APRO Co., Ltd.

3D NAND Flash

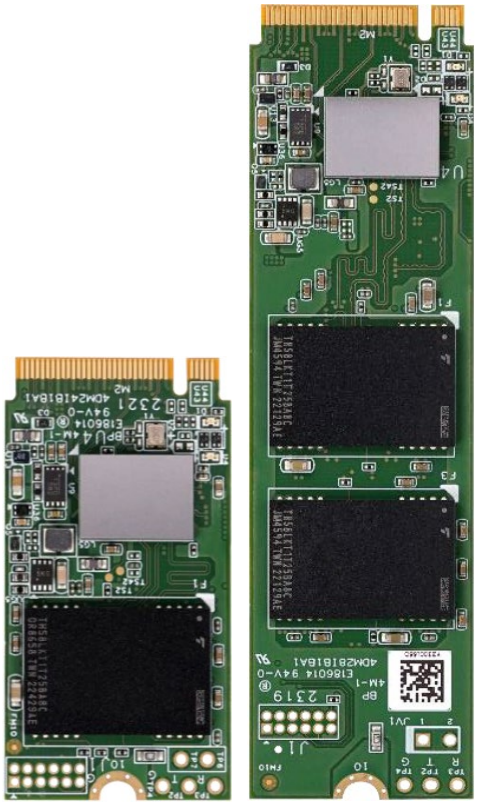
(KIOXIA BiCS5)

M.2 PCIe NVMe Module

HERCULES-PA Series

(2242/2280 Form-factor)

(Gen-III x 4)



Document No. : 100-xBMDP-MPAT5

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ISO 9001 : 2015 CERTIFIED

Product Features

- **Flash IC**
  - **KIOXIA BiCS FLASH™.*4**
  - KIOXIA **BiCS5** 3D-NAND Flash.

- **Compatibility**
  - NVM Express™ 1.3 Standard.
  - PCI Express® Base Specification Rev 3.0

- **Additional Capabilities**
  - S.M.A.R.T.***1** (Self-Monitoring, Analysis and Reporting Technology) feature set support.
  - Static and Dynamic wear-leveling algorithm.
  - Hardware Low Density Parity Check Code, LDPC support.
  - End to End Data Path Protection
  - Hybrid Write Mode with SLC Cache Enable
  - Thermal Throttling Supported.

- **Mechanical**
  - PCI Gen3 x 4 NVMe interface(2280)
  - M.2 keying notches in **M** positions.
  - **M.2 2242/2280-D2-M** placement
  - **Dimension:**
  - **2280:** 80.0 mm x 22.0 mm
  - **2242:** 42.0 mm x 22.0 mm

- **Power**
  - Operating Voltage 3.3V(+/-) 5%
  - Read Mode: 3.9W (RMS.)
  - Write Mode: 4.0W (RMS.)
  - Idle Mode: 0.6W (RMS.)

- **Performance (512GB Maximum value) [2, 3]**
  - Sequential Read: 2,600.0 MB/sec.
  - Sequential Write: 1,750.0 MB/sec.
  - Sustained Seq. Read: 2,200.0 MB/sec.
  - Sustained Seq. Write: 590.0 MB/sec.
  - 4KB Random Read (IOPS.): 231.0K
  - 4KB Random Write (IOPS.): 299.0K

- **Capacity**
  - **2242:** 128GB, 256GB, 512GB
  - **2280:** 128GB, 256GB, 512GB, 1TB

- **Reliability**
  - **TBW:** Up to 1,300 TBW at 1TB Capacity. (Client workload by JESD-219A)
  - **ECC:** Designed with hardware LDPC ECC engine with hard-decision and soft-decision decoding.
  - **MTBF:** >3,000,000
  - **Temperature:** (Operating)
    Standard Grade: 0ºC ~ +70ºC
    Wide Temp. Grade: -40ºC ~ +85ºC
  - **Vibration:** 7 Hz~2K Hz/20G.
  - **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. Typical I/O performance using IOmeter with a queue depth of 32 (Standard grade)
3. Sequential performance is based on CrystalDiskMark 6.0.2 with file size 1000MB (Standard grade)
4. **BiCS** means Bit Cost Scalable Technology.
   BiCS FLASH is a trademark of Toshiba Corporation.

