APRO Co., Ltd.

3D NAND Flash

(KIOXIA BiCS5 3D NAND) / (3D aSLC Mode)

SATA III CFast™ Card

PHANES-W Series

Document No. : 100-xPCFA-PWCT5

Version No. : 02V0

Date : November, 2023

ISO 9001 : 2015 CERTIFIED

Image just for reference.

Product Features

- **Flash IC**
  - KIOXIA BiCS5 3D-NAND Flash IC.
  - KIOXIA **BiCS FLASH™ *3**
  - KIOXIA BiCS5 3D-NAND Flash w/aSLC Technology.

- **Compatibility**
  - Compliant with SATA Revision 3.2
  - SATA 1.5Gb/s; SATA 3Gb/s & SATA 6Gb/s
  - Interface compatible.
  - ATA-8 ACS4 command set

- **Additional Capabilities**
  - S.M.A.R.T.***1** (Self-Monitoring, Analysis and Reporting Technology) feature set support.
  - Native Command Queuing (NCQ) support.
  - TRIM maintenance command support.
  - Dynamic wear-leveling algorithm
  - Hardware Low Density Parity Check Code, LDPC support.
  - Support bad Block Management
  - Support DIPM/HIPM Mode for power saving
  - Support of AES 256 / TCG OPAL (Optional)***4**

- **Mechanical**
  - 7-pin (data) + 17-pin (power) SATA III CFast™ Card connector.
  - Dimension: 42.8 mm x 36.4 mm x 3.5 mm.
  - Weight: 10g / 0.35 oz.

- **Power Operating Voltage**

  3.3V, +/- 5% (3.14 ~ 3.46V)
  - Read Mode: 1,200.0 mW (1TB.)
  - Write Mode: 1,350.0 mW (1TB.)
  - Idle Mode: 180.0 mW (1TB.)

- **Performance (Maximum value) *2**
  - Sequential Read: 540.0 MB/sec. (1TB.)
  - Sequential Write: 500.0 MB/sec. (1TB.)

- **Capacity**
  - **3D NAND :** 64GB, 128GB, 256GB, 512GB, 1TB.
  - **3D aSLC :** 32GB, 64GB, 128GB.

- **Reliability**
  - **TBW:** (Client workload by JESD-219A)
  - **3D NAND :** Up to 1,400 TBW at 1TB Capacity.
  - **3D aSLC :** Up to 64,000 TBW at 128GB Capacity.
  - **ECC:** Designed with hardware LDPC ECC engine with hard-decision and soft-decision decoding.
  - **MTBF :** > 3.0 million hours
  - **Temperature:** (Operating)

    Standard Grade: 0ºC ~ +70ºC

    Wide Temp. Grade: -40ºC ~ +85ºC
  - **Vibration:** 80 Hz to 2000 Hz, 20G, 3 axes.
  - **Shock:** 0.5ms, 1500 G, 3 axes.

- **Certifications and Declarations**
  - **Certifications**: CE & FCC
  - **Declarations**: RoHS & REACH

Remarks:

1. Support official S.M.A.R.T. Utility.
2. Sequential performance is based on CrystalDiskMark 5.1.2 with file size 1000MB
3. **BiCS** means Bit Cost Scalable Technology.

   BiCS FLASH is a trademark of KIOXIA Corporation.
4. **AES:** Supported if system BIOS support to Set AES HDD Password.

   TCG OPAL: Optional; Requires third-party software management from customer's system.

Order Information

I. Part Number List

◆ **APRO SATA III CFast™ Card (BiCS5 NAND FLASH) PHANES-W Series**

Product Picture	Grade	Standard grade (0ºC ~ 70ºC)	Wide Temp. Grade (-40ºC ~ +85ºC)
		Kioxia BiCS-5 3D-TLC	
	64GB	SPCFA064G-PWCT5(TG)	WPCFA064G-PWIT5(TG)C
	128GB	SPCFA128G-PWCT5(TG)	WPCFA128G-PWIT5(TG)C
	256GB	SPCFA256G-PWCT5(TG)	WPCFA256G-PWIT5(TG)C
	512GB	SPCFA512G-PWCT5(TG)	WPCFA512G-PWIT5(TG)C
	1TB	SPCFA001T-PWCT5(TG)	WPCFA001T-PWIT5(TG)C
		Kioxia BiCS-5 3D-TLC aSLC mode	
	32GB	SPCFA032G-PWCT5AS(TG)	WPCFA032G-PWIT5AS(TG)C
	64GB	SPCFA064G-PWCT5AS(TG)	WPCFA064G-PWIT5AS(TG)C
	128GB	SPCFA128G-PWCT5AS(TG)	WPCFA128G-PWIT5AS(TG)C

