innodisk

Total Solution For Industrial Flash Storage

CFexpress

3TE6 Series

Customer: _____

Customer Part Number: _____

Innodisk Part Number: _____

Innodisk Model Name: _____

Date: _____

Innodisk Approver	Customer Approver

Features:

- PCIe Gen 3 x 2, NVMe SSD
- Kioxia 3D TLC NAND
- CFexpress 3TE6
- iPower Guard
- iData Guard
- Dynamic Thermal Management
- Hybrid Write Mode with SLC Cache Enable
- Write Protect Function

Performance:

- Sequential Read up to 2,000 MB/s
- Sequential Write up to 1,900 MB/s

Power Requirements:

Input Voltage:	3.3V± 5%
Max Operating Wattage:	3.1W
Idle Wattage:	1.2W

Reliability:

Capacity	TBW	DWPD
64GB	27	0.46
128GB	93	0.68
256GB	206	0.75
512GB	471	0.86
1TB	1086	1

Data Retention	1 Year
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
1.0	Official Release	Mar., 2021
2.0	Add 112L 3D TLC Information TPS format adjustment Performance and TBW adjustment according to [PCN_F2136] PCIe 3TE6 Firmware Update	Oct., 2021
2.1	Revised transfer mode	Apr., 2022
2.2	Update Power consumption & Product Information	Sep., 2023
2.3	Update Mechanical Drawing	Jan., 2024

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1. Product Overview

1.1 Introduction of Innodisk CFexpress 3TE6

Innodisk CFexpress 3TE6 adopts CFexpress Version 1.0 type B Form-Factor. With PCIe interface and TLC NAND Flash, CFexpress 3TE6 supports PCIe Gen III x2 and is compliant with NVMe 1.3, providing excellent top and sustained performance. Moreover, it adopts TLC NAND Flash providing high endurance and reliability. With sophisticated error detection and correction (ECC) functions, the module can ensure full End-to-end Data Path Protection that secures the data transmission between host system and NAND Flash.

Innodisk CFexpress 3TE6 is a small and removable memory card providing low latency and extreme speed but with low power consumption. It is ideal for gaming, edge computing and professional digital recording.

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 CFexpress 3TE6 is available in follow capacities within TLC flash ICs

CFexpress 3TE6 64GB
CFexpress 3TE6 128GB
CFexpress 3TE6 256GB
CFexpress 3TE6 512GB
CFexpress 3TE6 1TB

Figure 1: Innodisk CFexpress 3TE6 (type B)

1.3 PCIe Interface

Innodisk CFexpress 3TE6 supports PCIe Gen III interface and compliant with NVMe 1.3. CFexpress 3TE6 can work under PCIe Gen 1, Gen 2 and Gen 3.

Most of operating systems includes NVMe in-box driver now. For more information about the driver support in each OS, please visit https://nvmexpress.org/drivers.

2. Product Specifications

2.1 Capacity and Device Parameters

CFexpress 3TE6 device parameters are shown in Table 1.

Table 1: Device parameters

Capacity	Cylinders	Heads	Sectors	LBA	User Capacity(MB)
64GB	16383	16	63	117231408	57242
128GB				234441648	114473
256GB				468862128	228937
512GB				937703088	457863
1TB				1875385008	915715

2.2 Performance

Burst Transfer Rate: 2GB/s

Table 2: Performance – 64 Layers 3D TLC

Capacity	Unit	64GB	128GB	256GB	512GB	1TB
Sequential* Read (Q32T1)	MB/s	640	1,200	1,600	1,600	2,000
Sequential* Write (Q32T1)		110	530	600	1,600	1,900
Sustained Sequential Read (Avg.) ***		420	540	490	960	960
Sustained Sequential Write (Avg.) ***		80	160	180	640	1,000
4KB Random* Read (Q8T8)	IOPS	37,000	77,000	86,000	235,000	285,000
4KB Random* Write (Q8T8)		20,000	41,000	55,000	298,000	343,000

Note: * Performance results are measured in Room Temperature with Out-of-Box devices and may vary depending on overall system setup. In addition, 3TE6 series adopt hybrid mode which enables SLC Cache up to 3% of total user capacity followed by TLC direct write to strike balance between burst performance and steady overall stability.

Note: ** Performance results are based on CrystalDiskMark 6.0.2 with file size 1000MB. Unit of 4KB items is I.O.P.S.

Note: *** Performance results are based on AIDA 64 v5.98 with block size 1MB of Linear Read & Write Test Item.

