Apacer

RoHS Compliant

PCI Express Flash Drive

Professional PB4480-R Product Specifications

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Version 1.4

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Specifications Overview:

- **PCIe Interface**
  - Compliant with PCI Express 4.0
  - Compliant with NVMe 1.4
  - Compatible with PCIe Gen4 x4 interface
- **Capacity**
  - 512 GB
  - 1, 2, 4 TB
- **Performance**[1]
  - Interface burst read/write: 8 GB/sec
  - Sequential read: Up to 5,000 MB/sec
  - Sequential write: Up to 4,400 MB/sec
  - Random read (4K): Up to 450,000 IOPS
  - Random write (4K): Up to 340,000 IOPS
- **Flash Management**
  - Low-Density Parity-Check (LDPC) Code
  - Global Wear Leveling
  - Flash bad-block management
  - Flash Translation Layer: Page Mapping
  - Power Failure Management
  - S.M.A.R.T.
  - TRIM
  - Hyper Cache Technology
  - SMART Read Refresh™
- **NAND Flash Type:** 3D TLC
- **MTBF:** > 2,000,000 hours
- **Endurance (in Terabytes Written: TBW)**
  - 512 GB: 500 TBW
  - 1 TB: 1,000 TBW
  - 2 TB: 2,000 TBW
  - 4 TB: 4,000 TBW
- **Temperature Range**
  - Operating (Tc): 0°C to 70°C
  - Storage (Ta): -40°C to 85°C
- **Supply Voltage**
  - 3.3V ± 5%
- **Power Consumption**[1]
  - Active mode (Max.): 1,525 mA
  - Idle mode: 435 mA
- **Power Management**
  - Supports APST
  - Supports ASPM L1.2
- **NVMe Features**[2]
  - Supports HMB (Host Memory Buffer)
- **Reliability**
  - Thermal Throttling
  - Heat Spreader
- **Connector Type**
  - 75-pin M.2 module pinout
- **Physical Characteristics**
  - Form factor: Single-sided M.2 2280-M
  - Dimensions: 22.00 x 80.00 x 2.43(max.), unit: mm
- **RoHS Compliant**
- **Warranty: 5 years or TBW (whichever occurs first)**

Notes:
1. Varies from capacities. The values for performances and power consumptions presented are typical and may vary depending on flash configurations or platform settings. The term idle refers to the standby state of the device.
2. Windows 10 (version 1703) onwards supports the HMB (Host Memory Buffer) function.

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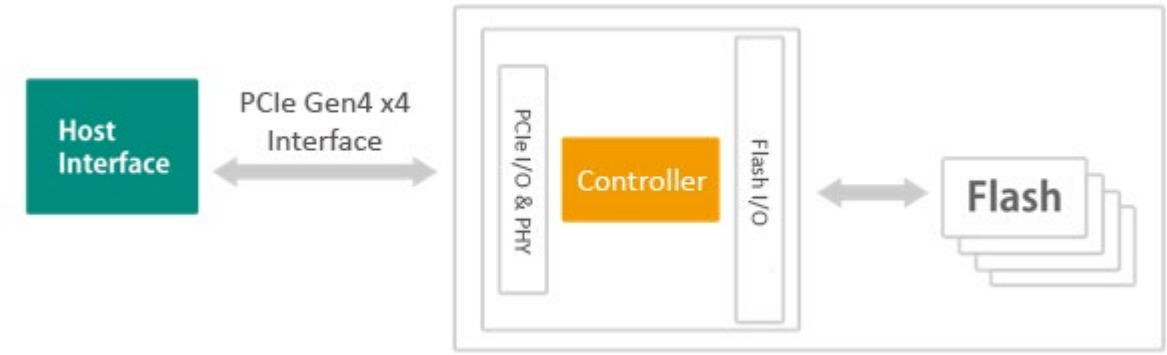
1. Product Specifications

1.1 Functional Block



Note: The actual number of NAND flash used on Apacer Professional PB4480-R varies from capacities. The illustration is for reference only.

Figure 1-1 Functional Block Diagram

1.2 Performance

Performance of Apacer Professional PB4480-R is listed below in Table 1-1.

Table 1-1 Performance Specifications

Capacity / Performance	512 GB	1 TB	2 TB	4 TB
Sequential Read (MB/s)	4,500	5,000	4,800	3,600
Sequential Write (MB/s)	2,500	4,400	4,400	3,200
4K Random Read (IOPS)	380,000	450,000	440,000	430,000
4K Random Write (IOPS)	280,000	340,000	340,000	150,000

Notes:
- Results may differ from various flash configurations or host system setting.
- Sequential performance is based on CrystalDiskMark 8.0.4 with file size 1,000MB.
- Random performance measured using IOMeter with Queue Depth 128.