II. Part Number Decoder:

X1 X2 X3 X4 X5 X6 X7 X8 X9 – X11 X12 X13 X14 X15 – X17 X18 X19

X1 : **Grade**

S: Standard Grade – operating temp. 0º C ~ 70 º C

W: Wide Temp. Grade- operating temp. -40º C ~ +85 º C

X2 : **The material of case**

R : Rugged Metal

X3 X4 X5 : **Product category**

CFA : CFast™ Card

X6 X7 X8 X9 : **Capacity**

032G:	32GB	**256G:**	256GB
064G:	64GB	**512G:**	512GB
128G:	128GB	**001T:**	1TB

X11 : **Controller**

P : PHANES Series

X12 : **Controller version**

A, B, C.....W

X13 : **Controller Grade**

C : Commercial grade

I : Wide Temp. grade

X14 : **Flash IC**

T : KIOXIA 3D NAND Flash IC

X15 X16 X17 : **Flash IC grade / Type**

5 : BiCS-5 3D-NAND Flash IC.

AS : KIOXIA 3D NAND Flash IC w/aSLC Technology.

X18 X19 X20: **Reserved for specific requirement**

TG: TCG Opal 2.0 & AES 256-bits **(Optional)**

C : Conformal coating

Revision History

Revision	Description	Date
2.0	Initial release.	2023/11/10

Contents

1. Introduction

APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series provides high-capacity flash memory Solid State Drive (SSD) that electrically complies with SATA Revision 3.2. APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series support SATA 1.5Gb/s; SATA 3Gb/s & SATA 6Gb/s data transfer rate with high performance.

The available disk capacities are from 64GB up to 1TB for **Kioxia BiCS5 3D NAND** solution, the capacities from 32GB to 128GB are the **Kioxia BiCS5 aSLC mode solution**. The operating temperature grade support standard temp. 0°C ~ +70°C and wide temp. -40°C ~ +85°C.

APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series is suitable to handheld device embedded system, inventory recorder and particularly for serious environment monitor recorder system. The sequential read speed is 540 MB/sec and sequential write speed is 470 MB/se which were testing based on **Kioxia BiCS5 3D NAND and 3D aSLC mode solution.**

APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series provides a high-level interface to the host computer. This interface allows a host computer to issue commands to the APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series to read or write blocks of memory. A powerful hardware design is architecture multiplied LDPC (Low Density Parity Check) for Error Correcting Coding (ECC). APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series intelligent controller manages interface protocols, data storage and retrieval as well as ECC, bad block management and diagnostics, power management and clock control.