Order Information

I. Part Number List

◆ **APRO 3D NAND TLC M.2-2242 Form-factor PCIe NVMe Module HERCULES-PA Series**

Product Picture	Grade	Standard grade (0ºC ~ 70ºC)	Wide Temp Grade (-40ºC ~ +85ºC)
	128GB	SBMDP128G-MPAT54M	WBMDP128G-MPAT54MC
	256GB	SBMDP256G-MPAT54M	WBMDP256G-MPAT54MC
	512GB	SBMDP512G-MPAT54M	WBMDP512G-MPAT54MC

◆ **APRO 3D NAND TLC M.2-2280 Form-factor PCIe NVMe Module HERCULES-PA Series**

Product Picture	Grade	Standard grade (0ºC ~ 70ºC)	Wide Temp Grade (-40ºC ~ +85ºC)
	128GB	SBMDP128G-MPAT58M	WBMDP128G-MPAT58MC
	256GB	SBMDP256G-MPAT58M	WBMDP256G-MPAT58MC
	512GB	SBMDP512G-MPAT58M	WBMDP512G-MPAT58MC
	1TB	SBMDP001T-MPAT58M	WBMDP001T-MPAT58MC

II. Part Number Decoder:

X1 X2 X3 X4 X5 X6 X7 X8 X9 – X11 X12 X13 X14 X15 – X17 X18 X19 X20

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**

B : Bare PCBA w/o Casing

X3 X4 X5 : **Product category**

MDP: M.2 PCIe NVMe Module

X6 X7 X8 X9 : **Capacity**

128GB: 128GB **001T:** 1TB

256GB: 256GB

512GB: 512GB

X11 : **Controller**

M : HERCULES Series

X12 X13 :**Controller version**

PA : HERCULES-PA Series

X14 : **Flash IC**

T : KIOXIA NAND Flash IC

X15 : **Flash IC grade / Type**

5 : BiCS5 3D-NAND Flash IC.

X16 X17: **Form-Factor**

4: 2242 Type

8: 2280 Type

M: with the notches in M positions

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

SE: Self-Encrypting Drive (Optional)

C: Conformal coating (Optional)

Revision History

Revision	Description	Date
1.0	Initial release.	2024/10/11

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1. Introduction

APRO 3D NAND TLC PCIe NVMe Module HERCULES-PA Series provides high-capacity flash memory Solid State Drive (SSD) that electrically complies with NVM Express™ 1.3 Standard and support PCI Gen3 x 4 NVMe interface with high performance.

The HERCULES-PA Series M.2 2242/2280 SSD available disk capacities are 128GB, 256GB, 512GB, 1TB. Standard temperature range is from 0°C to +70°C with an optional wide temperature range from -40°C to +85°C. APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series comes with M positions, supports PCIe Gen III x 4 and it is compliant with NVM 1.3 providing excellent top and sustained performance.

APRO's HERCULES-PA Series 3D NAND TLC M.2 PCIe NVMe 2242/2280 SSD provides the ultra-high random speed but in low power consumption. It is the most favorable solution for heavy-loading embedded systems or server computing with space limitation. The data transfer performance of 4K random read is 231,000 IOPS and the 4K random write is up to 299,000 IOPS; the sequential read is up to 2,600 MB/sec, and the sequential write is up to 1,700 MB/sec. test by a 512GB capacity 2242/2280 M.2 SSD.

The powerful controller provides LDPC (Low Density Parity Check) to detect eventual errors while writing and increases the reliability in comparison to a standard ECC mechanism.

