innodisk

Total Solution For
Industrial Flash Storage

SATA Slim

3TE7 Series

Customer: _____

Customer

Part Number: _____

Innodisk

Part Number: _____

Innodisk

Model Name: _____

Date: _____

Innodisk Approver	Customer Approver

Features:

- SATA III
- Kioxia 3D TLC NAND
- Standard & Wide-temperature
- iPower Guard
- iData Guard
- Dynamic Thermal Management
- Hybrid Write

Performance:

- Sequential Read up to 550 MB/s
- Sequential Write up to 510 MB/s

Power Requirements:

Input Voltage:	5V±5%
Max Operating Wattage:	2.3W
Idle Wattage:	1.0W

Reliability:

Capacity	TBW	DWPD
32GB	37	1.08
64GB	75	1.09
128GB	150	1.09
256GB	300	1.09
512GB	600	1.09
1TB	1200	1.09
2TB	2400	1.09

Data Retention	10 Years
Warranty	3 Years

For warranty details, please refer to:

https://www.innodisk.com/en/support_and_service/warranty

Table of contents

Revision History

Revision	Description	Date
Preliminary	First Released	Sep., 2018
Rev 1.0	Add TRIM note Modify Performance Table Modify Power Consumption Table Modify TBW Table Update RoHS report	Apr., 2019
Rev 1.1	Modify Performance Table Add Die RAID Add Quick Erase (optional) Update RoHS to 2019 version Update CE/FEE certification	May, 2019
Rev 2.0	Add 64 Layers & 96 Layers 3D TLC NAND Information Add SMART Feature Set	Dec., 2020
Rev 2.1	Add 112 Layers 3D TLC Information	Jan., 2022
Rev 2.2	Correct Power Requirement table	Nov., 2022
Rev 2.3	Correct 2TB LBA value	Dec., 2022
Rev 2.4	Add Mechanical Drawing (Slime inside PCBA)	Mar., 2023
Rev 2.5	Correct typo in Die RAID feature ("3TE7" mistakenly written)	Mar., 2023
Rev 2.6	Update Boot Up Power Consumption	Dec., 2023
Rev 2.7	Add 112 Layers 3D TLC 64GB Information	May, 2024
Rev 2.8	Remove EOL products	Sep., 2024

List of Tables

List of Figures

1. Product Overview

1.1 Introduction of Innodisk SATA Slim 3TE7.

Innodisk SATA Slim 3TE7 products provide high capacity flash memory Solid State Drive (SSD) that electrically complies with Serial ATA (SATA) standard. It supports SATA III standard (6.0GHz) with high performance., achieves excellent performance up to 4CH standard by cost effective controller with 4CH.

With Innodisk L^3 FW architecture, combining our signature 4K mapping algorithm L^2 FW architecture with powerful LDPC technology, 3TE7 series has outstanding high IOPS, better data integrity and extended lifespan through reducing the bad block number happening.

For real industrial application, 3TE7 series is built in thermal sensor to monitor the environment temperature. iData Guard, the power loss management mechanism developed by Innodisk, ensures data integrity while power sudden loss happened.

CAUTION TRIM must be enabled.

TRIM enables SSD's controller to skip invalid data instead of moving. It can free up significant amount of resources, extends the lifespan of SSD by reducing erase, and write cycles on the SSD. Innodisk's handling of garbage collection along with TRIM command improves write performance on SSDs.

1.2 Product View and Models

Innodisk SATA Slim 3TE7 is available in follow capacities within TLC flash ICs.

SATA Slim 3TE7 32GB SATA Slim 3TE7 64GB

SATA Slim 3TE7 128GB SATA Slim 3TE7 256GB

SATA Slim 3TE7 512GB SATA Slim 3TE7 1TB

SATA Slim 3TE7 2TB

Figure 1: Innodisk SATA Slim 3TE7

1.3 SATA Interface

Innodisk SATA Slim 3TE7 supports SATA III(6.0Gb/s) interface, and compliant with SATA I (1.5Gb/s) and SATA II(3.0Gb/s).