Table 3: Performance- 112 Layers 3D TLC

Capacity	Unit	128GB	256GB	512GB	1TB
Sequential* Read (Q32T1)	MB/s	780	1,600	1,850	1,850
Sequential* Write (Q32T1)		550	1,100	1,600	1,650
Sustained Sequential Read (Avg.)***		490	490	960	1,150
Sustained Sequential Write (Avg.)***		100	210	400	770
4KB Random** Read (Q8T8)	IOPS	44,000	89,000	165,000	296,000
4KB Random** Write (Q8T8)		24,000	50,000	292,000	309,000

Note: * Performance results are 3TE6 with Kioxia BiCS5 NAND composition measured in Room Temperature with Out-of-Box devices and may vary depending on overall system setup. In addition, 3TE6 series adopt hybrid mode whicj enables SLC cache followed by TLC direct write to strike balance between burst performance and steady overall stability.

Note: ** Performance results are based on CrystalDiskMark 6.0.2 with file size 1000MB. Unit of 4KB item is IOPS.

Note: *** 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 CFexpress 3TE6 Power Requirement

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

2.3.2 Power Consumption

Table 5: Typical Power Consumption

Mode	Power Consumption (W)
Read	3.1
Write	3.0
Idle	1.2
Power-on Peak	1.8

Target: CFexpress 3TE6 1TB

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 CFexpress 3TE6

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 CFexpress 3TE6

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)

Table 8 summarizes the MTBF prediction results for various CFexpress 3TE6 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: CFexpress 3TE6 MTBF

Product	Condition	MTBF (Hours)
Innodisk CFexpress 3TE6	Telcordia SR-332 GB, 25°C	>3,000,000

2.5 CE and FCC Compatibility

CFexpress 3TE6 conforms to CE and FCC requirements.

2.6 RoHS Compliance

CFexpress 3TE6 is fully compliant with RoHS directive.

2.7 Reliability

Table 9: CFexpress 3TE6 TBW

Parameter	Value
Flash endurance	3,000 P/E cycles
Error Correct Code	Support(LDPC)
Data Retention	Under 40°C: 10 Years at Initial NAND Status (PE cycles under 100);1 Year at NAND Life End (PE cycles reach 3,000)

TBW* (Total Bytes Written) Unit: TB

Capacity	Sequential workload	Client workload
64GB	170	27
128GB	340	93
256GB	680	206
512GB	1363	471
1TB	2727	1086

* Note:

1. Sequential: Mainly sequential write are estimated by PassMark Burnin Test v8.1 pro.
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

CFexpress 3TE6 support following transfer mode:

PCIe Gen III 2GB/s

PCIe Gen II 1GB/s

PCIe Gen I 0.5GB/s

2.9 Pin Assignment

Innodisk CFexpress 3TE6 follows CFexpress 1.0 type B pinout define. See Table 10 for CFexpress 3TE6 pin assignment.

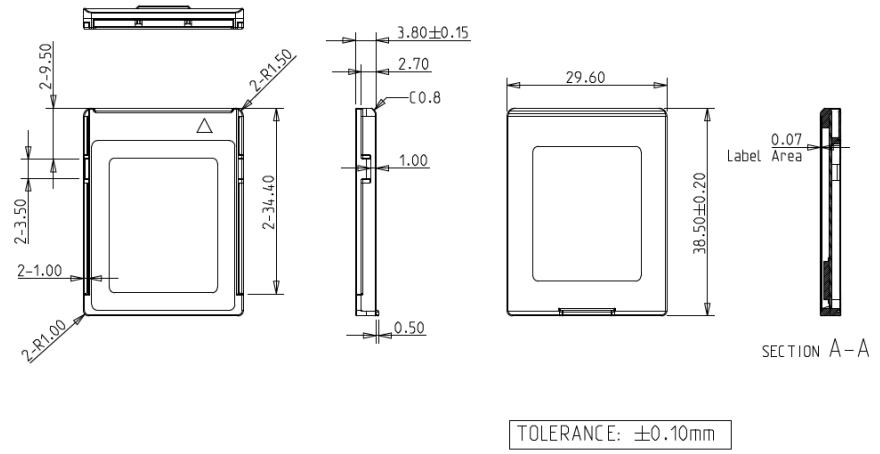
Table 10: Innodisk CFexpress 3TE6 Pin Assignment