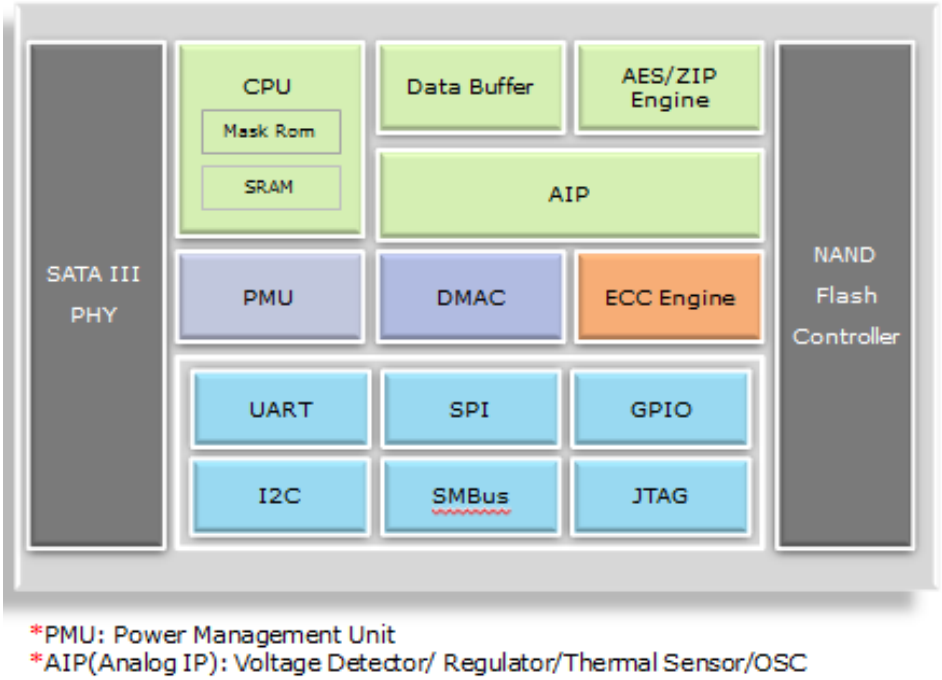

Figure 1: APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series block diagram

1.1. Scope

This document describes features, specifications and installation guide of APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series. In the appendix, there provides order information, warranty policy, RMA/DOA procedure for the most convenient reference.

1.2. *Flash Management Technology –Dynamic Wear Leveling*

NAND flash devices can only undergo a limited number of program/erase cycles, and in most cases, the flash media are not used evenly. If some areas get updated more frequently than others, the lifetime of the 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.

APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W 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.

1.3. *Bad Block Management*

- **Early Bad Block**

The fault block generated during the manufacturing process of NAND Flash is called Early Bad Block.

- **Later Bad Block**

In the process of use, as the number of operations of writing and erasing increases, a fault block is gradually generated, which is called a Later Bad Block.

Bad block management is a management mechanism for a bad block to be detected by the control IC and mark bad blocks in the NAND Flash and improve the reliability of data access. The bad block management mechanism of the control IC will establish a **Bad Block Table** when the NAND Flash is started for the first time, and will also record the errors found in the process of use in the bad block table, and data is ported to new valid blocks to avoid data loss.

In order to detect the initial bad blocks to handle run time bad blocks, APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series provides the **Bad Block Management** scheme. It remaps a bad block to one of the reserved blocks so that the data contained in one bad block is not lost and new data writes on a bad block is avoided.

1.4. *Error Correcting Coding (ECC)*

APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series provides a high-level interface to the host computer. This interface allows a host computer to issue commands to the APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series to read or write blocks of memory. A powerful hardware design is architecture multiplied LDPC (Low Density Parity Check) for Error Correcting Coding (ECC). APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series intelligent controller manages interface protocols, data storage and retrieval as well as ECC, bad block management and diagnostics, power management and clock control.

1.5. *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.

1.6. *Thermal Monitor*

Thermal monitors are devices for measuring temperature, and can be found in SSDs in order to issue warnings when SSDs go beyond a certain temperature. The higher temperature the thermal monitor detects, the more power the SSD consumes, causing the SSD to get aging quickly. Hence, the processing speed of a SSD should be under control to prevent temperature from exceeding a certain range. Meanwhile, the SSD can achieve power savings.

1.7. *DEVSLP Mode (Optional)*

With the increasing need of aggressive power/battery life, SATA interfaces include a new feature, Device Sleep (DEVSLP)mode, which helps further reduce the power consumption of the device. DEVSLP enables the device to completely power down the device PHY and other sub-systems, making the device reach a new level of lower power operation. The DEVSLP does not specify the exact power level a device can achieve in the DEVSLP mode, but the power usage can be dropped down to 5mW or less.

1.8. *DIPM/HIPM Mode*

SATA interfaces contain two low power management states for power saving: Partial and Slumber modes. For Partial mode, the device has to resume to full operation within 10 microseconds, whereas the device will spend 10 milliseconds to become fully operational in the Slumber mode. SATA interfaces allow low power modes to be initiated by Host (HIPM, Host Initiated Power Management) or Device (DIPM, Device Initiated Power Management). As for HIPM, Partial or Slumber mode can be invoked directly by the software. For DIPM, the device will send requests to enter Partial or Slumber mode.