1.4 MO-297 Form Factor

SATA Slim 3TE7 has a compact design 54.0mm (W) x 39.0mm (L) x 4.0mm (H) without metal material case, and is easy for installation.

2. Product Specifications

2.1 Capacity and Device Parameters

SATA Slim 3TE7 device parameters are shown in Table 1.

Table 1: Device parameters

Capacity	Cylinders	Heads	Sectors	LBA	User Capacity(MB)
32GB	16383	16	63	53742528	26241
64GB	16383	16	63	107463888(112-L)	52473
				117231408	57241
128GB	16383	16	63	234441648	114473
256GB	16383	16	63	468862128	228936
512GB	16383	16	63	937703088	457862
1TB	16383	16	63	1875385008	915715
2TB	16383	16	63	3750748848	1831420

2.2 Performance

Burst Transfer Rate: 6.0Gbps

Table 2: Performance- 64 Layers 3D TLC[1]

Capacity	Unit	32GB	64GB	128GB	256GB	512GB	1TB
Sequential Read (max.)[2]	MB/s	175	350	550	550	550	550
Sequential Write (max.)[2]		35	70	140	290	330	370
4KB Random Read (QD32)[2]	IOPS	10,000	21,000	43,000	76,000	82,000	87,000
4KB Random Write (QD32)[2]		7,000	17,000	35,000	66,000	73,000	58,000

Note:

1. Performance may vary based on various firmware version or test platform
2. Performance based on CrystalDiskMark 5.1.2 with file size 1000MB of Queue Depth 32

Table 3: Performance - 112 Layers 3D TLC[1]

Capacity	Unit	64GB	128GB	256GB	512GB	1TB	2TB
Sequential[2] Read (Q32T1)	MB/s	270	440	550	550	550	550
Sequential[2] Write (Q32T1)		160	290	480	490	510	470
Sustained[3] Sequential Read (Avg.)		220	350	420	420	420	410
Sustained[3] Sequential Write (Avg.)		45	85	160	310	320	280
4KB Random[2] Read (Q32T1)	IOPS	24,000	43,000	80,000	83,000	83,000	83,000
4KB Random[2] Write (Q32T1)		17,000	29,000	42,000	75,000	72,000	76,000

Note:

1. Performance may vary based on various firmware version or test platform. In addition, Kioxia 112 layers 3D TLC series adopt hybrid mode which enables SLC Cache up to 3% of total user.
2. Performance results are based on CrystalDiskMark 6.0.2 with file size 1000MB of Queue Depth32.
3. Performance results are based on AIDA 64 v5.98 with block size 1MB of Linear Read & Write Test Item

2.3 Electrical Specifications

2.3.1 Power Requirement

Table 4: Innodisk SATA Slim 3TE7 Power Requirement

Item	Symbol	Rating	Unit
Input voltage	V_{IN}	+5 DC +- 5%	V

2.3.2 Power Consumption

Table 5: Typical Power Consumption

Mode	Power consumption (W)
Read	2.0
Write	2.3
Idle	1.0
Boot-Up	5.3

Note: Current results may vary depending on system components and power circuit design. Please refer to the test report for other capacities.

2.4 Environmental Specifications

2.4.1 Temperature Ranges

Table 6: Temperature range for SATA Slim 3TE7

Temperature	Range
Operating	Standard Grade: 0°C to +70°C
	Industrial Grade: -40°C to +85°C
Storage	-40°C to +85°C

2.4.2 Humidity

Relative Humidity: 10-95%, non-condensing

2.4.3 Shock and Vibration

Table 7: Shock/Vibration Testing for SATA Slim 3TE7

Reliability	Test Conditions	Reference Standards
Vibration	7 Hz to 2K Hz, 20G, 3 axes	IEC 60068-2-6
Mechanical Shock	Duration: 0.5ms, 1500 G, 3 axes	IEC 60068-2-27

2.4.4 Mean Time between Failures (MTBF)

The following table summarizes the MTBF prediction results for various SATA Slim 3TE7 configurations. The analysis was performed using a RAM Commander™ failure rate prediction.