Pin No.	Signal #	I/O
21	GND	
20	PETp0	I
19	PETn0	I
18	GND	
17	PERp0	O
16	PERn0	O
15	GND	
14	REFCLK+	I
13	REFCLK-	I
12	INS#	O
11	CLKREQ#	O
10	+3.3V	
9	PERST#	I
8	Reserved(Write	I
7	Reserved	
6	PETp1	I
5	PETn1	I
4	GND	
3	PERp1	O
2	PERn1	O
1	GND	

2.10 Mechanical Dimensions

CFexpress Type B

Without HW WP switch



With HW WP switch

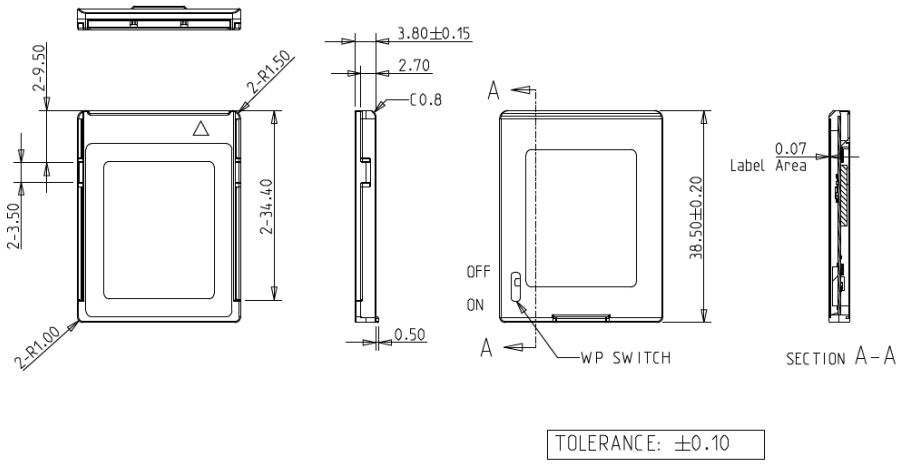


Figure 2: Innodisk CFexpress 3TE6 diagram

2.11 Assembly Weight

An Innodisk CFexpress 3TE6 within NAND flash ICs, 1TB's weight is 14 grams approximately.

2.12 Seek Time

Innodisk CFexpress 3TE6 is not a magnetic rotating design. There is no seek or rotational latency required.

2.13 NAND Flash Memory

Innodisk CFexpress 3TE6 uses TLC NAND flash memory, which is non-volatility, high reliability and high speed memory storage.

3. Theory of Operation

3.1 Overview

Figure 3 shows the operation of Innodisk CFexpress 3TE6 from the system level, including the major hardware blocks.

