innodisk

Total Solution For
Industrial Flash Storage

M.2 (S42)

3TG6-P Series

AES Function

Customer: _____

Customer Part Number: _____

Innodisk Part Number: _____

Innodisk Model Name: _____

Date: _____

Innodisk Approver	Customer Approver

Features:

- SATA III
- Kioxia 3D TLC NAND
- M.2 2242-D2-B+M
- Standard & Wide-temperature
- AES 256bits encrypted Key function
- iPowerguard
- iDataguard
- Dynamic Thermal Management

Performance:

- Sequential Read up to 510 MB/s
- Sequential Write up to 450 MB/s

Power Requirements:

Input Voltage:	3.3V±5%
Max Operating Wattage:	3.2W
Idle Wattage:	1.1W

Reliability:

Capacity	TBW	DWPD
128GB	289	2.36
256GB	578	2.36
512GB	1154	2.36

Data Retention	10 Years
Warranty	3 Years

For warranty details, please refer to:

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

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Revision History

Revision	Description	Date
V1.0	First Released	May., 2022
V1.1	Update LBA	Oct., 2022

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1. Product Overview

1.1 Introduction of Innodisk M.2 (S42) 3TG6-P with AES function

Innodisk M.2 (S42) 3TG6-P is characterized by L^3 architecture with the latest SATA III (6.0GHz) Marvell NAND controller. Innodisk's exclusive L^3 architecture is L^2 architecture multiplied LDPC (Low Density Parity Check). L^2 (Long Life) architecture is a 4K mapping algorithm that reduces WAF and features a real-time wear leveling algorithm to provide high performance and prolong lifespan with exceptional reliability. Innodisk M.2 (S42) 3TG6-P is designed with AES engine, which is a built-in controller. When controller receives the data package from host, AES engine encrypts the data package and saves the encrypted data into NAND flash. Thus, unauthorized personal has no access to decrypt the data in NAND flash.

Innodisk M.2 (S42) 3TG6-P is designed for industrial field, and supports several standard features, including TRIM, NCQ, and S.M.A.R.T. In addition, Innodisk's exclusive industrial-oriented firmware provides a flexible customization service, making it perfect for a variety of industrial applications.

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 M.2 (S42) 3TG6-P is available in follow capacities within 3D TLC flash ICs.

M.2 (S42) 3TG6-P 128GB

M.2 (S42) 3TG6-P 256GB

M.2 (S42) 3TG6-P 512GB

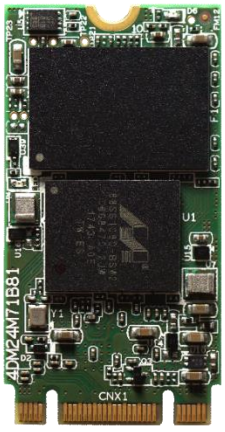

Figure 1: Innodisk M.2 (S42) 3TG6-P (type 2242)

1.3 SATA Interface

Innodisk M.2 (S42) 3TG6-P supports SATA III interface, and compliant with SATA I and SATA II. SATA III interface can work with Serial Attached SCSI (SAS) host system, which is used in server computer. Innodisk M.2 (S42) 3TG6-P is compliant with Serial ATA Gen 1, Gen 2 and Gen 3 specification (Gen 3 supports 1.5Gbps /3.0Gbps/6.0Gbps data rate).

2. Product Specifications

2.1 Capacity and Device Parameters

M.2 (S42) 3TG6-P device parameters are shown in Table 1.

Table 1: Device parameters

Capacity	Cylinders	Heads	Sectors	LBA	User Capacity(MB)
128GB	16383	16	63	234441648	114473
256GB	16383	16	63	468862128	228936
512GB	16383	16	63	937703088	457862

2.2 Performance

Burst Transfer Rate: 6.0Gbps

Table 2: Performance

Capacity	Unit	128GB	256GB	512GB
Sequential* Read (max.)	MB/s	510	510	510
Sequential* Write (max.)		150	300	450
4KB Random** Read (QD32)	IOPS	45,000	70,000	71,000
4KB Random** Write (QD32)		38,000	57,000	57,000

Note: * Sequential performance is based on CrystalDiskMark 5.1.2 with file size 1000MB

