CFX PCIe/NVMe SSD 720-C Datasheet

(SQF-CFXxx-xxxGCEDC)

CONTENTS

Revision History

Rev.	Date	History
1.0	2021/1/29	1. Preliminary release

1. Overview

Advantech SQFlash 720-C series CFX PCIe/NVMe SSD (Solid State Drive) delivers all the advantages of flash disk technology with PCIe Gen3 x 2 interface. The SQF-CFX could provide the capacity range from 128GB to 512GB. Moreover, it can reach up to 1700 MB/s[1] read as well as 1200/s write high performance. Its lower power consumption makes it an ideal storage choice for high performance embedded platforms.

Notes:
1. Achieved by 512GB SSD at FOB (fresh-out-of-box) state on CrystalDiskMark 6.0

2. Features

- **Capacity**
  - 3D TLC : 128GB, 256GB, 512GB
  - Support 32-bit addressing mode
- **PCIe Interface**
  - Compliant with NVMe 1.3
  - PCI Express Base 3.1
  - PCIe Gen 3 x 2 lane & backward compatible to PCIe Gen 2 and Gen 1
  - Support up to QD 128 with queue depth of up to 64K
  - Support power management (optional)
- **Operating Voltage：3.3V**
- **Support LDPC + RAID ECC algorithm**
- **Support SMART and TRIM commands**
- **Temperature Ranges[1]**
  - Commercial Temperature
    - 0℃ to 70℃ for operating
    - -40℃ to 85℃ for storage
  - Industrial Temperature
    - -40℃ to 85℃ for operating
    - -40℃ to 85℃ for storage

*Note : 1. Based on SMART Attribute (Byte index [2 :1] of PCIe-SIG standard, which measured by thermal sensor

- **Mechanical Specification**
  - Shock：1,500G / 0.5ms
  - Vibration：20G / 80~2,000Hz
- **Humidty**
  - Humidity：5% ~ 95% under 55℃
- **Acquired RoHS、WHQL、CE、FCC Certificate**
- **Acoustic：0 dB**
- **Dimension：38.5 mm x 29.6 mm x 3.8 mm**

3. Specification Table

■ Performance

* Preliminary, subject to change based on firmware migration. (Without Host Memory Buffer)

		Sequential Performance (MB/sec)		Random Performance (IOPS @4K)	
		Read	Write	Read	Write
3D TLC (BiCS4)	128 GB	1,550	360	70K	120K
	256 GB	1,700	1,100	150K	250K
	512 GB	1,700	1,400	210K	295K

NOTES:
1. Performance was estimated based on Toshiba BiCS4 TLC NAND flash.
2. Performance may differ according to flash configuration and platform.
3. The tables are for reference only. Any criteria for accepting goods shall be further discussed based on different flash configurations.
4. Performance is measured with the following conditions
   (a) CrystalDiskMark 6.0, 1GB range, QD=32
   (b) IOMeter, 1GB range, 4K data size, QD=32
   (c) ATTO, transfer Size 8192 KB
5. OS Version: Win10 (64bit), version 1703

Endurance

JEDEC defined an endurance rating TBW (TeraByte Written), following by the equation below, for indicating the number of terabytes a SSD can be written which is a measurement of SSDs' expected lifespan, represents the amount of data written to the device.

TBW = [(NAND Endurance) x (SSD Capacity)] / WAF

- **NAND Endurance**: Program / Erase cycle of a NAND flash.
  - SLC: 100,000 cycles
  - Ultra MLC: 30,000 cycles
  - MLC: 3,000 cycles
  - 3D TLC (BiCS3/ BiCS4): 3,000 cycles
- **SSD Capacity**: SSD physical capacity in total of a SSD.
- **WAF**: Write Amplification Factor (WAF), as the equation shown below, is a numerical value representing the ratio between the amount of data that a SSD controller needs to write and the amount of data that the host's flash controller writes. A better WAF, which is near to 1, guarantees better endurance and lower frequency of data written to flash memory.

WAF = (Lifetime write to flash) / (Lifetime write to host)

Endurance measurement is based on JEDEC 219 client workload and verified with following workload conditions,

- PreCond%full = 100%
- Trim commands enabled
- Random data pattern.

- **SQFlash 720-C CFX TBW**

	WAF	TBW
		3D TLC (BiCS4)
128 GB	3.5	110
256 GB	3.2	240
512 GB	2.9	520

4. General Description

■ Error Correction Code (ECC)

Flash memory cells will deteriorate with use, which might generate random bit errors in the stored data. Thus, SQF-CFX 720-C PCIe SSD applies Phison 4th Gen LDPC (Low Density Parity Check) and RAID ECC algorithm, which can detect and correct errors occur during read process, ensure data been read correctly, as well as protect data from corruption.