APRO's sophisticated S.M.A.R.T. tool is available for customers' request. It can monitor the health status of the HERCULES-PA Series 3D NAND TLC PCIe NVMe Module. The optional product with "Thermal Sensor" function, the user may detect its operating temperature by the S.M.A.R.T. tool whenever the SSD is operating. Currently, the S.M.A.R.T. tool is only for Windows OS based systems.

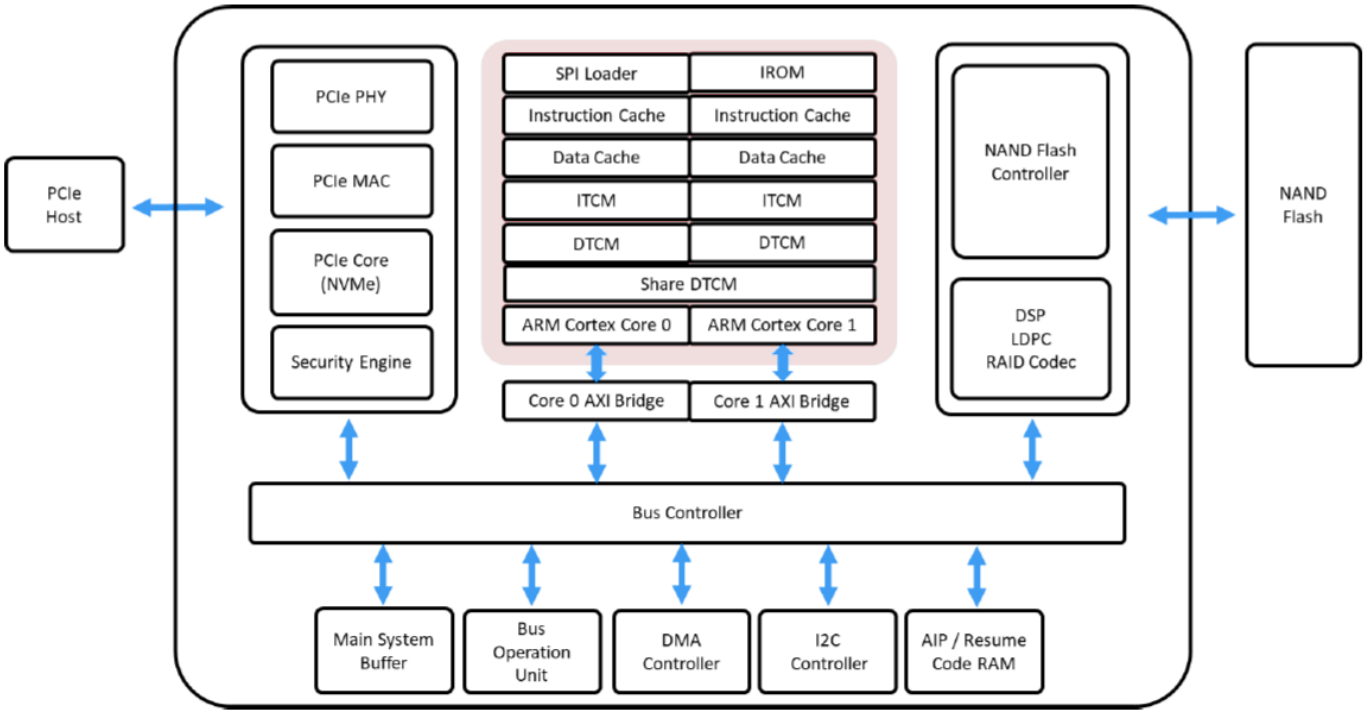


Figure 1: APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series block diagram

1.1. *Scope*

This document describes features, specifications and installation guide of APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series. In the appendix, there provides order information, warranty policy, RMA/DOA procedure for the most convenient reference.