1.3 Environmental Specifications

Environmental specifications of Apacer Professional PB4480-R are shown in Table 1-2.

Table 1-2 Environmental Specifications

Parameter	Type	Specifications
Temperature	Operating (Tc)	0°C to 70°C
	Non-operating (Ta)	-40°C to 85°C
Vibration	Operating	7.69 GRMS, 20~2000 Hz/random (compliant with MIL-STD-810G)
	Non-operating	4.02 GRMS, 15~2000 Hz/random (compliant with MIL-STD-810G)
Shock	Operating	Acceleration, 50(G)/11(ms)/half sine (compliant with MIL-STD-202G)
	Non-operating	Acceleration, 1500(G)/0.5(ms)/half sine (compliant with MIL-STD-883K)

Notes:
- This Environmental Specification table indicates the conditions for testing the device. Real world usages may affect the results.
- Tc: case temperature; Ta: ambient temperature. The operating temperature is determined by the case temperature. Adequate airflow is advisable as it enables the device to maintain optimal temperatures, especially in environments with heavy workloads.

1.4 Mean Time Between Failures (MTBF)

Mean Time Between Failures (MTBF) is predicted based on reliability data for the individual components in Apacer Professional PB4480-R. The prediction result for Apacer Professional PB4480-R is more than 2,000,000 hours.

1.5 Endurance

The endurance of a storage device is predicted by TeraBytes Written based on several factors related to usage, such as the amount of data written into the drive, block management conditions, and daily workload for the drive. Thus, key factors, such as Write Amplifications and the number of P/E cycles, can influence the lifespan of the drive.

Table 1-3 Endurance Specifications

Capacity	TeraBytes Written
512 GB	500
1 TB	1,000
2 TB	2,000
4 TB	4,000

Notes:
- The endurance of SSD could be estimated based on users' behaviors, NAND endurance cycles, and write amplification factor. It is not guaranteed by the flash vendor.
- TBW may vary from flash configuration and platform.
- The endurance test is based on JEDEC 218A & JEDEC 219A client workload.

1.6 Certification and Compliance

Apacer Professional PB4480-R complies with the following standards:

- CE
- UKCA
- FCC
- RoHS

2. Pin Assignments

This connector does not support hot plug capability. There are a total of 75 pins. 12 pin locations are used for mechanical key locations; this allows such a module to plug into Key M connectors.

