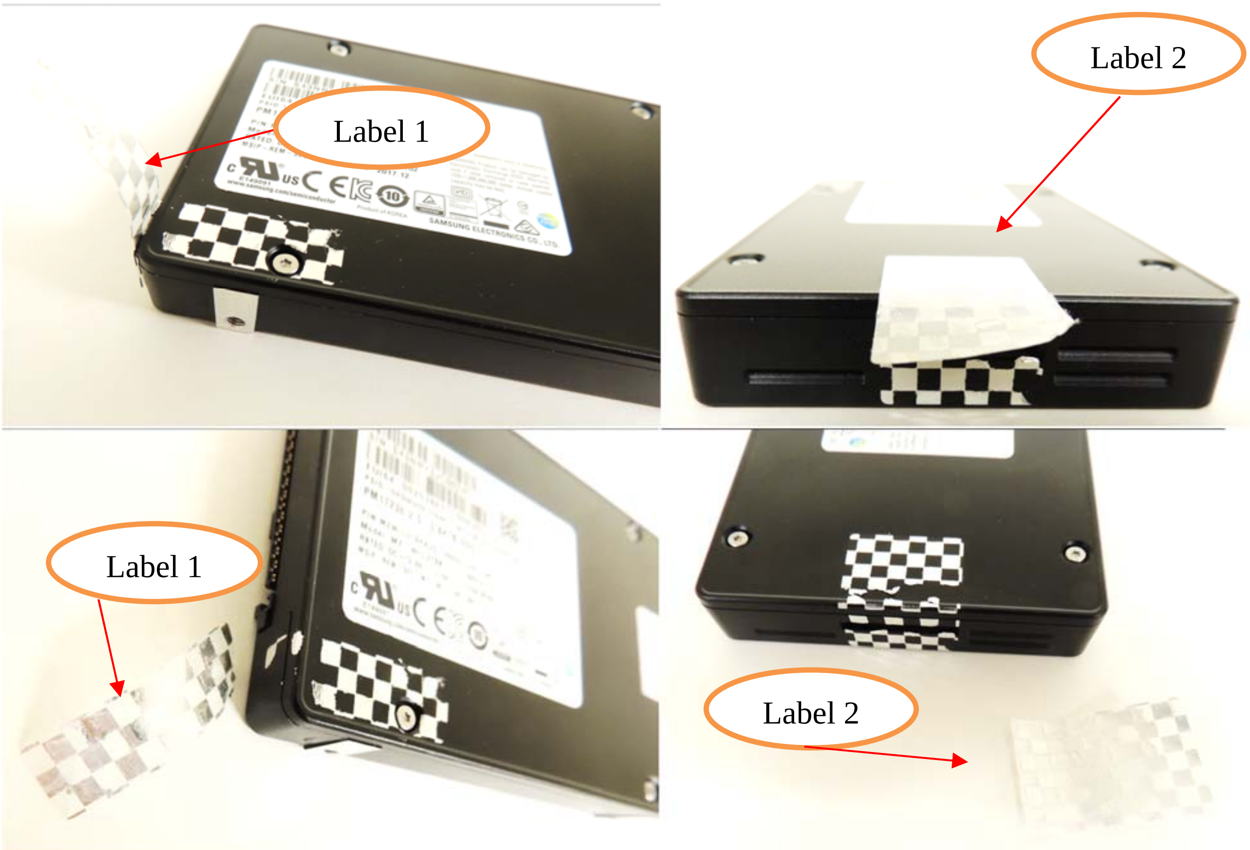


Exhibit 16 – ***Tamper Evident Label Placement***



<u>Exhibit 17</u> – *Signs of Tamper*

NOTE: Samsung Electronics Co., Ltd has excluded the following components as per AS01.09:

- Power electronics:
  - BOM Code 2203-009819 (Capacitor)
  - BOM Code 2203-009821 (Capacitor)
  - BOM Code 2703-004649 (Inductor)
- Storage IC:
  - BOM code K9OMGY8H5A-C### (NAND Flash)

The components do not process any CSPs, Plaintext data, or other information that if misused could lead to compromise.

8. Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC)

The cryptographic module conforms to the EMI/EMC requirements specified by 47 Code of Federal Regulations, Part 15, Subpart B, Unintentional Radiators, Digital Devices, Class B.

9. Mitigation of Other Attacks Policy

The cryptographic module has not been designed to mitigate any specific attacks beyond the scope of FIPS 140-2.

Other Attacks	Mitigation Mechanism	Specific Limitations
N/A	N/A	N/A

Exhibit 18 - ***Mitigation of Other Attacks (FIPS 140-2 Table C6)***

10. Security rules

The following specifies the security rules under which the cryptographic module shall operate in accordance with FIPS 140-2:

- The cryptographic module operates always in FIPS Mode once shipped from the vendor's manufacturing site.
- The steps necessary for the secure installation, initialization and start-up of the cryptographic module as per FIPS 140-2 VE10.03.01 are as follows:

10.1. Secure Installation

- Step1. User should examine the tamper evidence
  - Inspect the entire perimeter for cracks, gouges, lack of screw(s) and other signs of tampering including the tamper evident sealing label.
  - If there is any sign of tampering, do not use the product and contact Samsung.
- Step2. Identify the firmware version in the device
  - Confirm that the firmware version is equivalent to the version(s) listed in this document via NVM express Identify Controller command.
- Step3. Take the drive's ownership
  - Disable Admin SP's Admin1 authority
  - Change SID's PIN by setting a new PIN
  - Activate the Locking SP by using the Activate method.
  - Change Admin1~4's PIN by setting a new PIN.
  - Configure the Locking Global Range by setting ReadLockEnabled and WriteLockEnabled columns to True.
  - Don't change LockOnReset column in Locking Table so that the drive always gets locked after a power cycle
- Step4. Periodically examine the tamper evidence
  - If there is any sign of tampering, stop using the product to avoid a potential security hazard or information leakage.

10.2. Operational description of Module

- The cryptographic module shall maintain logical separation of data input, data output, control input, status output, and power.
- The cryptographic module shall not output CSPs in any form.
- The cryptographic module shall use the Approved DRBG for generating all cryptographic keys.
- The cryptographic module shall enforce role-based authentication for security relevant services.
- The cryptographic module shall enforce a limited operational environment by the secure firmware load test using ECDSA P-224 with SHA-256.
- The cryptographic module shall provide a production-grade, opaque, and tamper-evident cryptographic boundary.
- The cryptographic module enters the error state upon failure of Self-tests. All commands from the Host (General Purpose Computer (GPC) outside the cryptographic boundary) are rejected in the error state and the cryptographic module returns an Internal Error (SC=0x6, SCT=0x0) defined in NVMe specification via the status output. Cryptographic services and data output are explicitly inhibited when in the error state.
- The cryptographic module satisfies the requirements of FIPS 140-2 IG A.9 (i.e. key_1 ≠ key_2)
- The module generates at a minimum 256 bits of entropy for use in key generation.

10.3. Power-on Self-Tests

Algorithm	Test
AES	Encrypt KAT and Decrypt KAT for AES-256-XTS at power-on
SHS	KAT for SHA-256 at power-on
DRBG	KAT for Hash_DRBG (SHA-256) at power-on
ECDSA	KAT for ECDSA P-224 SHA-256 signature verification at power-on

Exhibit 19 – ***Power-on Self-tests.***

- F/W integrity check
  - F/W integrity check is performed by using 106-bit error detection code at power-on

- Conditional Self-tests
  - Pairwise consistency: N/A
  - Bypass Test: N/A
  - Manual key entry test: N/A
  - F/W load test
    : F/W load test is performed by using ECDSA algorithm with P-224 and SHA-256
  - Continuous random number generator test on Approved DRBG
  - Continuous random number generator test on NDRNG