1.9. *TCG Opal 2.0 (Optional, Not Default Function)*

- **AES 256-bitHardware Self Encryption (Default)**
- Deploy Storage Device & Take Ownership: The Storage Device is integrated into its target system and ownership transferred by setting or changing the Storage Device's owner credential.
- Activate or Enroll Storage Device: LBA ranges are configured and data encryption and access control credentials (re)generated and/or set on the Storage Device. Access control is configured for LBA range unlocking.
- Lock & Unlock Storage Device: unlocking of one or more LBA ranges by the host and locking of those ranges under host control via either an explicit lock or implicit lock triggered by a reset event. MBR shadowing provides a mechanism to boot into a secure pre-boot authentication environment to handle device unlocking.
- Repurpose & End-of-Life: erasure of data within one or more.

1.10. *3D-NAND Flash*

3D NAND is a vertical implementation of the NAND flash cell memory array. The memory cell transistors forming the NAND string are connected in a series vertically and the memory transistors are changed from the floating-gate type to a trapped charge type.
In floating-gate technology, die density is increased by shrinking peripheral circuits and active circuits.
With 3D, holding the X/Y dimension of the die constant, die density is increased through multiple layers of the active circuits on the Z axis. Higher-density 3D NAND die enables applications needing high-density NAND chip solutions.

1.11. *UBER*

Table 1: UBER Calculation.

Capacity	UBER
32GB	< 1 sector per 10^{16} bits read
64GB	
128GB	
256GB	
512GB	
1TB	

Notes:

- *UBER (Uncorrectable Bit Error Rates) means the uncorrectable error per bits read.*
- *UBER = FER (fail rate)/ Data Size (user data bit)*
- *FER = uncorrectable ECC frame number / total ECC frame number*
- *LDPC for Kioxia 3D aSLC ECC capability > 120bit/KB.*

1.12. *MTBF*

MTBF, Mean Time Between Failures, is a measure of reliability of a device. Its value represents the average time between a repair and the next failure. The unit of MTBF is in hours. The higher the MTBF value, the higher the reliability of the device.

Our MTBF result is based on simulation software (Relex7.3). Please note that a lower MTBF should be expected for higher capacity drives, and we apply the lowest MTBF for all capacities.

Table 2: MTBF Calculation.

Capacity	MTBF
32GB	> 3 million hours
64GB	
128GB	
256GB	
512GB	
1TB	

2. Product Specifications

For all the following specifications, values are defined at ambient temperature and nominal supply voltage unless otherwise stated.

2.1. System Environmental Specifications

Table 1: Environmental Specification

APRO SATA III CFast™ Card (3D NAND / 3D aSLC) PHANES-W Series		Standard Grade	Wide Temp. Grade
Temperature	**Operating:**	0ºC ~ +70ºC	-40ºC ~ +85ºC
	Non-operating:	-20ºC ~ +80ºC	-50ºC ~ +95ºC
Humidity	**Operating & Non-operating:**	10% ~ 95% non-condensing	
Vibration	**Frequency/Acceleration:**	80 Hz to 2000 Hz, 20G, 3 axes	
Shock	**Operating & Non-operating:**	0.5ms, 1500 G, 3 axes	
Electrostatic Discharge (ESD)	**Temperature:**	24ºC	
	Relative Humidity:	49% (RH)	
	+/-4KV:	Device functions are affected, but EUT will be back to its normal or operational state automatically.	