** Random performance is based on IO meter with Queue Depth 32

2.3 Electrical Specifications

2.3.1 Power Requirement

Table 3: Innodisk M.2 (S42) 3TG6-P Power Requirement

Item	Symbol	Rating	Unit
Input voltage	V_{IN}	+3.3 DC +- 5%	V

2.3.2 Power Consumption

Table 4: Power Consumption

Mode	Power Consumption (W)
Read	2.7
Write	3.2
Idle	1.1

* Target: 512GB M.2 (S42) 3TG6-P

2.4 Environmental Specifications

2.4.1 Temperature Ranges

Table 5: Temperature range for M.2 (S42) 3TG6-P

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 6: Shock/Vibration Testing for M.2 (S42) 3TG6-P

Reliability	Test Conditions	Reference Standards
Vibration	7 Hz to 2K Hz, 20G, 3 axes	IEC 68-2-6
Mechanical Shock	Duration: 0.5ms, 1500 G, 3 axes	IEC 68-2-27

2.4.4 Mean Time between Failures (MTBF)

Table 7 summarizes the MTBF prediction results for various M.2 (S42) 3TG6-P 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 7: M.2 (S42) 3TG6-P MTBF

Product	Condition	MTBF (Hours)
Innodisk M.2 (S42) 3TG6-P	Telcordia SR-332 GB, 25°C	>3,000,000

2.5 CE and FCC Compatibility

M.2 (S42) 3TG6-P conforms to CE and FCC requirements.

2.6 RoHS Compliance

M.2 (S42) 3TG6-P is fully compliant with RoHS directive.

2.7 Reliability

Table 8: M.2 (S42) 3TG6-P TBW

Parameter		Value
Read Cycles		Unlimited Read Cycles
Flash endurance		3,000 P/E cycles
Wear-Leveling Algorithm		Support
Bad Blocks Management		Support
Error Correct Code		Support
TBW* (Total Bytes Written) Unit: TB		
Capacity	**Sequential workload**	**Client workload**
128GB	340.9	150
256GB	681.8	300
512GB	1364	600

* 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

M.2 (S42) 3TG6-P support following transfer mode:

Serial ATA III 6.0Gbps

Serial ATA II 3.0Gbps

Serial ATA I 1.5Gbps

2.9 Pin Assignment

Innodisk M.2 (S42) 3TG6-P uses a standard SATA pin-out. See Table 9 for M.2 (S42) 3TG6-P pin assignment.

Table 9: Innodisk M.2 (S42) 3TG6-P Pin Assignment

Signal Name	Pin #	Pin #	Signal Name
		75	GND
3.3V	74	73	GND
3.3V	72	71	GND
3.3V	70	69	GND
NC	68	67	NC

Notch	66	65	Notch
Notch	64	63	Notch
Notch	62	61	Notch
Notch	60	59	Notch
NC	58		
NC	56	57	GND
NC	54	55	NC
NC	52	53	NC
NC	50	51	GND
NC	48	49	RX+
NC	46	47	RX-
NC	44	45	GND
NC	42	43	TX-
NC	40	41	TX+
DEVSLP	38	39	GND
NC	36	37	NC
NC	34	35	NC
NC	32	33	GND
NC	30	31	NC
NC	28	29	NC
NC	26	27	GND
NC	24	25	NC
NC	22	23	NC
NC	20	21	GND
Notch	18	19	Notch
Notch	16	17	Notch
Notch	14	15	Notch
Notch	12	13	Notch
DAS/DSS	10	11	NC
NC	8	9	NC
NC	6	7	NC
3.3V	4	5	NC
3.3V	2	3	GND
		1	GND