- **Failure Rate**: The total number of failures within an item population, divided by the total number of life units expended by that population, during a particular measurement interval under stated condition.
- **Mean Time between Failures (MTBF)**: A basic measure of reliability for repairable items: The mean number of life units during which all parts of the item perform within their specified limits, during a particular measurement interval under stated conditions.

Table 8: SATA Slim 3TE7 MTBF

Product	Condition	MTBF (Hours)
Innodisk SATA Slim 3TE7	Telcordia SR-332 GB, 25°C	>3,000,000

2.5 CE and FCC Compatibility

SATA Slim 3TE7 conforms to CE and FCC requirements.

2.6 RoHS Compliance

SATA Slim 3TE7 is fully compliant with RoHS directive.

2.7 Reliability

Parameter	Value
Flash endurance	3,000 P/E cycles
Error Correct Code	Support
Data Retention	Under 40 C: 1 Year at NAND Life End

TBW* (Total Bytes Written) Units: TB

Capacity	Sequential workload	Client workload
32GB	85	38
64GB	170	75
128GB	341	150
256GB	682	300
512GB	1364	600
1TB	2727	1200
2TB	5455	2400

* Note:

1. Sequential: Mainly sequential write, tested by Vdbench.
2. Client: Follow JESD218 Test method and JESD219A Workload, tested by ULINK. (The capacity lower than 64GB client workload is not specified in JEDEC219A, the values are estimated.)
3. Based on out-of-box performance.

2.8 Transfer Mode

SATA Slim 3TE7 support following transfer mode:

Serial ATA III 6.0Gbps

Serial ATA II 3.0Gbps

Serial ATA I 1.5Gbps

2.9 Pin Assignment

Innodisk SATA Slim 3TE7 uses a standard SATA pin-out.

See following table for SATA Slim 3TE7 pin assignment.

Table 9: Innodisk SATA Slim 3TE7 Pin Assignment

Name	Type	Description
S1	GND	NA
S2	A+	Differential Signal Pair A
S3	A-	
S4	GND	NA
S5	B-	Differential Signal Pair B
S6	B+	
S7	GND	NA
Key and Spacing separate signal and power segments		
P1	NC	NA
P2	NC	NA
P3	NC	NA
P4	GND	NA
P5	GND	NA
P6	GND	NA
P7	V5	5V Power, Pre-Charge
P8	V5	5V Power
P9	V5	5V Power
P10	GND	NA
P11	DAS/DSS	Device Activity Signal / Disable Staggered
P12	GND	NA
P13	NC	NA
P14	NC	NA
P15	NC	NA