1.2. *Flash Management Technology – Static & 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 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series provides advanced Wear Leveling algorithm, which can efficiently spread out the flash usage through the whole flash media area. Moreover, by implementing both wear-leveling algorithms, the life expectancy of the NAND flash are greatly improved, as dynamic and also static data is shifted, if necessary, in order to guarantee an evenly use of all flash cells.

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 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA 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. *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.

1.5. *Thermal Management*

APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series 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.

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 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series		Standard Grade	Wide Temp Grade
		SBMDPxxxG-MPAT5XM	WBMDPxxxG-MPAT5XMC
Temperature	Operating:	0ºC ~ +70ºC	-40ºC ~ +85ºC
	Non-operating:	-20ºC ~ +80ºC	-50ºC ~ +95ºC
Humidity	Operating & Non-operating:	10% ~ 95% non-condensing	
	Frequency/Acceleration:	7 Hz to 2K Hz, 20G, 3 axes (IEC 68-2-6)	
Shock	Operating & Non-operating:	0.5ms, 1500 G, 3 axes (IEC 68-2-27)	
Electrostatic Discharge (ESD)	Temperature:	24ºC	
	Relative Humidity:	51%	
	+/-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

APRO 3D NAND TLC M.2-2280 Form-factor PCIe NVMe HERCULES-PA Series		
DC Input Voltage 3.3V±5% (VCC)		512GB
Maximum average value	Reading Mode :	3.8W (RMS.)
	Writing Mode :	3.9W (RMS.)
	Idle Mode :	0.7W (RMS.)
	Power-On Peak	3.6W (RMS.)

*Note: * Current results may vary depending on system components and power circuit design.*

2.3. Capacity and Device Parameters

Capacity	Cylinders	Heads	Sectors	LBA	User Capacity(MB)
128GB	16,383	16	63	234,441,648	114,473
256GB				468,862,128	228,937
512GB				937,703,088	457,863
1TB				1,875,385,008	915,715

2.4. *System Performance*

Table 3: System Performances

Data Transfer Mode supporting		PCI Gen3 x 4 NVMe interface			
Maximum Performance	Form-factor	2242/2280			
	Capacity	128GB	256GB	512GB	1TB
	Sequential Read (MB/s)	1200	2,400	2,600	2,600
	Sequential Write (MB/s)	530	1,100	1,750	1,800
	Sustained Seq. Read (MB/s) (avg.)	930	1,900	2200	2,300
	Sustained Seq. Write (MB/s)(avg.)	170	370	590	680
	4KB Random Read IOPS (QD32)	51,000	123,000	231,000	251,000
	4KB Random Write IOPS (QD32)	128,000	259,000	299,000	314,000

Note:

- *Performance results are measured in Room Temperature with Out-of-Box devices and may vary depending on overall system setup. In addition, HERCULES-PA 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.*
- *Performance results are based on CrystalDiskMark 6.0.2 with file size 1000MB. Unit of 4KB items is I.O.P.S.*
- *Performance results are based on AIDA 64 v5.98 with block size 1MB of Linear Read & Write Test Item.*

2.5. *System Reliability*

Table 4: System Reliability

Wear-leveling Algorithms		Static and Dynamic wear-leveling algorithms
Bad Block Management		Supportive
ECC Technology		Hardware design LDPC (Low Density Parity Check)
Erase counts		NAND 3D NAND TLC Flash Cell Level : 3K P/E Cycles
TBW (Tera Bytes Written)		Client workload
Capacity	128GB	162.5
	256GB	325
	512GB	650
	1TB	1,300

Note:

- *Sequential: Mainly sequential write are estimated by PassMark Burnin Test v8.1 pro.*
- *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.)*
- *Based on out-of-box performance.*

2.6. *Physical Specifications*

Refer to Table 5 and see Figure 2 for 3D NAND TLC M.2-2242&2280 Form-factor PCIe NVMe Module HERCULES-PA Series physical specifications and dimensions.