2.10 Mechanical Dimensions

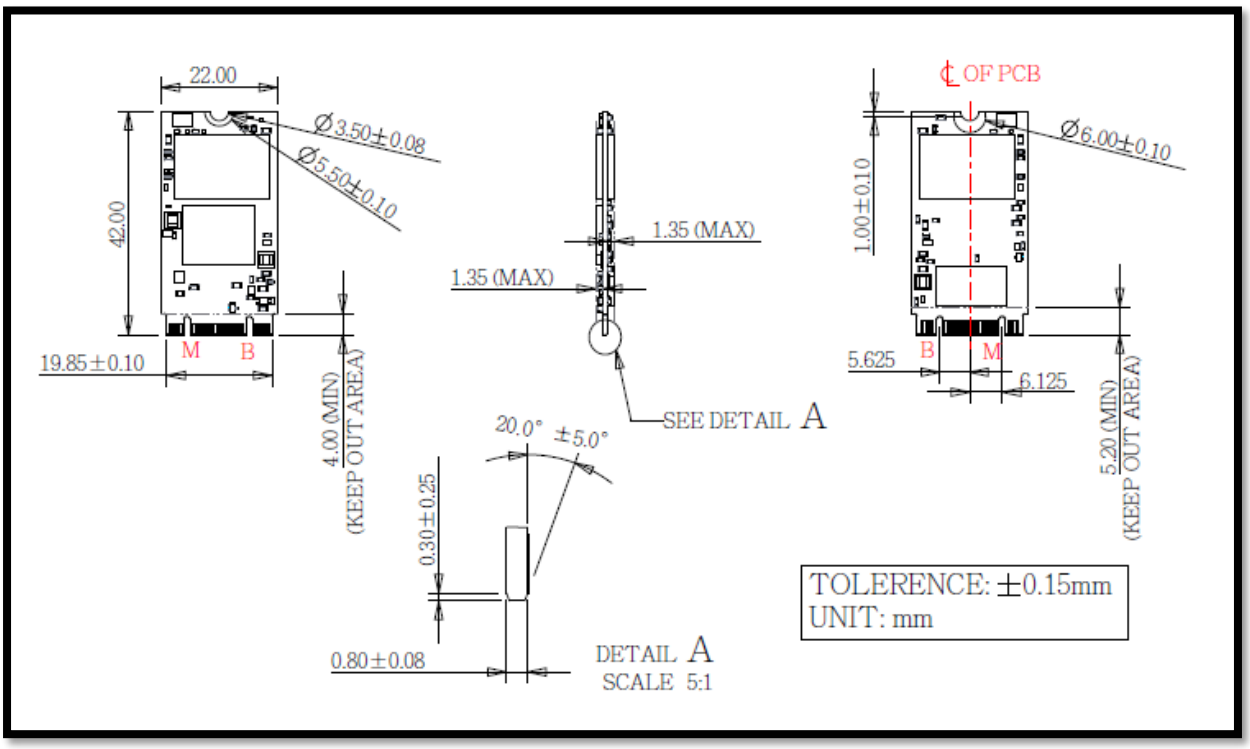

Figure 2: Innodisk M.2 (S42) 3TG6-P diagram

2.11 Assembly Weight

An Innodisk M.2 (S42) 3TG6-P within flash ICs, 512GB's weight is 3.9 grams approximately.

2.12 Seek Time

Innodisk M.2 (S42) 3TG6-P is not a magnetic rotating design. There is no seek or rotational latency required.

2.13 Hot Plug

The SSD support hot plug function and can be removed or plugged-in during operation. User has to avoid hot plugging the SSD which is configured as boot device and installed operation system.

Surprise hot plug : The insertion of a SATA device into a backplane (combine signal and power) that has power present. The device powers up and initiates an OOB sequence.

Surprise hot removal: The removal of a SATA device from a powered backplane, without first being placed in a quiescent state.

2.14 NAND Flash Memory

Innodisk M.2 (S42) 3TG6-P uses Triple Level Cell (TLC) NAND flash memory, 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 M.2 (S42) 3TG6-P from the system level, including the major hardware blocks.