■ Wear Leveling

NAND flash devices can only undergo a limited number of program/erase cycles, when flash media is not used evenly, some blocks get updated more frequently than others and the lifetime of device would be reduced significantly. Thus, wear leveling is applied to extend the lifespan of NAND flash by evenly distributing write and erase cycles across the media.

SQF 720-C series provides advanced wear leveling algorithm, which can efficiently spread out the flash usage through the whole flash media area. Moreover, by implementing both dynamic and static wear leveling algorithms, the life expectancy of the NAND flash is greatly improved.

■ Bad Block Management

Bad blocks are blocks that do not function properly or contain more invalid bits causing stored data unstable, and their reliability is not guaranteed. Blocks that are identified and marked as bad by the manufacturer are referred to as “Early Bad Blocks”. Bad blocks that are developed during the lifespan of the flash are named “Later Bad Blocks”. SQF 720-C series implements an efficient bad block management algorithm to detect the factory-produced bad blocks and manages bad blocks that appear with use. This practice prevents data being stored into bad blocks and further improves the data reliability.

■ Power Loss Protection: Flush Manager

Power Loss Protection is a mechanism to prevent data loss during unexpected power failure. DRAM is a volatile memory and frequently used as temporary cache or buffer between the controller and the NAND flash to improve the SSD performance. However, one major concern of the DRAM is that it is not able to keep data during power failure. Accordingly, SQFlash SSD applies the Flush Manager technology, only when the data is fully committed to the NAND flash will the controller send acknowledgement (ACK) to the host. Such implementation can prevent false-positive performance and the risk of power cycling issues.
In addition, it is critical for a controller to shorten the time the in-flight data stays in the controller internal cache. Thus, SQFlash applies an algorithm to reduce the amount of data resides in the cache to provide a better performance. With Flush Manager, incoming data would only have a “pit stop” in the cache and then move to NAND flash directly. Also, the onboard DDR will be treated as an “organizer” to consolidate incoming data into groups before written into the flash to improve write amplification.

■ TRIM

TRIM is a feature which helps improve the read/write performance and speed of solid state drives (SSD). Unlike hard disk drives (HDD), SSDs are not able to overwrite existing data, so the available space gradually becomes smaller with each use. With the TRIM command, the operating system can inform the SSD so that blocks of data that are no longer in use can be removed permanently. Thus, the SSD will perform the erase action, which prevents unused data from occupying blocks at all time.

■ SMART

SMART, an acronym for Self-Monitoring, Analysis and Reporting Technology, is an open standard that allows a solid state drive to automatically detect its health and report potential failures. When a failure is recorded by SMART, users can choose to replace the drive to prevent unexpected outage or data loss. Moreover, SMART can inform users impending failures while there is still time to perform proactive actions, such as save data to another device.

Over-Provision

Over Provisioning refers to the preserving additional area beyond user capacity in a SSD, which is not visible to users and cannot be used by them. However, it allows a SSD controller to utilize additional space for better performance and WAF. With Over Provisioning, the performance and IOPS (Input/Output Operations per Second) are improved by providing the controller additional space to manage P/E cycles, which enhances the reliability and endurance as well. Moreover, the write amplification of the SSD becomes lower when the controller writes data to the flash.

Thermal Throttling

The purpose of thermal throttling is to prevent any components in a SSD from over-heating during read and write operations. SQF 720-C series is designed with an external thermal sensor and with its accuracy, firmware can apply different levels of throttling to achieve the purpose of protection efficiently and proactively via SMART reading.

Advanced Device Security Features

- Advanced Encryption Standard (AES)

  An AES 256-bit encryption key is generated in the drive's security controller before the data gets stored on the NAND flash. When the controller or firmware fails, the data that is securely stored in the encryption key becomes inaccessible through the NAND flash.