Table 5: Physical Specifications

Form-factor	2242	2280
Length:	42.0 mm	80.0 mm
Width:	22.0 mm	22.0 mm
Weight:	4.5g (max.)	8.0g (max.)

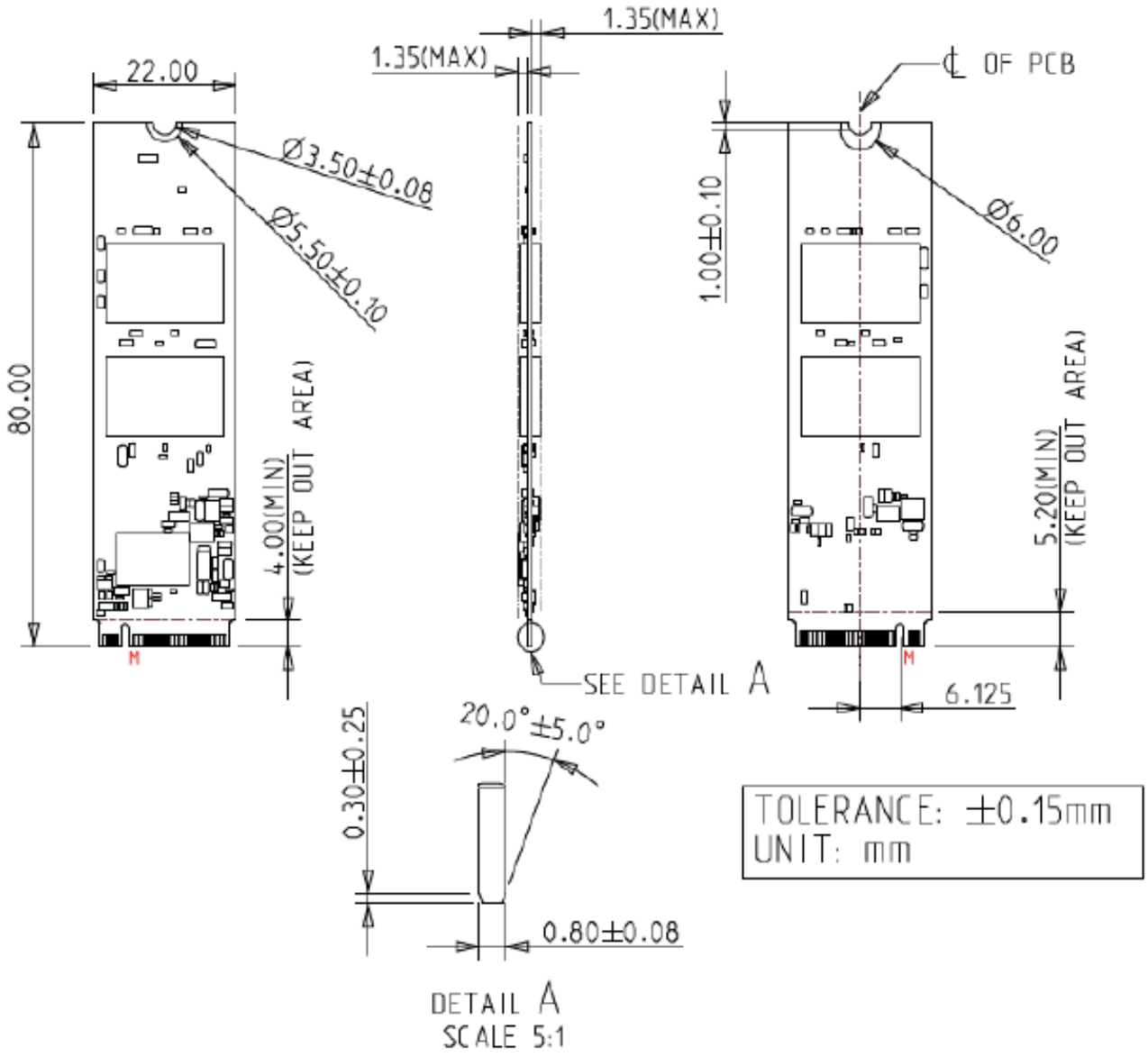


Figure 2-1: APRO 3D NAND TLC M.2-2280 Form-factor PCIe NVMe Module HERCULES-PA Series w/o Heat Sink Dimension