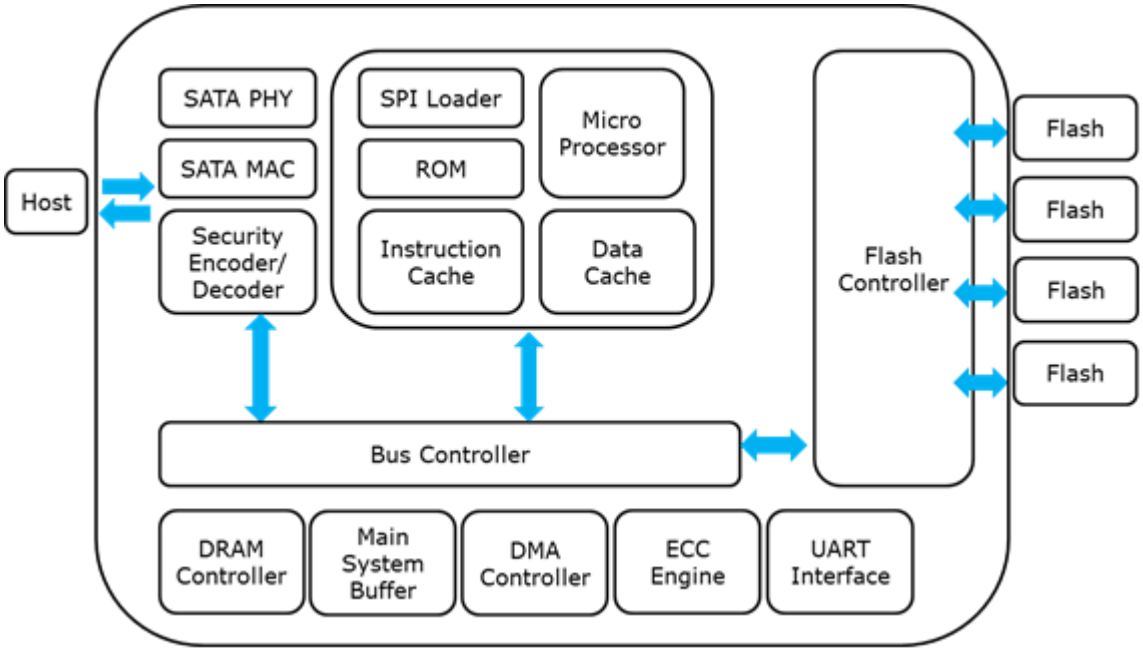

Figure 3: Innodisk M.2 (S42) 3TG6-P Block Diagram

Innodisk M.2 (S42) 3TG6-P 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. The AES engine was built in the controller. When M.2 (S42) 3TG6-P is initiated with Firmware, AES engine will generate a random number to be an AES key. Each SSD has a unique AES key when it leaves the factory.

3.2 SATA III Controller

Innodisk M.2 (S42) 3TG6-P is designed with 88NV1120, 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 2 channels for flash interface.

3.3 Error Detection and Correction

Innodisk 2.5”SATA SSD 3TG6-P 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 M.2 (S42) 3TG6-P 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

Innodisk’s 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. Innodisk’s 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 M.2 (S42) 3TG6-P series is default enable the Die RAID function for the industrial application.

3.11 M.2 (S42) 3TG6-P AES function flow chart

In order to complete the physical security layer of protection, encryption needs to be paired with an ATA user password by ATA security command. After setting the authorized key by ATA security command, every time when you power on the system with SSD encrypted, you will be requested for a password to access the SSD. If the password is correct, the SSD will run well; if not, then you will not be able to access the SSD then.

3.11.1 Encrypted Key Management

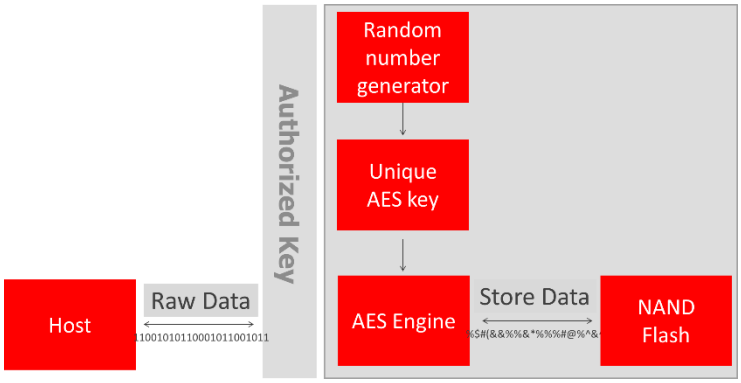

Figure 4: Innodisk M.2 (S42) 3TG6-P AES flow chart

Innodisk M.2 (S42)3TG6-P includes two methods of key management to apply to different applications. The first is a standard approach that allows the firmware to generate a random number and a unique key when it leaves the factory. This method ensures that the user can easily apply the SSD with the data encrypted key. Another approach is to meet unique customer requirements with an encrypted key generated by an SSD from the SATA interface host. The SSD must keep the encrypted key value when receiving the reset commands. This method works best for the SSD as a removable device in different systems. Innodisk provides the test tool to execute the AES hardware encryption. This user-friendly tool, developed by Innodisk Corporation, allows

the customer to use/test encryption functions.