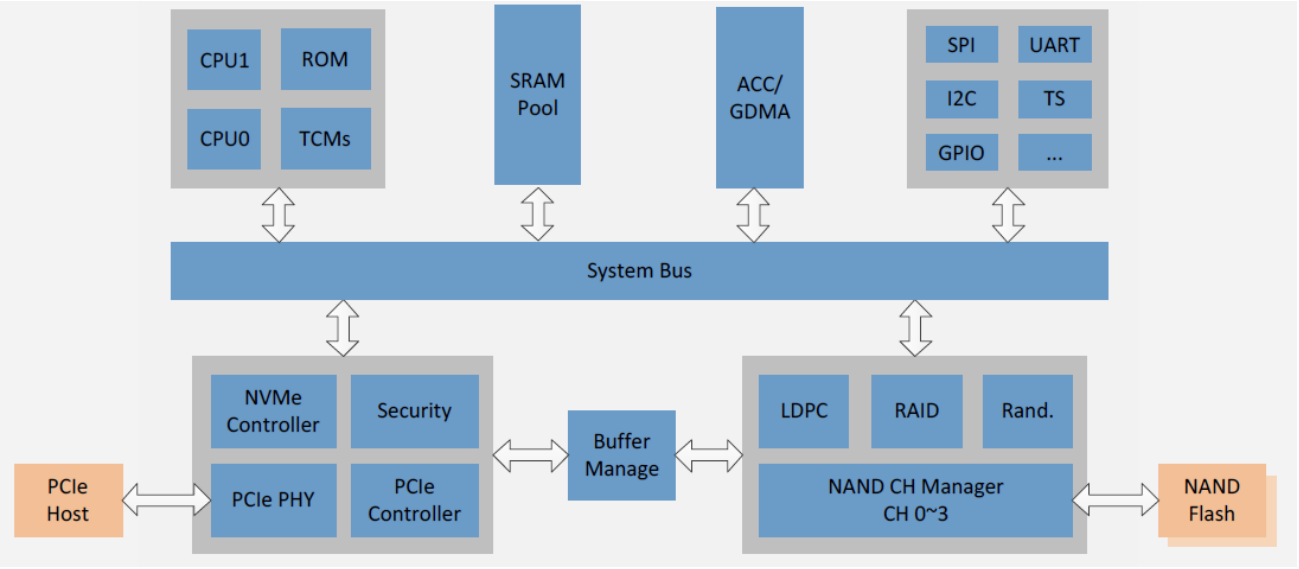


Figure 3: Innodisk CFexpress 3TE6 Block Diagram

Innodisk CFexpress 3TE6 integrates a PCIe Gen III x4 controller and NAND flash memories. Communication with the host occurs through the host interface, using the standard NVMe protocol. Communication with the flash device(s) occurs through the flash interface.

3.2 PCIe Gen III x4 Controller

Innodisk CFexpress 3TE6 is designed with innodisk ID303, a PCIe Gen III x4 controller which is compliant with NVMe 1.3, up to 32.0Gbps transfer speed. In addition, it is compliant with PCIe Gen. 1, Gen. 2 and Gen. 3 specification. The controller supports up to four channels for flash interface.

3.3 Error Detection and Correction

Innodisk CFexpress 3TE6 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 CFexpress 3TE6 uses a combination of two types of wear leveling- dynamic and static wear leveling- to distribute write cycling across an SSD and balance erase count of each block, 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 Garbage Collection/TRIM

Garbage collection and TRIM technology 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.

3.7 End to End Data Path Protection

End-to-end Data Path Protection that secures the data transmission between host system and NAND Flash. In the transmission path, no matter in or out, all buffer and storage implement Error Code Correction that optimizes the data integrity in the whole transmission of SSD.

3.8 Thermal Management

CFexpress 3TE6 has built-in thermal sensor which can detect environment temperature of SSD. In the meantime, firmware will monitor the thermal sensor to prevent any failure of

overheating. During extreme temperature, firmware will adjust the data transfer behavior to maintain the SSD’s reliable operation.

3.9 iData Guard

iData Guard is a comprehensive data protection mechanism that functions before and after a sudden power outage to the 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.

4. Installation Requirements

4.1 CFexpress 3TE6 Insert Directions

When CFexpress card is inserted to the host slot, INS# is internally strapped to ground.

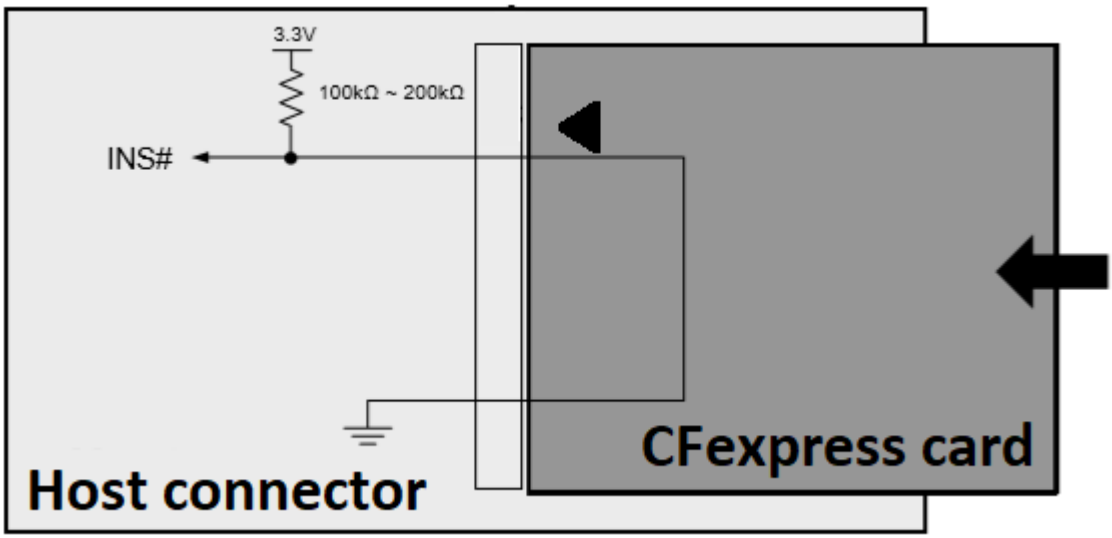


Figure 4: Signal Segment and Power Segment

4.2 Electrical Connections for CFexpress 3TE6

CFexpress 3TE6 is PCIe interface; it follows CFexpress 1.0 type B pin assignment. For pin define please refer to 2.9 Pin Assignment.