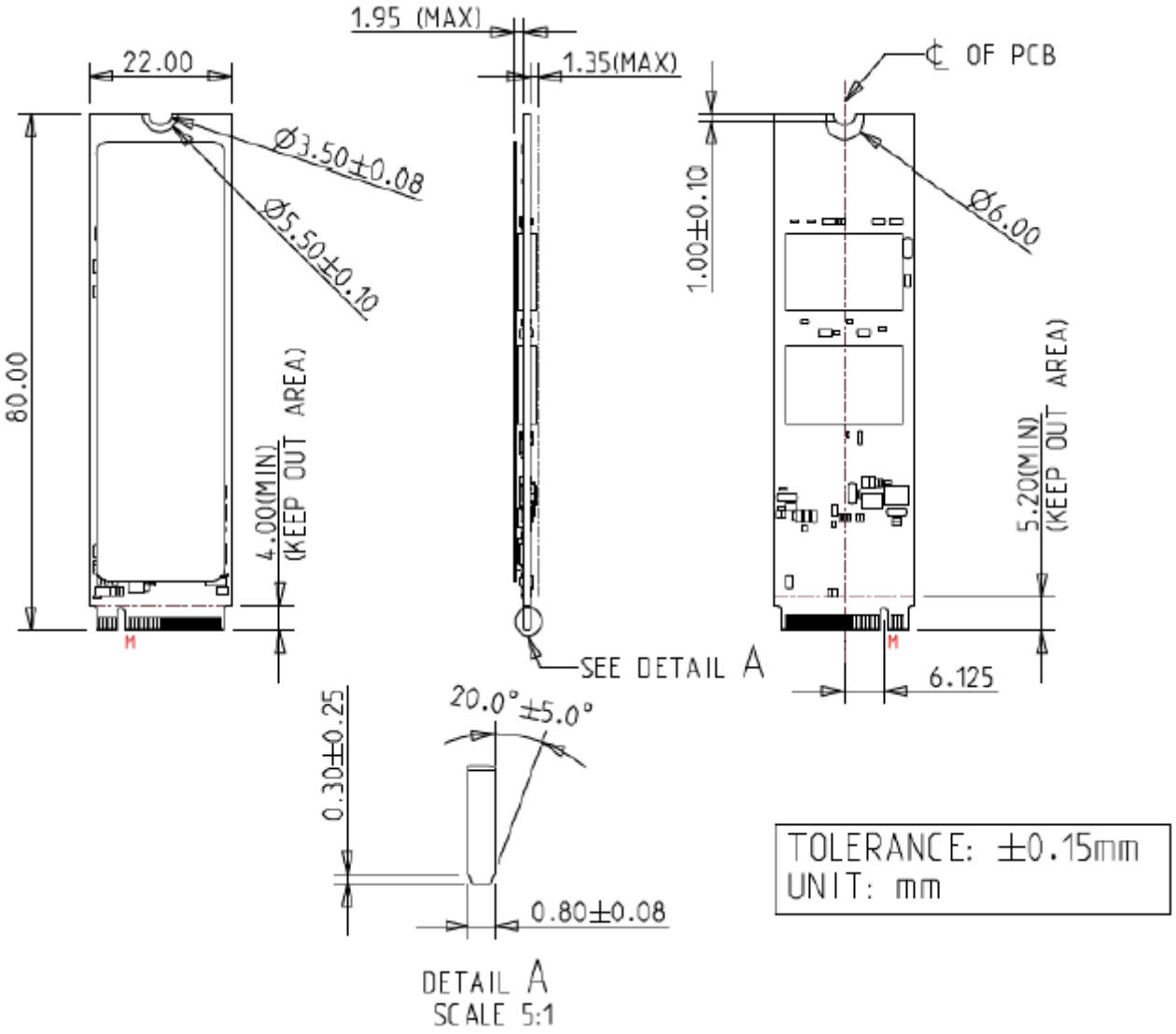


Figure 2-2: APRO 3D NAND TLC M.2-2280 Form-factor PCIe NVMe Module HERCULES-PA Series W/Heat Sink Dimension