2.10 Mechanical Dimensions

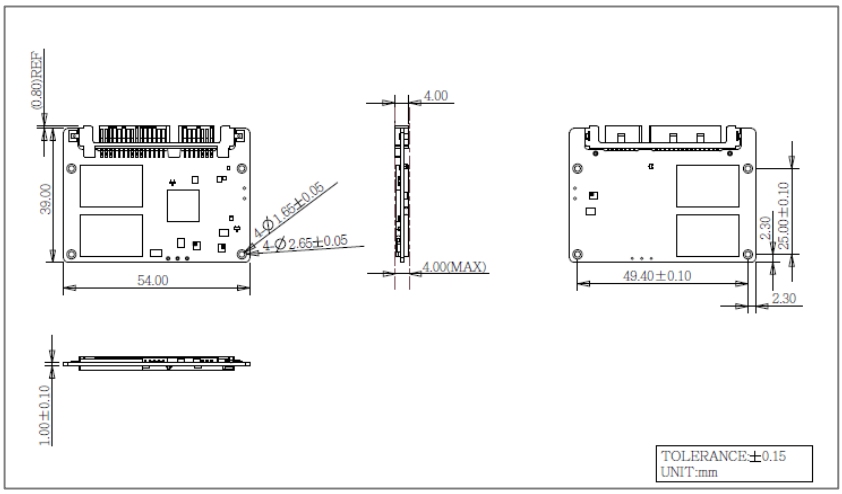

Figure 2 : SATA Slim PCBA diagram

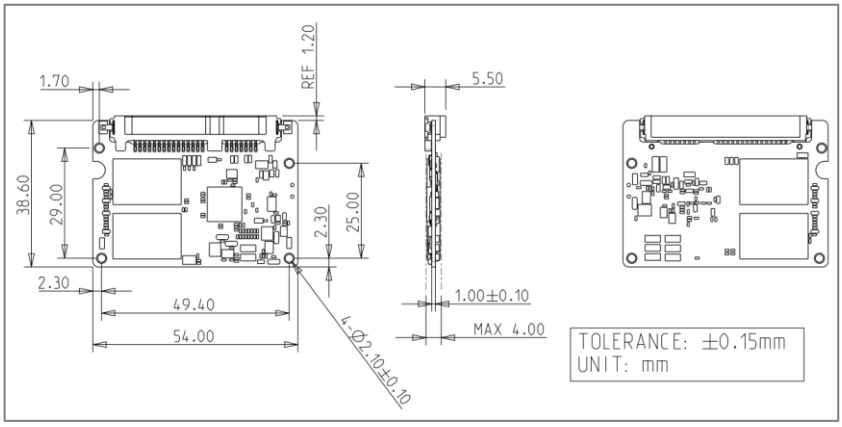

Figure 3 : SATA Slim (Inside) PCBA diagram

2.11 Assembly Weight

An Innodisk SATA Slim 3TE7 within flash ICs, 2TB's weight is 13 grams approximately.

2.12 Seek Time

Innodisk SATA Slim 3TE7 is not a magnetic rotating design. There is no seek or rotational latency required.

2.13 NAND Flash Memory

Innodisk SATA Slim 3TE7 uses 3D TLC NAND flash memory, with 3,000 program & erase cycles, which is non-volatility, high reliability and high speed memory storage.

3. Theory of Operation

3.1 Overview

Figure 4 shows the operation of Innodisk SATA Slim 3TE7 from the system level, including the major hardware blocks.