4.3 Device Drive

CFexpress 3TE6 is compliant with NVMe 1.3. To make sure NVMe storage devices can work in your system, both operation system and BIOS can support NVMe. Most of OS includes NVMe in-box driver now. For more information about the NVMe driver support in each OS, please visit the website https://nvmexpress.org/drivers. For BIOS NVMe driver support please contact with your motherboard manufacturers.

4.4 Write Protection (Optional)

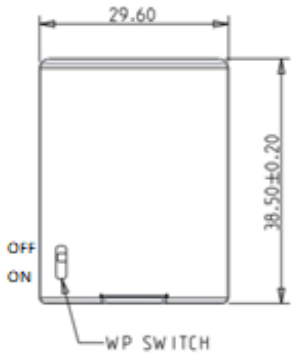


Figure 5: Write Protect Switch

Innodisk CFexpress 3TE6 within the write-protect function could prevent the device from modification and deletion. Write-protected data that is read only, that is, users could not write to it, edit it, append data to it, or delete it. When users would like to make sure that neither themselves nor others could modify or destroy the file, users could switch on write-protection. Thus, CFexpress 3TE6 could process write-protect mechanism and disable flash memory to be written-in any data. Only while the system power-off, users could switch on write-protection. Write-protection could not be switched-on, after OS booting.

5. SMART / Health Information

This log page is used to provide SMART and general health information. The information provided is over the life of the controller and is retained across power cycles. More details about Set Features command, please refer to NVM Express 1.3.

5.1 Get Log Page(Log Identifier 02h)

Innodisk 3TE6 series SMART / Health Information Log are listed in following table.

Table 11: Get Log Page – SMART / Health Information Log

<table>
<tr><th>Bytes</th><th>Description</th></tr>
<tr><td>0</td><td>Critical Warning: This field indicates critical warnings for the state of the controller. Each bit corresponds to a critical warning type; multiple bits may be set. If a bit is cleared to ‘0’, then that critical warning does not apply. Critical warnings may result in an asynchronous event notification to the host. Bits in this field represent the current associated state and are not persistent.
<table>
<tr><th>Bit</th><th>Definition</th></tr>
<tr><td>00</td><td>If set to ‘1’, then the available spare space has fallen below the threshold.</td></tr>
<tr><td>01</td><td>If set to ‘1’, then a temperature is above an over temperature threshold or below an under</td></tr>
<tr><td>02</td><td>If set to ‘1’, then the NVM subsystem reliability has been degraded due to significant media related</td></tr>
<tr><td>03</td><td>If set to ‘1’, then the media has been placed in read only mode.</td></tr>
<tr><td>04</td><td>If set to ‘1’, then the volatile memory backup device has failed. This field is only valid if the</td></tr>
<tr><td>07:05</td><td>Reserved</td></tr>
</table></td></tr>
<tr><td>2:1</td><td>Composite Temperature: Contains a value corresponding to a temperature in degrees Kelvin that represents the current composite temperature of the controller and namespace(s) associated with that controller. The manner in which this value is computed is implementation specific and may not represent the actual temperature of any physical point in the NVM subsystem. The value of this field may be used to trigger an asynchronous event.</td></tr>
</table>

	Warning and critical overheating composite temperature threshold values are reported by the WCTEMP and CCTEMP fields in the Identify Controller data structure.
3	**Available Spare:** Contains a normalized percentage (0 to 100%) of the remaining spare capacity available.
4	**Available Spare Threshold:** When the Available Spare falls below the threshold indicated in this field, an asynchronous event completion may occur. The value is indicated as a normalized percentage (0 to 100%).
5	**Percentage Used:** Contains a vendor specific estimate of the percentage of NVM subsystem life used based on the actual usage and the manufacturer's prediction of NVM life. A value of 100 indicates that the estimated endurance of the NVM in the NVM subsystem has been consumed, but may not indicate an NVM subsystem failure. The value is allowed to exceed 100. Percentages greater than 254 shall be represented as 255. This value shall be updated once per power-on hour (when the controller is not in a sleep state). Refer to the JEDEC JESD218A standard for SSD device life and endurance measurement techniques.
31:6	**Reserved**
47:32	**Data Units Read:** Contains the number of 512 byte data units the host has read from the controller; this value does not include metadata. This value is reported in thousands (i.e., a value of 1 corresponds to 1000 units of 512 bytes read) and is rounded up. When the LBA size is a value other than 512 bytes, the controller shall convert the amount of data read to 512 byte units. For the NVM command set, logical blocks read as part of Compare and Read operations shall be included in this value.
63:48	**Data Units Written:** Contains the number of 512 byte data units the host has written to the controller; this value does not include metadata. This value is reported in thousands (i.e., a value of 1 corresponds to 1000 units of 512 bytes written) and is rounded up. When the LBA size is a value other than 512 bytes, the controller shall convert the amount of data written to 512 byte units. For the NVM command set, logical blocks written as part of Write operations shall be included in this value. Write Uncorrectable commands shall not impact this value.
79:64	**Host Read Commands:** Contains the number of read commands completed by the controller. For the NVM command set, this is the number of Compare and Read commands.