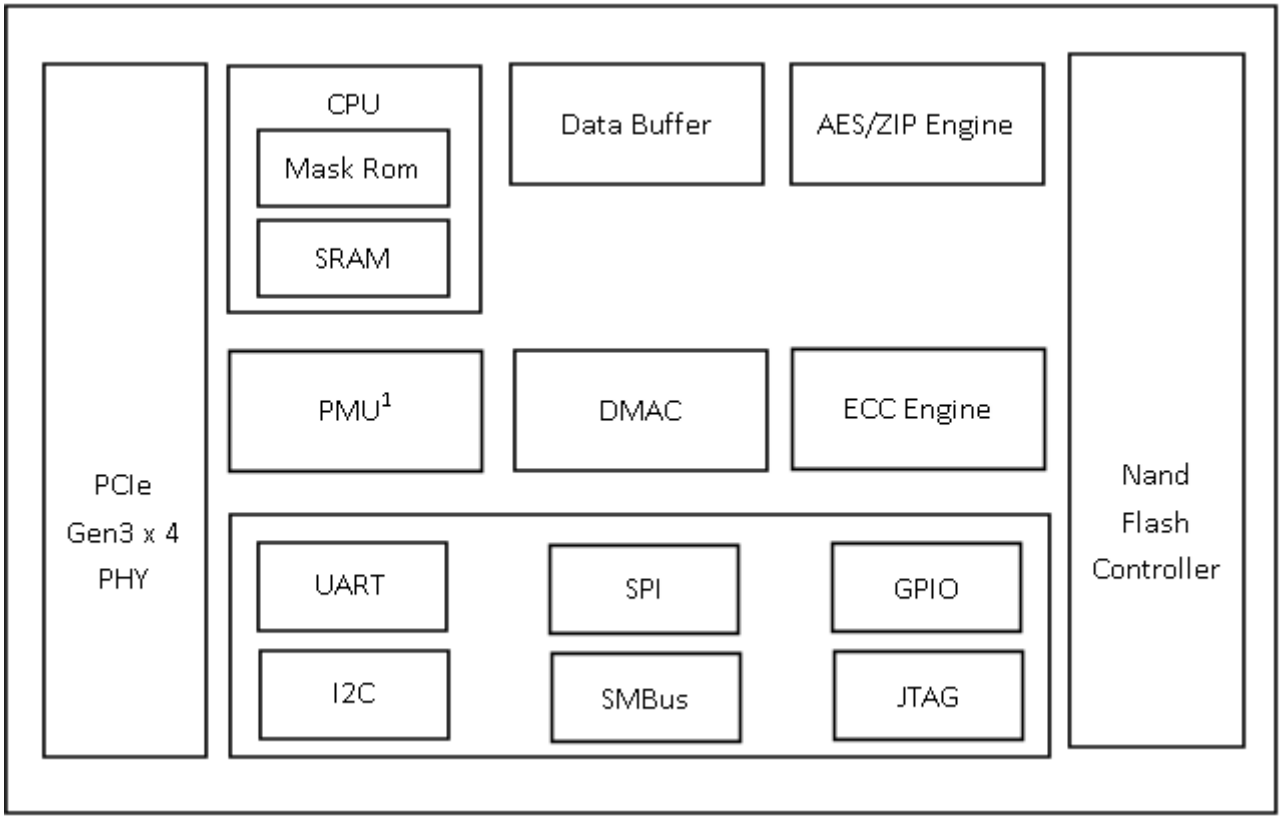
- Secure Erase

  SQFlash 720-C series supports standard NVMe command secure erase. Also, with internal AES encryption support, the erase process will start with resetting AES key. By doing so, existing data will be scrumbled within 10ms and cannot be recovered anymore. Moreover, erase flag is set when erase function is triggered, which will ensure the whole erase process can be 100% completed. Even there's power interrupt, after power resume, erase operation will be resume right away as well.

- OPAL 2.0 support

  SQFlash 720-C series supports standard OPAL 2.0 function for advance Self-Encryption Drive (SED) feature sets. Advantech provides also user friendly interface for setting disk / system bonding to prevent SSD be used in non-authorized platforms, which is called Flash Lock function.

■ Block Diagram



■ LBA value

Density	LBA
128 GB	250,069,680
256 GB	500,118,192
512 GB	1,000,215,216

5. Pin Assignment and Description

The I/O column indicates the signal direction viewed from the media: "I" indicates the signal input to the media and "O" indicates the signal output from the media. In the Connection column, "R" indicates the signal is required, "Opt" indicates the signal is optional, and "NC" indicates the signal shall not be connected.

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

1. A host pull-up resistor in the range of 100kΩ-200kΩ is required on this pin.
2. A host pull-up resistor (≥5kΩ) is required on this pin.
3. If the PCI Express Transmitter differential pair Lane 1 and Receiver differential pair Lane 1 are implemented, this pin shall be connected to ground.
4. Note that this pin is assigned to USBEN in XQD specification.