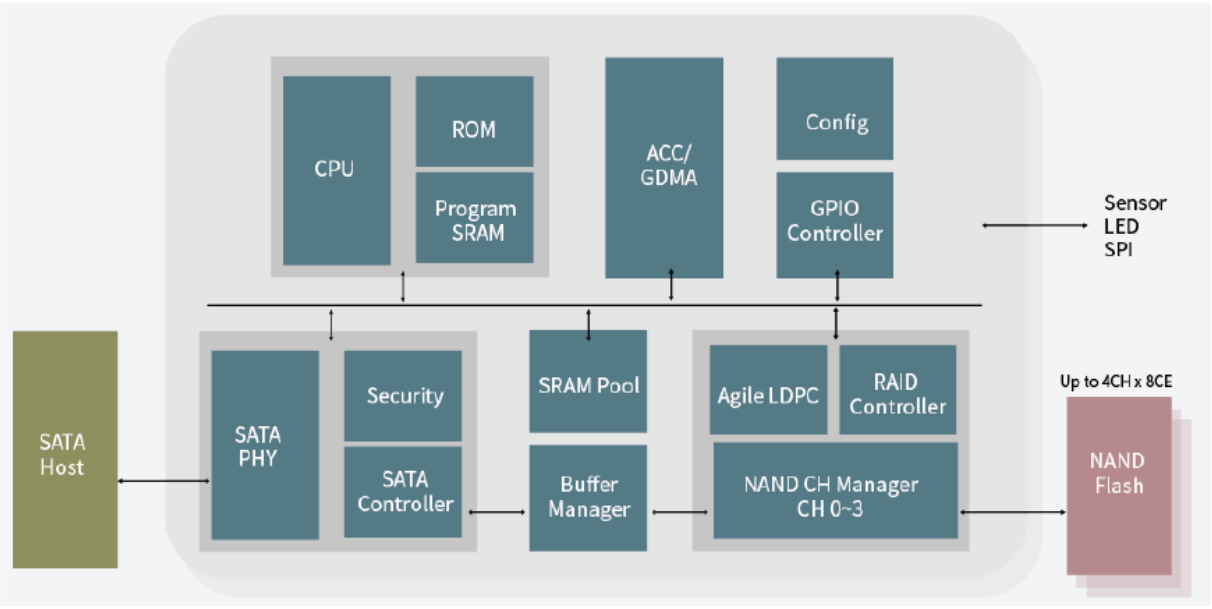

Figure 4: Innodisk SATA Slim 3TE7 Block Diagram

Innodisk SATA Slim 3TE7 integrates a SATA III controller and NAND flash memories. Communication with the host occurs through the host interface, using the standard ATA protocol. Communication with the flash device(s) occurs through the flash interface.

3.2 SATA III Controller

Innodisk SATA Slim 3TE7 is designed with a SATA III 6.0Gbps (Gen 3) controller. The Serial ATA physical, link and transport layers are compliant with Serial ATA Gen 1, Gen 2 and Gen 3 specification (Gen 3 supports 1.5Gbps/3.0Gbps/6.0Gbps data rate). The controller has 4 channels for flash interface.

3.3 Error Detection and Correction

Innodisk SATA Slim is designed with hardware LDPC ECC engine with hard-decision and Soft-decision decoding. Low-density parity-check (LDPC) codes have excellent error correcting Performance close to the Shannon limit when decoded with the belief-propagation (BP) algorithm using soft-decision information.

3.4 Wear-Leveling

Flash memory can be erased within a limited number of times. This number is called the ***erase cycle limit*** or ***write endurance limit*** and is defined by the flash array vendor. The erase cycle limit applies to each individual erase block in the flash device.
Innodisk SATA Slim 3TE7 uses a static wear-leveling algorithm to ensure that consecutive writes of a specific sector are not written physically to the same page/block in the flash. This spreads flash media usage evenly across all pages, thereby extending flash lifetime.

3.5 Bad Blocks Management

Bad Blocks are blocks that contain one or more invalid bits whose reliability are not guaranteed. The Bad Blocks may be presented while the SSD is shipped, or may develop during the life time of the SSD. When the Bad Blocks is detected, it will be flagged, and not be used anymore. The SSD implement Bad Blocks management, Bad Blocks replacement, Error Correct Code to avoid data error occurred. The functions will be enabled automatically to transfer data from Bad Blocks to spare blocks, and correct error bit.

3.6 iData Guard

iData Guard is a comprehensive data protection mechanism that functions before and after a sudden power outage to SSD. Low-power detection terminates data writing before an abnormal power-off, while table-remapping after power-on deletes corrupt data and maintains data integrity. iData Guard provides effective power cycling management, preventing data stored in flash from degrading with use.

3.7 Garbage Collection

Garbage collection is used to maintain data consistency and perform continual data cleansing on SSDs. It runs as a background process, freeing up valuable controller resources while sorting good data into available blocks, and deleting bad blocks. It also significantly reduces write operations to the drive, thereby increasing the SSD’s speed and lifespan.

3.8 Trim

The Trim command is designed to enable the operating system to notify the SSD which pages no longer contain valid data due to erases either by the user or operating system itself. During a delete operation, the OS will mark the sectors as free for new data and send a Trim command to the SSD to mark them as not containing valid data. After that the SSD knows not to preserve the contents of the block when writing a page, resulting in less write amplification with fewer writes to the flash, higher write speed, and increased drive life.

3.9 iPower Guard

iPower Guard technology is a set of preventive measures that protect the SSD in an unstable power supply environment. This comprehensive package comprises safeguards for startup and shutdown to maintain device performance and ensure data integrity.