3.11.2 Authorized Key Management

In order to complete the physical security layer of protection, encryption needs to be bundled with an ATA user password provided by an ATA Security command. Unlike the AES key, the authorized key must be set by the user via the BIOS configuration. Every time you power on the system with SSD encryption, a password request prompt is sent to access the SSD. If the password is correct, the SSD will run well; if not, you will not be able to access the SSD.

Command	Command Code
SECURITY SET PASSWORD	0XF1
SECURITY UNLOCK	0XF2
SECURITY ERASE PREPARE	0XF3
SECURITY ERASE UNIT	0XF4
SECURITY FREEZE LOCK	0XF5
SECURITY DISABLE PASSWORD	0XF6

3.11.3 TCG OPAL

OPAL is a set of specifications for features of data storage devices that enhance security. These specifications are published by the Trusted Computing Group's Storage Work Group. Innodisk M.2 (S42) 3TG6-P is compliant with TCG OPAL 2.0(*1). The capability of TCG OPAL Security mode allows multiple users with independent access control to read/write/erase independent data areas (LBA ranges). Each locking range adjusts by authenticated authority. Note that by default there is a single "Global Range" that encompasses the whole user data area. In TCG Opal Security Mode, Revert, Revert SP and GenKey command can erase all of data including global range and locking range; in the meantime generate the new encrypted key.

*1. You need to install TCG OPAL software to implement OPAL function, which is supplied by TCG OPAL software developed company

4. Installation Requirements

4.1 M.2 (S42) 3TG6-P Pin Directions

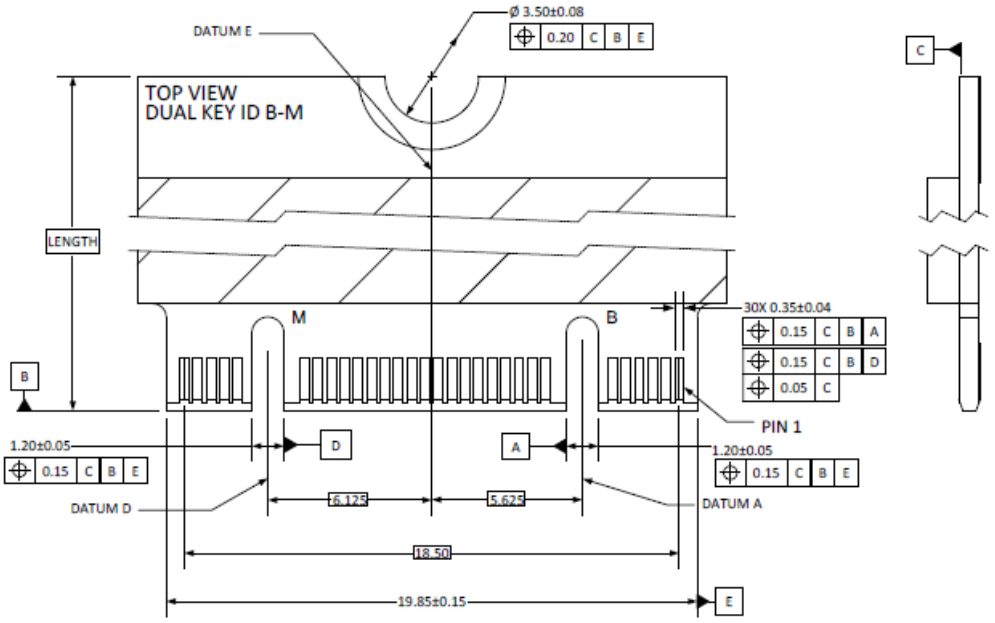

Figure 5: Signal Segment and Power Segment

4.2 Electrical Connections for M.2 (S42) 3TG6-P

A Serial ATA device may be either directly connected to a host or connected to a host through a cable. For connection via cable, the cable should be no longer than 1meter. 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 M.2 (S42) 3TG6-P can be configured as a boot device.