95:80	**Host Write Commands:** Contains the number of write commands completed by the controller. For the NVM command set, this is the number of Write commands.
111:96	**Controller Busy Time:** Contains the amount of time the controller is busy with I/O commands. The controller is busy when there is a command outstanding to an I/O Queue (specifically, a command was issued via an I/O Submission Queue Tail doorbell write and the corresponding completion queue entry has not been posted yet to the associated I/O Completion Queue). This value is reported in minutes.
127:112	**Power Cycles:** Contains the number of power cycles.
143:128	**Power On Hours:** Contains the number of power-on hours. This may not include time that the controller was powered and in a non-operational power state.
159:144	**Unsafe Shutdowns:** Contains the number of unsafe shutdowns. This count is incremented when a shutdown notification (CC.SHN) is not received prior to loss of power.
175:160	**Media and Data Integrity Errors:** Contains the number of occurrences where the controller detected an unrecovered data integrity error. Errors such as uncorrectable ECC, CRC checksum failure, or LBA tag mismatch are included in this field.
191:176	**Number of Error Information Log Entries:** Contains the number of Error Information log entries over the life of the controller.
195:192	**Warning Composite Temperature Time:** Contains the amount of time in minutes that the controller is operational and the Composite Temperature is greater than or equal to the Warning Composite Temperature Threshold (WCTEMP) field and less than the Critical Composite Temperature Threshold (CCTEMP) field in the Identify Controller data structure. If the value of the WCTEMP or CCTEMP field is 0h, then this field is always cleared to 0h regardless of the Composite Temperature value.
199:196	**Critical Composite Temperature Time:** Contains the amount of time in minutes that the controller is operational and the Composite Temperature is greater than the Critical Composite Temperature Threshold (CCTEMP) field in the Identify Controller data structure. If the value of the CCTEMP field is 0h, then this field is always cleared to 0h regardless of the Composite Temperature value.
201:200	**Temperature Sensor 1:** Contains the current temperature reported by temperature sensor 1.
203:202	**Temperature Sensor 2:** Contains the current temperature reported by temperature sensor 2.

205:204	**Temperature Sensor 3:** Contains the current temperature reported by temperature sensor 3.
207:206	**Temperature Sensor 4:** Contains the current temperature reported by temperature sensor 4.
209:208	**Temperature Sensor 5:** Contains the current temperature reported by temperature sensor 5.
211:210	**Temperature Sensor 6:** Contains the current temperature reported by temperature sensor 6.
213:212	**Temperature Sensor 7:** Contains the current temperature reported by temperature sensor 7.
215:214	**Temperature Sensor 8:** Contains the current temperature reported by temperature sensor 8.
511:216	**Reserved**

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**	**C**	**F**	**X**	**-**	**6**	**4**	**G**	**D**	**D**	**1**	**E**	**C**	**A**	**D**	**F**	**(W)**	**-**	**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℃)
E : Embedded series		
Code 3rd ~5th (Form factor)		**Code 15th (Internal control)**
CFX: CFexpress (Type B)		A~Z: BGA PCB version.
Code 7th ~9th (Capacity)		**Code 16th (Channel of data transfer)**
64G: 64GB	A28G: 128GB	B56: 256GB	D: Dual Channels
C12: 512GB	01T: 1TB		Q: Quad Channels
Code 10th ~12th (Controller)		**Code 17th (Flash Type)**
DD1:3TE6 Series		F: Kioxia 3D TLC
Code 13th (Flash mode)		**Code 18th**
E: 64 layers 3D TLC		W: H/W Write Protect function
K: 112 layers 3D TLC		**Code 19th ~21st (Customize code)**