2.2. System Power Requirements

Table 2: Power Requirement

BiCS-5 3D NAND						Unit: mW
Operating Voltage: 3.3V, +/- 5% (3.14 ~ 3.46V)						
Capacity	**Flash Structure**	**Read**	**Write**	**Partial**	**Slumber**	**Idle**
64GB	64GB x 1, BiCS5 TLC, BGA	820	750	55	20	180
128GB	128GB x 1, BiCS5 TLC, BGA	1,100	1,050	55	20	180
256GB	256GB x 1, BiCS5 TLC, BGA	1,100	1,200	55	20	180
512GB	256GB x 2, BiCS5 TLC, BGA	1,150	1,250	55	20	180
1TB	256GB x 4, BiCS5 TLC, BGA	1,200	1,350	55	20	180
BiCS-5 3D NAND aSLC mode						
32GB	64GB x 2, BiCS5 aSLC, BGA	1,150	1,150	65	25	175
64GB	128GB x 2, BiCS5 aSLC, BGA	1,150	1,150	65	25	175
128GB	256GB x 2, BiCS5 aSLC, BGA	1,250	1,200	65	25	175

Note:

- *The average value of power consumption is achieved based on 100% conversion efficiency.*
- *Samples were built using Kioxia BiCS5 3D-TLC NAND Flash.*
- *Sequential R/W is measured while testing 4000MB sequential R/W 5 times by CyrstalDiskMark.*
- *Power Consumption may differ according to flash configuration, SDR configuration, or platform.*
- *Measurement environment: Room temperature: 20~25℃, humidity: 40~60%RH.*

2.3. *System Performance*

Table 3: System Performances

Data Transfer Mode supporting		Serial ATA Gen-III (6.0Gb/s = 768MB/s)			
Capacity	Flash Structure	Sequential (MB/s)		4K Random (IOPS)	
		Read	Write	Read	Write
BiCS-5 3D NAND					
64GB	64GB x 1, BiCS5 TLC, BGA	320.0	260.0	24.0K	56.0K
128GB	128GB x 1, BiCS5 TLC, BGA	530.0	450.0	47.5K	77.5K
256GB	256GB x 1, BiCS5 TLC, BGA	540.0	485.0	72.5K	82.5K
512GB	256GB x 2, BiCS5 TLC, BGA	545.0	500.0	87.0K	83.5.0K
1TB	256GB x 4, BiCS5 TLC, BGA	540.0	500.0	88.0K	83.5K
BiCS-5 3D NAND aSLC mode					
32GB	64GB x 2, BiCS5 aSLC, BGA	550.0	465.0	49.5K	78.5K
64GB	128GB x 2, BiCS5 aSLC, BGA	550.0	485.0	85.5K	84.5K
128GB	256GB x 2, BiCS5 aSLC, BGA	550.0	500.0	96.0K	86.0K

Note:

- *Performance may differ according to flash configuration, use condition, environment and platform.*
- *Tested with Iometer, QD32T8, 1GB range.*
- *Performance is measured without Thermal Throttling.*
- *Operating System: Windows 10 Professional (x64), Version 1809*
- *Measurement environment: Room temperature: 20~25℃, humidity: 40~60%RH.*
- *64GB is running in single channel performance.*

2.4. *System Reliability*

Table 4: System Reliability

Wear-leveling Algorithms		Static & Dynamic Wear-leveling	
ECC Technology		Hardware design LDPC (Low Density Parity Check)	
Erase counts		**KIOXIA BiCS-5 NAND TLC Flash** Cell Level : 3K P/E Cycles	
Capacity	**Flash Type**	**TBW**	**DWPD**
64GB	TLC	70	0.99
128GB	TLC	100	0.71
256GB	TLC	250	0.89
512GB	TLC	600	1.07
1TB	TLC	1,400	1.24
Erase counts		**KIOXIA BiCS-5 aSLC mode** : 30K P/E Cycles	
Capacity	**Flash Type**	**TBW**	**DWPD**
32GB	TLC w/aSLC mode	1,000	28.53
64GB	TLC w/aSLC mode	3,000	42.81
128GB	TLC w/aSLC mode	6,400	45.66

Note:

- *The test followed JEDEC 219A client endurance workload.*
- *TBW may differ according to flash configuration, platform and data written.*
- *DWPD is calculated based on 3-year lifetime.*
- *DWPD (Drive Write Per Day) = TBW/ (365 x years x User Capacity(TB))*
- *The endurance of SSD could be estimated based on user behavior, NAND endurance cycles, and write amplification factor. It is not guaranteed by flash vendor.*