■ Signal / Pin Descriptions

Category	Signal Name	Description
PCI Express	PETp0 PETn0 PERp0 PERn0 PETp1 PETn1 PERp1 PERn1	PCI Express 8 GT/s two Lane. 2 transmitter differential pairs and 2 receiver differential pairs.
Auxiliary	REFCLK+ REFCLK-	PCI Express differential (and spread-spectrum) reference clock.
	PERST#	PCI Express functional reset.
	INS#	This signal is used for media detection and power control.
	CLKREQ#	This signal is used to indicate when REFCLK is needed for the PCI Express interface.
Power Source	+3.3V	3.3V power
Ground	GND	Ground

6. NVMe Command List

■ 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

■ Admin Commands – NVM Command Set Specific

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

■ NVM Commands

Opcode	Command Description
00h	Flush
01h	Write
02h	Read
04h	Write Uncorrectable
05h	Compare
08h	Write Zeroes
09h	Dataset Management

7. Identify Device Data

The following table details the sector data returned by the IDENTIFY DEVICE command.

Bytes	O/M	Description	Default Value
01:00	M	PCI Vendor ID (VID)	0x1987
03:02	M	PCI Subsystem Vendor ID (SSVID)	0x1987
23:04	M	Serial Number (SN)	SN
63:24	M	Model Number (MN)	Model Number
71:64	M	Firmware Revision (FR)	FW Name
72	M	Recommended Arbitration Burst (RAB)	0x01
75:73	M	IEEE OUI Identifier (IEEE)	0
76	O	Controller Multi-Path I/O and Namespace Sharing Capabilities (CMIC)	0x00
77	M	Maximum Data Transfer Size (MDTS)	0x09
79:78	M	Controller ID (CNTLID)	0x0000
83:80	M	Version (VER)	0x00010300
87:84	M	RTD3 Resume Latency (RTD3R)	(TBD)
91:88	M	RTD3 Entry Latency (RTD3E)	(TBD)
95:92	M	Optional Asynchronous Events Supported (OAES)	0x00000100
99:96	M	Controller Attributes (CTRATT)	0x00000002
111:100	-	Reserved	0x00
127:112	O	FRU Globally Unique Identifier (FGUID)	0x00
239:128	-	Reserved	0x00
255:240	-	Refer to the NVMe Management Interface Specification for definition	0
257:256	M	Optional Admin Command Support (OACS)	0x0017
258	M	Abort Command Limit (ACL)	0x00
259	M	Asynchronous Event Request Limit (AERL)	0x03
260	M	Firmware Updates (FRMW)	0x12(TBD)
261	M	Log Page Attributes (LPA)	0x06
262	M	Error Log Page Entries (ELPE)	0x0F
263	M	Number of Power States Support (NPSS)	0x04
264	M	Admin Vendor Specific Command Configuration (AVSCC)	0x01
265	O	Autonomous Power State Transition Attributes (APSTA)	0x01
267:266	M	Warning Composite Temperature Threshold (WCTEMP)	(TBD)
269:268	M	Critical Composite Temperature Threshold (CCTEMP)	(TBD)
271:270	O	Maximum Time for Firmware Activation (MTFA)	0x0000
275:272	O	Host Memory Buffer Preferred Size (HMPRE)	(TBD)
279:276	O	Host Memory Buffer Minimum Size (HMMIN)	(TBD)
295:280	O	Total NVM Capacity (TNVMCAP)	non-zero
311:296	O	Unallocated NVM Capacity (UNVMCAP)	0
315:312	O	Replay Protected Memory Block Support (RPMBS)	(TBD)
317:316	O	Extended Device Self-test Time (EDSTT)	0x001E
318	O	Device Self-test Options (DSTO)	0x01
319	M	Firmware Update Granularity (FWUG)	0x1
321:320	M	Keep Alive Support (KAS)	0x0001
323:322	O	Host Controlled Thermal Management Attributes (HCTMA)	1