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

2.8. *Heat Sink copper layer*

APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series industrial temperature models come with a Heat Sink copper layer installed on top of M.2 PCIe NVMe SSD with dimension of 68x20x0.25 mm. This design will increase M.2 PCIe NVMe SSD height to 1.95mm max due to the thermal pad and copper layer itself.

3. Interface Description

4.1. M.2 PCIe NVMe Module HERCULES-PA Series interface

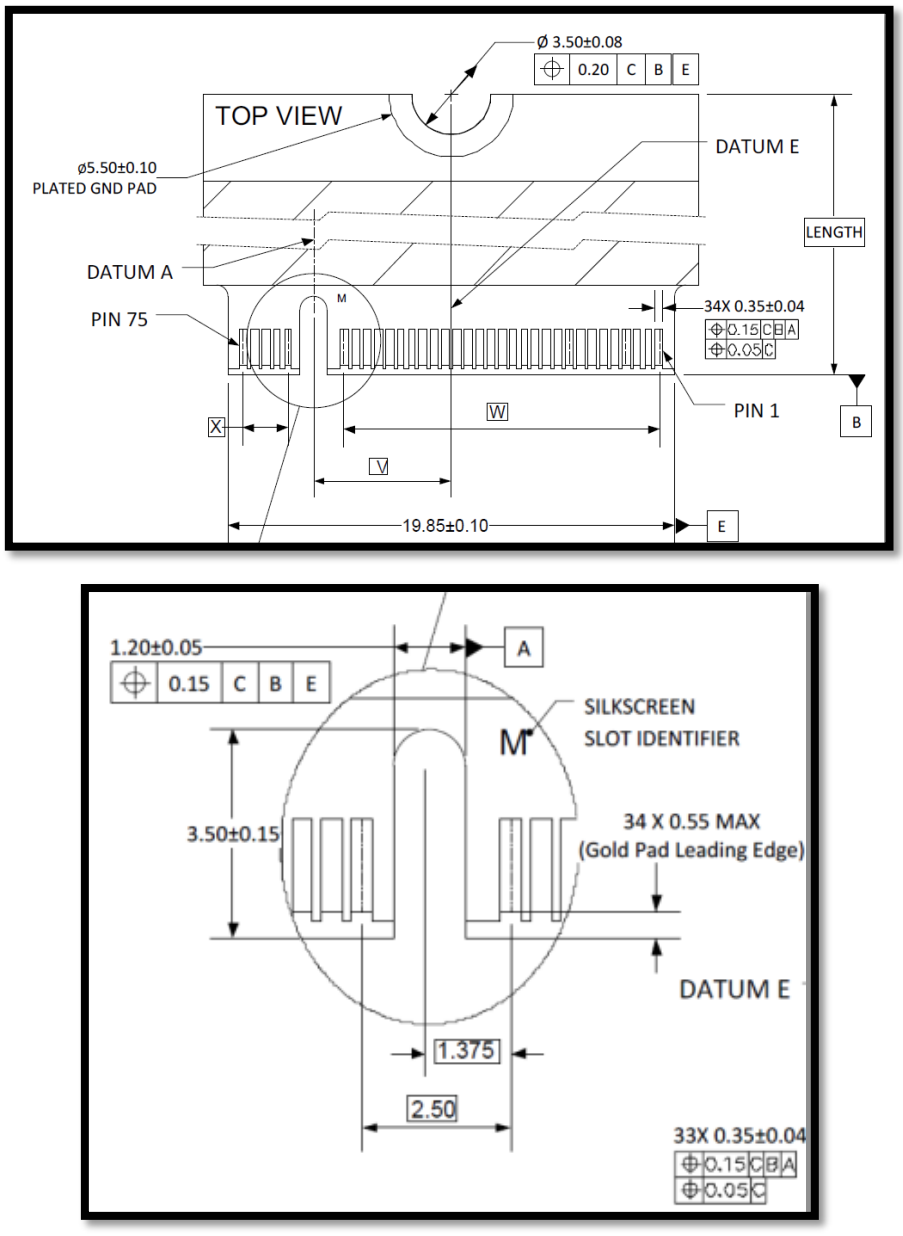


Figure 3: The connectors of Signal Segment and Power Segment

4.2. Pin Assignments

APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series follows standard M.2 spec, socket 3 key M PCIe-based SSD pinout.

Table 6 - Pin Assignments

Signal Name	*Pin Number*		*Signal Name*
		75	GND
3.3V	**74**	**73**	GND
3.3V	**72**	**71**	GND
3.3V	**70**	**69**	NC
NC	**68**	**67**	NC
Notch	**66**	**65**	Notch
Notch	**64**	**63**	Notch
Notch	**62**	**61**	Notch
Notch	**60**	**59**	Notch
NC (Reversed)	**58**		
NC (Reversed)	**56**	**57**	GND
NC	**54**	**55**	REFCLKp
CLKREQ# (I/O)(0/3.3V)	**52**	**53**	REFCLKn
PERST# (I)(0/3.3V)	**50**	**51**	GND
NC	**48**	**49**	PERp0
NC	**46**	**47**	PERn0
NC	**44**	**45**	GND
NC. (SMB_DATA)	**42**	**43**	PETp0
NC. (SMB_CLK)	**40**	**41**	PETn0
NC	**38**	**39**	GND
NC	**36**	**37**	PERp1
NC	**34**	**35**	PERn1
NC	**32**	**33**	GND
NC	**30**	**31**	PETp1
NC (reserved for ROM code)	**28**	**29**	PETn1
NC	**26**	**27**	GND
NC	**24**	**25**	**PERp2**
NC	**22**	**23**	**PERn2**