2.5. *Device Capacity*

Table 7: User Capacity and Addressable Sectors

Capacity	Number of Total LBA		User Available Bytes
	512Bytes/Sector	4KBytes/Sector	
32GB	62,533,296	7,816,662	32,017,047,552
64GB	125,045,424	15,630,678	64,023,257,088
128GB	250,069,680	31,258,710	128,035,676,160
256GB	500,118,192	62,514,774	256,060,514,304
512GB	1,000,215,216	125,026,902	512,110,190,592
1TB	2,000,409,264	250,051,158	1,024,209,543,168

Note:

- *1 Gigabyte (GB) is equal to 1,000,000,000 Bytes; 1 sector is equal to 512 Bytes or 4K Bytes.*
- *The calculation is following IDEMA Standard.*
- *The total actual user usable capacity of the SSD may be less than device capacity due to SSD format, SSD partition, operating system.*

  (Eg : OS shows 119.24GB (NTFS) with 128GB SSD device.)

2.6. *Physical Specifications*

Refer to Table 5 and see Figure 2 for APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series physical specifications and dimensions.

Table 5: Physical Specifications of APRO SATA III CFast™ Card (BiCS5 NAND FLASH) PHANES-K Series

Length:	42.8 mm
Width:	36.4 mm
Thickness:	3.5 mm
Weight:	Plastic frame-kit: 10g (0.35 oz.)