325:324	O	Minimum Thermal Management Temperature (MNTMT)	(TBD)
327:326	O	Maximum Thermal Management Temperature (MXTMT)	(TBD)
331:328	O	Sanitize Capabilities (SANICAP)	0x00000006
511:316	-	Reserved	0
NVM Command Set Attributes			
512	M	Submission Queue Entry Size (SQES)	0x66
513	M	Completion Queue Entry Size (CQES)	0x44
515:514	M	Maximum Outstanding Commands (MAXCMD)	0x0080
519:516	M	Number of Namespaces (NN)	0x000000001
521:520	M	Optional NVM Command Support (ONCS)	0x005F
523:522	M	Fused Operation Support (FUSES)	0
524	M	Format NVM Attributes (FNA)	0x01
525	M	Volatile Write Cache (VWC)	0x01
527:526	M	Atomic Write Unit Normal (AWUN)	0x00FF
529:528	M	Atomic Write Unit Power Fail (AWUPF)	0x0000
530	M	NVM Vendor Specific Command Configuration (NVSCC)	0x01
531	M	Reserved	0x00
533:532	O	Atomic Compare & Write Unit (ACWU)	0x0000
535:534	M	Reserved	0x0000
539:536	O	SGL Support (SGLS)	0x0000000000
767:540	M	Reserved	0x00
IO Command Set Attributes			
2047:704	M	Reserved	0
2079:2048	M	Power State 0 Descriptor	(TBD)
2111:2080	O	Power State 1 Descriptor	(TBD)
2143:2112	O	Power State 2 Descriptor	(TBD)
2175:2144	O	Power State 3 Descriptor	(TBD)
2207:2176	O	Power State 4 Descriptor	(TBD)
…	-	(N/A)	0
3071:3040	O	Power State 31 Descriptor	(TBD)
Vendor Specific			
4095:3072	O	Vendor Specific (VS)	Reserved

■ Identify Namespace Data Structure & NVM Command Set Specific

Bytes	Description
7:0	Namespace Size (NSZE)
15:8	Namespace Capacity (NCAP)
23:16	Namespace Utilization (NUSE)
24	Namespace Features (NSFEAT)
25	Number of LBA Formats (NLBAF)
26	Formatted LBA Size (FLBAS)
27	Metadata Capabilities (MC)
28	End-to-end Data Protection Capabilities (DPC)
29	End-to-end Data Protection Type Settings (DPS)
30	Namespace Multi-path I/O and Namespace Sharing Capabilities (NMIC)
31	Reservation Capabilities (RESCAP)
32	Format Progress Indicator (FPI)
33	Deallocate Logical Block Features (DLFEAT)
35:34	Namespace Atomic Write Unit Normal (NAWUN)
37:36	Namespace Atomic Write Unit Power Fail (NAWUPF)
39:38	Namespace Atomic Compare & Write Unit (NAWWU)
41:40	Namespace Atomic Boundary Size Normal (NABSN)
43:42	Namespace Atomic Boundary Offset (NABO)
45:44	Namespace Atomic Boundary Size Power Fail (NABSPF)
47:46	Namespace Atomic Optimal IO Boundary (NOIOB)
63:48	NVM Capacity (NVMCAP)
103:64	Reserved
119:104	Namespace Globally Unique Identifier (NGUID)
127:120	IEEE Extended Unique Identifier (EUI64)
131:128	LBA Format 0 Support (LBAF0)
135:132	LBA Format 1 Support (LBAF1)
139:136	LBA Format 2 Support (LBAF2)
143:140	LBA Format 3 Support (LBAF3)
147:144	LBA Format 4 Support (LBAF4)
151:148	LBA Format 5 Support (LBAF5)
155:152	LBA Format 6 Support (LBAF6)
159:156	LBA Format 7 Support (LBAF7)
163:160	LBA Format 8 Support (LBAF8)
167:164	LBA Format 9 Support (LBAF9)
171:168	LBA Format 10 Support (LBAF10)
175:172	LBA Format 11 Support (LBAF11)
179:176	LBA Format 12 Support (LBAF12)
183:180	LBA Format 13 Support (LBAF13)
187:184	LBA Format 14 Support (LBAF14)
191:188	LBA Format 15 Support (LBAF15)
383:192	Reserved
4095:384	Vendor Specific (VS)

List of Device Identification for Each Capacity

Capacity	Byte[7:0]: Namespace Size (NSZE)
128 GB	EE7C2B0
256 GB	1DCF32B0
512 GB	3B9E12B0

8. SMART Attributes

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
[203:202]	2	Temperature Sensor 2
[205:204]	2	Temperature Sensor 3
[207:206]	2	Temperature Sensor 4