5. SMART Feature Set

Innodisk 3TG6-P series support the SMART command set and defines some vendor-specific data to report SMART attributes of SSD.

Table 10: 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 3TG6-P series SMART data attributes are listed in following table.

Table 11: SMART attribute

Attribute ID (hex)	Value	Raw Attribute Value						Rsv	Attribute Name
05	64_{hex}	LSB			MSB	00	00	00	Later Bad
09	LSB	LSB			MSB	00	00	00	Power-On hours Count
0C	LSB	LSB			MSB	00	00	00	Drive Power Cycle Count
A3	LSB	LSB					MSB	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	64_{hex}	LSB	00	00	00	00	00	00	Device Life
AA	64_{hex}	LSB					MSB	00	Spare Block Count
AB	LSB	LSB					MSB	00	Program fail count
AC	LSB	LSB					MSB	00	Erase fail count
B8	00	LSB			MSB	00	00	00	Error Corrected Count
BB	00	LSB			MSB	00	00	00	Reported Uncorrect Count

C0	LSB	LSB			MSB	00	00	00	Unexpected Power Loss Count
C2	Cur. *	Cur.*	00	MIN	00	MAX	03	Cur. *	Temperature
E5	64_{hex}	ID 0	ID 1	ID 2	ID 3	ID 4	ID 5	00	Flash ID
EB	00		MSB	LSB	MSB	LSB	MSB	LSB	Later bad block info (Read/Write/Erase)
F1	64_{hex}	LSB					MSB	00	Total LBA written(LBA=32MB)
F2	64_{hex}	LSB					MSB	00	Total LBA read(LBA=32MB)

Cur. * =Current

6. AES Algorithm Certification

The following provides technical information about controller implementations that have been validated as confirming to the Advanced Encryption Standard (AES) Algorithm, Deterministic Random Bit Generator (DRBG) Algorithm, and Secure Hash Standard (SHS).

6.1 AES Algorithm

Val. No	Operational Environment	Val. Date	Modes/States/Key sizes/Description/Notes
AES 3668	VCS Compiler version J-2014.12-1 simulator environment	Dec/11/2015	A high-speed, low gate count AES hardware module supporting different modes of operation, including ECB, CBC, CTR and XTS. ECB (Key Length: 128/256) CBC(Key Length: 128/256) CTR(Key Length: 128/256) XTS (Key Length: 128/256)

6.2 SHS Algorithm

Val. No	Operational Environment	Val. Date	Modes/States/Key sizes/Description/Notes
SHS 978	NCVerilog 5.5 simulation environmen0	Mar./25/2009	A compact Hash engine supporting the SHA-1, SHA-224 and SHA-256 standards. For HMAC operations, key length of up to 512 bits is supported. Configuration, control and status checking are done through the popular APB interface. A simple FIFO-like interface is employed for data input/output.

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	**G**	**M**	**2**	**4**	**-**	**3**	**2**	**G**	**M**	**7**	**2**	**E**	**C**	**A**	**D**	**F**	**-**	**X**	**X**	**X**

Definition		
Code 1st (Disk)		**Code 14th (Operation Temperature)**
D : Disk		C: Standard Grade (0℃~ +70℃)
Code 2nd (Feature set)		W: Industrial Grade (-40℃~ +85℃)
G : EverGreen series		
Code 3rd ~5th (Form factor)		**Code 15th (Internal control)**
M24: M.2 Type 2242-D2-B-M		1~9: TSOP PCB version.
		A: BGA PCB version.
Code 7th ~9th (Capacity)		**Code 16th (Channel of data transfer)**
A28: 128GB	B56:256GB	C12:512GB	D: Dual Channels
			Q: Quad Channels
Code 10th ~12th (Controller)		**Code 17th (Flash Type)**
M72: 3TG6-P with AES		F: Kioxia 3D TLC
Code 13th (Flash mode)		**Code 19th ~21st (Customize code)**
E: 64 layers 3D TLC		