NC	**20**	**21**	**GND**
3.3V	**18**	**19**	**PETp2**
3.3V	**16**	**17**	**PETn2**
3.3V	**14**	**15**	**GND**
3.3V	**12**	**13**	**PERp3**
LED1# (O) (OD)	**10**	**11**	**PERn3**
NC	**8**	**9**	GND
NC	**6**	**7**	**PETp3**
3.3V	**4**	**5**	**PETn3**
3.3V	**2**	**3**	GND
		1	GND

4.3. Electrical connectors of M.2

APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series interconnection is based on a 75 positions Edge Card connector. The 75 positions connector is intended to be keyed so as to distinguish between families of host interfaces and the various Sockets used in general Platforms.

APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series follows standard M.2 spec, socket 3 key M PCIe-based SSD pinout

4.4. Driver

APRO 3D NAND TLC M.2 PCIe NVMe Module HERCULES-PA Series is compliant with NVM Express™ 1.3 Standard.

The application's O.S. and BIOS should include NVMe driver to compatible with NVMe storage device. Most of O.S. includes NVMe in-box driver now.

O.S. Driver: Please visit the website http:/nvmexpress.org/resources/drivers for more information about the driver for each O.S

BIOS Driver: NVMe driver for BIOS support, please contact with motherboard manufacturers.

Appendix A: Limited Warranty

APRO warrants your 3D NAND TLC M.2-2242 & 2280 Form-factor PCIe NVMe Module HERCULES-PA 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 TLC (Standard grade / Wide temp. grade) 2 years / Within 3K Erasing Counts**

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