9. System Power Consumption

■ Supply Voltage

Parameter	Rating
Operating Voltage	3.3V

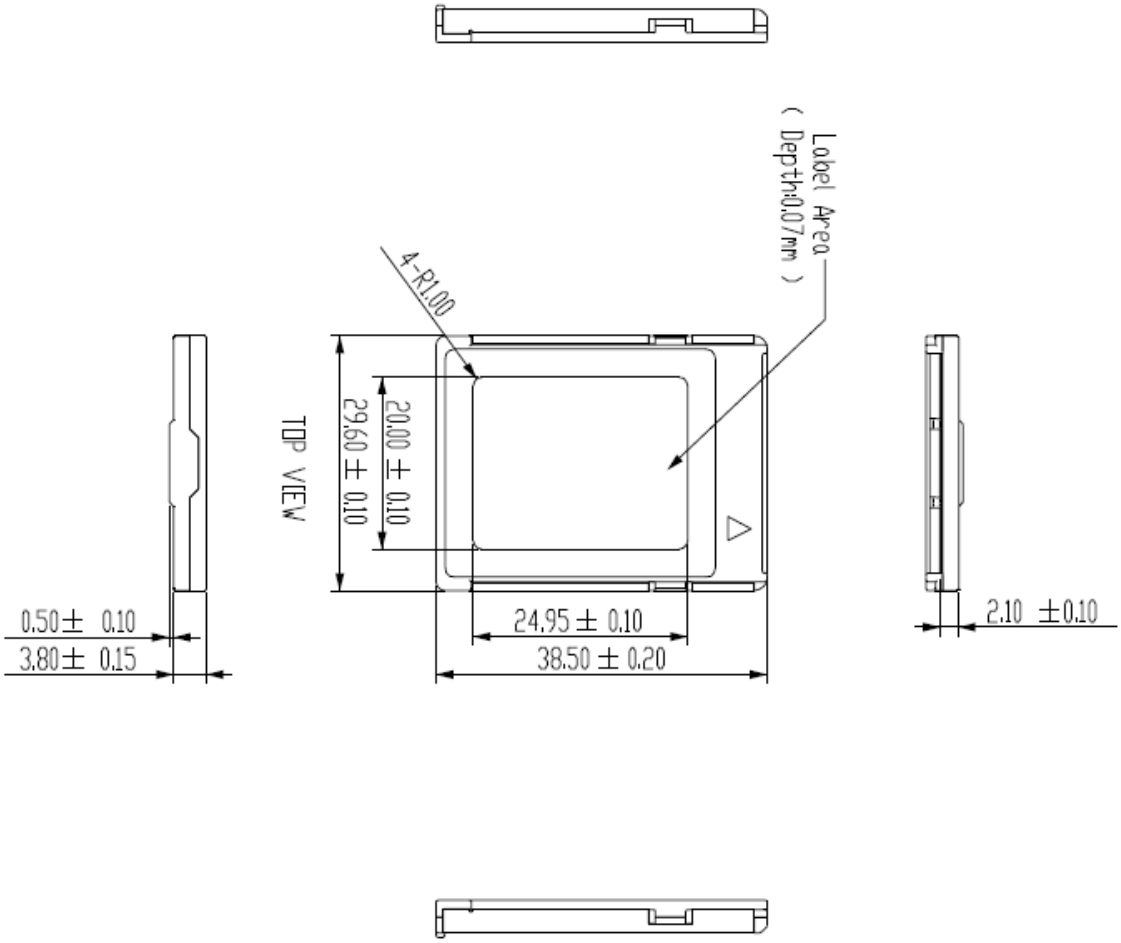
■ Power Consumption

(mW)		Read	Write
3D TLC (BiCS4)	128 GB	2,600	1,800
	256 GB	2,900	2,400
	512 GB	3,100	2,600

1. Based on EDFM0xxx-series under ambient temperature.
2. Use CrystalDiskMark 6.0 with the setting of 1000MB. Sequentially read and write the disk for 5 times, and measure power consumption during sequential Read [1/5]~[5/5] or sequential Write [1/5]~[5/5]
3. Power Consumption may differ according to flash configuration and platform.
4. The measured power voltage is 3.3V

10. Physical Dimension

CFX (Type B) PCIe/NVMe SSD (Unit: mm)



Appendix: Part Number Table

3D TLC (BiCS4)

Product	Advantech PN
SQF 720-C PCIe/NVMe CFX type-B 128G 3D TLC BiCS4 (0~70°C)	SQF-CFXV2-128GCEDC
SQF 720-C PCIe/NVMe CFX type-B 256G 3D TLC BiCS4 (0~70°C)	SQF-CFXV4-256GCEDC
SQF 720-C PCIe/NVMe CFX type-B 512G 3D TLC BiCS4 (0~70°C)	SQF-CFXV4-512GCEDC