3.10 Die RAID

Die RAID is a controller function which leveraged user capacity to back up the data in NAND flash. Die RAID supported can ensure the user data in the NAND Flash more consistent in certain scenario. Innodisk SATA Slim 3TE7 series is default enable the Die RAID function for the industrial application.

3.11 Quick Erase (optional)

Quick Erase function is designed for emergency data erase in few seconds by providing ATA command.

3.12 Quick Erase Command

- Protocol: No Data

- Inputs

Table 10: Execute Quick Erase command for inputs information

Register	7	6	5	4	3	2	1	0
Features	21h							
Sector Count	41h							
LBA Low	Na							
LBA Mid	Na							
LBA High	Na							
Device	1	1	1	0	Na			
Command	82h							

-Normal Outputs

Table 11: Quick Erase command for normal output information

Register	7	6	5	4	3	2	1	0
Error	Na							
Sector Count	Na							
LBA Low	Na							
LBA Mid	Na							
LBA High	Na							
Device	obs	Na	obs	DEV	Na	Na	Na	Na

Status	BSY	DRDY	DF	Na	DRQ	Na	Na	ERR

Device register-

DEV shall specify the selected device.

Status register

BSY will be cleared to zero indicating command completion

DRDY will be set to one.

DF (Device Fault) will be cleared to zero.

DRQ will be cleared to zero

ERR will be cleared to zero.

3.11 SLC cache

Table 12: mSATA 3TE7 SLC cache

Capacity	64GB	128GB	256GB	512GB	1TB	2TB
SLC cache (GB)	3	3	5	9	18	36
SLC cache (%)	4.6	2.3	1.9	1.7	1.7	1.7

3TE7 96 layers and 112 layers series adopt hybrid mode which enables SLC Cache up to 3% of total user capacity by TLC direct write to strike balance between burst performance and steady overall stability.

3.12 Thermal Throttling

Thermal throttling is a protective mechanism designed to safeguard components from potential damage caused by excessive temperatures. When an SSD approaches a critical temperature threshold, Innodisk firmware activates the thermal throttling mechanism to regulate the SSD's temperature. Thermal throttling is crucial for SSDs since it prevents drive damage, which could otherwise result in data loss. However, it's worth noting that when thermal throttling is activated, read and write tasks may experience a reduction in speed.

4. Installation Requirements

4.1 SATA Slim Pin Directions

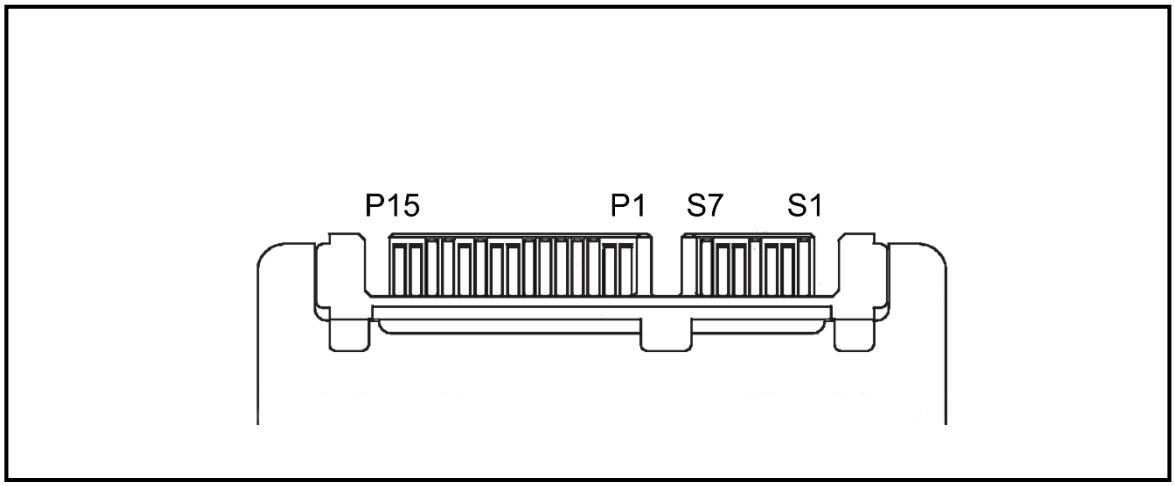

Figure 5: Signal Segment and Power Segment

4.2 Electrical Connections for SATA Slim 3TE7

A Serial ATA device may be either directly connected to a host or connected to a host through an adaptor card. The SATA interface has a separate connector for the power supply. Please refer to the pin description for further details.