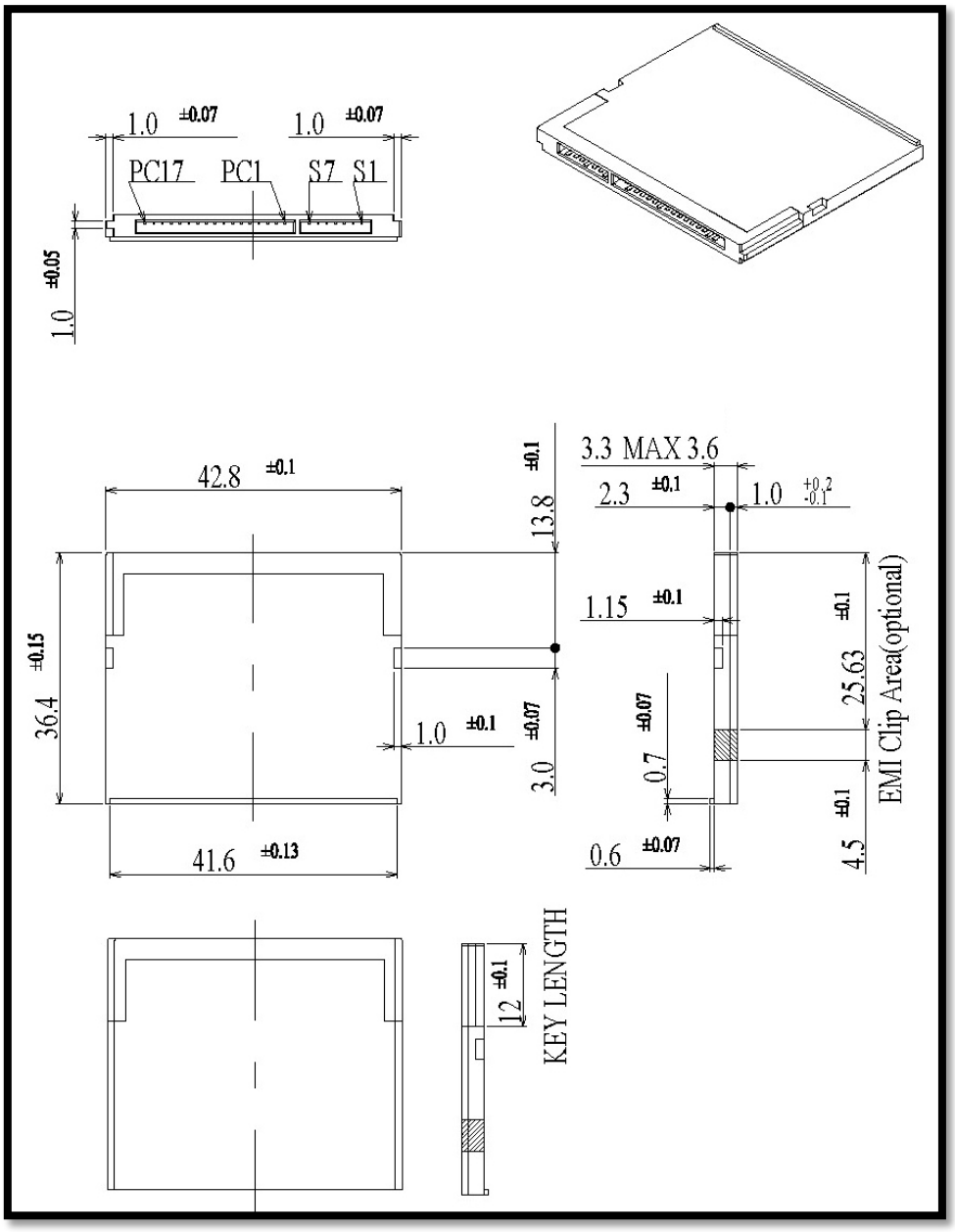

Figure 2: APRO SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series Dimension

2.7. *Conformal coating*

Conformal coating is a protective, dielectric coating designed to conform to the surface of an assembled printed circuit board. Commonly used conformal coatings include silicone, acrylic, urethane and epoxy. APRO applies only silicone on APRO storages products upon requested especially by customers. The type of silicone coating features good thermal shock resistance due to flexibility. It is also easy to apply and repair.

Conformal coating offers protection of circuitry from moisture, fungus, dust and corrosion caused by extreme environments. It also prevents damage from those Flash storages handling during construction, installation and use, and reduces mechanical stress on components and protects from thermal shock. The greatest advantage of conformal coating is to allow greater component density due to increased dielectric strength between conductors. APRO use MIL-I-46058C silicon conformal coating

3. Interface Description

3.1. SATA III CFast™ Card interface

APRO SATA III CFast™ Card (BiCS5 NAND FLASH) PHANES-W Series is equipped with 7 pins in the signal segment and 17 pins in the power segment.

Figure 3: The connectors of Signal Segment and Power Segment

3.2. Pin Assignments

APRO SATA III CFast™ Card (BiCS5 NAND FLASH) PHANES-K Series operates with standard SATA pin-out. The pin assignments are listed in below table 6.

Key and Spacing separate signal and power segments		
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

P1	CDI	Card Detect In
P2	PGND	Device Ground
P3	DEVSLP	Device Sleep
P4	NA	Reserved
P5	NA	Reserved
P6	NA	Reserved
P7	PGND	Device Ground
P8	LED1	LED Output
P9	LED2	LED Output
P10	NA	Reserved
P11	NA	Reserved
P12	IFDET	NA
P13	PWR	Device Power
P14	PWR	Device Power
P15	PGND	Device Ground
P16	PGND	Device Ground
P17	CDO	Card Detect Out

Table 6 - Pin Assignments

Appendix A: Limited Warranty

APRO warrants your SATA III CFast™ Card (3D NAND/3D aSLC) PHANES-W Series against defects in material and workmanship for the life of the drive. The warranty is void in the case of misuse, accident, alteration, improper installation, misapplication or the result of unauthorized service or repair. The implied warranties of merchantability and fitness for a particular purpose, and all other warranties, expressed or implied, except as set forth in this warranty, shall not apply to the products delivered. In no event shall APRO be liable for any lost profits, lost savings or other incidental or consequential damages arising out of the use of, or inability to use, this product.

BEFORE RETURNING PRODUCT, A RETURN MATERIAL AUTHORIZATION (RMA) MUST BE OBTAINED FROM APRO.

Product shall be returned to APRO with shipping prepaid. If the product fails to conform based on customers' purchasing orders, APRO will reimburse customers for the transportation charges incurred.

WARRANTY PERIOD:

- **3D NAND FLASH (Wide Temp. Grade) 2 years / Within 3K Erasing Counts**
- **3D aSLC (Wide Temp. Grade) 2 years / Within 30K Erasing Counts**

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