4.3 Device Drive

No additional device drives are required. The Innodisk SATA Slim 3TE7 can be configured as a boot device.

5. SMART Feature Set

Innodisk 3TE7 series support the SMART command set and defines some vendor-specific data to report SMART attributes of SSD.

Table 13: SMART command

Value	Command	Value	Command
D0h	Read Data	D5h	Read Log
D1h	Read Attribute Threshold	D6h	Return Status
D2h	Enable/Disable Auto save	D8h	Enable SMART Operations
D3h	Save Attribute Values	D9h	Disable SMART Operations
D4h	Execute OFF-LINE Immediate	DAh	Return Status

5.1 SMART Attributes

Innodisk 3TE7 series SMART data attributes are listed in following table.

Table 14: SMART attribute

Attribute ID (hex)	Value	Raw Attribute Value						Rsv	Attribute Name
01	X								Read Error Rate
05	X	LSB	MSB	00	00	00	00	00	Later Bad
09	LSB	LSB	MSB	00	00	00	00	00	Power-On hours Count
0C	LSB	LSB	MSB	00	00	00	00	00	Drive Power Cycle Count
A3	X	LSB			MSB	00	00	00	Total Bad Block Count
A5	LSB	LSB			MSB	00	00	00	Max Erase count
A7	LSB	LSB			MSB	00	00	00	Avg Erase count
A9	LSB	LSB	00	00	00	00	00	00	Device Life
AA	X	LSB	MSB	00	00	00	00	00	Spare Block Count
AB	LSB	LSB	MSB	00	00	00	00	00	Program fail count
AC	LSB	LSB	MSB	00	00	00	00	00	Erase fail count
C0	LSB	LSB	MSB	00	00	00	00	00	Unexpected Power Loss

									Count
C2	LSB			MIN		MAX	00	00	Temperature
E5		ID 0	ID 1	ID 2	ID 3	ID 4	ID 5		Flash ID
EB			**MSB**	**LSB**	**MSB**	**LSB**	**MSB**	**LSB**	Later bad block info (**Read**/**Write**/**Erase**)
F1	00	LSB			MSB	00	00	00	Total LBA written(LBA=32MB)
F2	00	LSB			MSB	00	00	00	Total LBA read(LBA=32MB)

6. Part Number Rule

CODE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	D	**E**	**S**	**L**	**M**	**-**	**A**	**2**	**8**	**D**	**K**	**1**	**K**	**C**	**A**	**D**	**F**	**-**	**X**	**X**	**X**

Definition	
Code 1st (Disk)	**Code 13th (Flash Mode)**
D : Disk	E: 64 layers 3D TLC
	K: 112 layers 3D TLC
Code 2nd ~ 5th (Form Factor)	**Code 14th (Operation Temperature)**
ESLM: SATA Slim	C: Standard Grade (0℃~ +70℃)
	W: Industrial Grade (-40℃~ +85℃)
Code 7th ~9th (Capacity)	**Code 15th (Internal control)**
32G: 32GB	1/A/B: PCBA version
64G: 64GB	
A28: 128GB	**Code 16th (Channel of data transfer)**
B56: 256GB	S: Single Channel
C12: 512GB	D: Dual Channels
01T: 1TB	Q: Quad Channels
02T: 2TB	**Code 17th (Flash Type)**
Code 10th ~12th (Controller)	F: Kioxia 3D TLC
DK1: SATA 3TE7	**Code 19th~21th (Customized Code)**