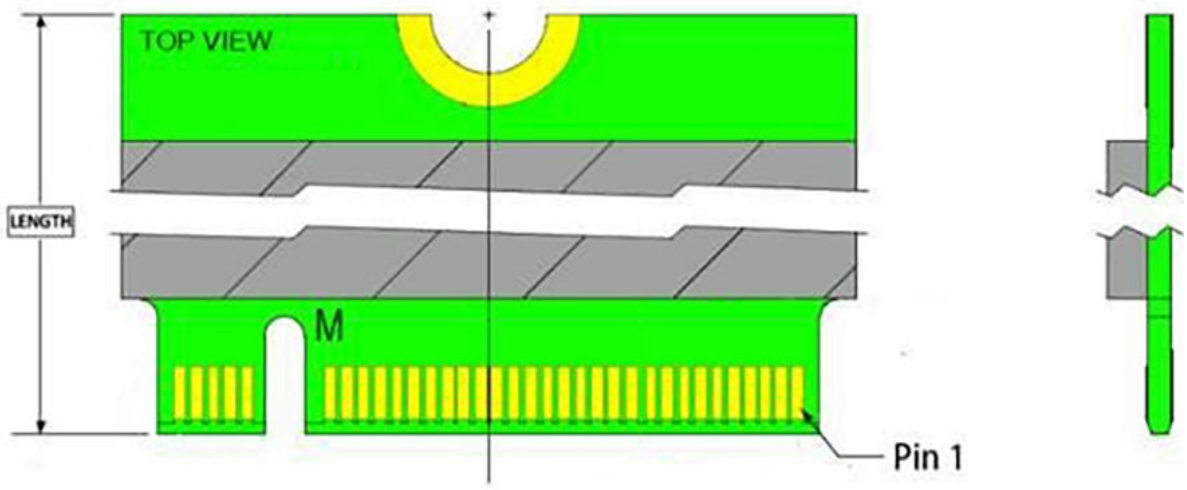


Figure 2-1 Pin Connectors

Table 2-1 Pin Assignments

Pin No.	PCIe Pin	Description
1	GND	Ground
2	3.3V	3.3V source
3	GND	Ground
4	3.3V	3.3V source
5	PETn3	PCIe TX Differential signal defined by the PCI Express M.2 spec
6	N/C	No connect
7	PETp3	PCIe TX Differential signal defined by the PCI Express M.2 spec
8	N/C	No connect
9	GND	Ground
10	LED1#	Open drain, active low signal. These signals are used to allow the add-in card to provide status indicators via LED devices that will be provided by the system.
11	PERn3	PCIe RX Differential signal defined by the PCI Express M.2 spec
12	3.3V	3.3V source
13	PERp3	PCIe RX Differential signals defined by the PCI Express M.2 spec
14	3.3V	3.3V source
15	GND	Ground
16	3.3V	3.3V source
17	PETn2	PCIe TX Differential signal defined by the PCI Express M.2 spec
18	3.3V	3.3V source
19	PETp2	PCIe TX Differential signal defined by the PCI Express M.2 spec

Table 2-1 Pin Assignments

Pin No.	PCIe Pin	Description
20	N/C	No connect
21	GND	Ground
22	N/C	No connect
23	PERn2	PCIe RX Differential signal defined by the PCI Express M.2 spec
24	N/C	No connect
25	PERp2	PCIe RX Differential signal defined by the PCI Express M.2 spec
26	N/C	No connect
27	GND	Ground
28	N/C	No connect
29	PETn1	PCIe TX Differential signal defined by the PCI Express M.2 spec
30	N/C	No connect
31	PETp1	PCIe TX Differential signal defined by the PCI Express M.2 spec
32	GND	Ground
33	GND	Ground
34	N/C	No connect
35	PERn1	PCIe RX Differential signal defined by the PCI Express M.2 spec
36	N/C	No connect
37	PERp1	PCIe RX Differential signal defined by the PCI Express M.2 spec
38	GND	Ground
39	GND	Ground
40	N/C	No connect
41	PETn0	PCIe TX Differential signal defined by the PCI Express M.2 spec
42	N/C	No connect
43	PETp0	PCIe TX Differential signal defined by the PCI Express M.2 spec
44	N/C	No connect
45	GND	Ground
46	N/C	No connect
47	PERn0	PCIe RX Differential signal defined by the PCI Express M.2 spec
48	N/C	No connect
49	PERp0	PCIe RX Differential signal defined by the PCI Express M.2 spec
50	PERST#(I)(0/3.3V)	PE-Reset is a functional reset to the card as specification. defined by the PCIe Mini CEM
51	GND	Ground
52	CLKREQ#(I/O)(0/3.3V)	Clock Request is a reference clock request signal as defined by the PCIe Mini CEM specification; Also used by L1 PM Substates.
53	REFCLKn	PCIe Reference Clock signals (100 MHz) spec. defined by the PCI Express M.2
54	N/C	No connect
55	REFCLKp	PCIe Reference Clock signals (100 MHz) spec. defined by the PCI Express M.2
56	Reserved for MFG Data	Manufacturing Data line. Used for SSD manufacturing only. Not used in normal operation. Pins should be left N/C in platform Socket.

Table 2-1 Pin Assignments

Pin No.	PCIe Pin	Description
57	GND	Ground
58	Reserved for MFG CLOCK	Manufacturing Clock line. Used for SSD manufacturing only. Not used in normal operation. Pins should be left N/C in platform Socket.
59	Module Key	Module Key
60	Module Key	Module Key
61	Module Key	Module Key
62	Module Key	Module Key
63	Module Key	Module Key
64	Module Key	Module Key
65	Module Key	Module Key
66	Module Key	Module Key
67	N/C	No connect
68	N/C	No connect
69	N/C	No connect
70	3.3V	3.3V source
71	GND	Ground
72	3.3V	3.3V source
73	GND	Ground
74	3.3V	3.3V source
75	GND	CONFIG_2 = Ground

3. Flash Management

3.1 Error Correction/Detection

Apacer Professional PB4480-R implements a hardware ECC scheme, based on the Low Density Parity Check (LDPC). LDPC is a class of linear block error correcting code which has apparent coding gain over BCH code because LDPC code includes both hard decoding and soft decoding algorithms. With the error rate decreasing, LDPC can extend SSD endurance and increase data reliability while reading raw data inside a flash chip.

3.2 Bad Block Management

Current production technology is unable to guarantee total reliability of NAND flash memory array. When a flash memory device leaves factory, it comes with a minimal number of initial bad blocks during production or out-of-factory as there is no currently known technology that produce flash chips free of bad blocks. In addition, bad blocks may develop during program/erase cycles. Since bad blocks are inevitable, the solution is to keep them in control. Apacer flash devices are programmed with ECC, page mapping technique and S.M.A.R.T to reduce invalidity or error. Once bad blocks are detected, data in those blocks will be transferred to free blocks and error will be corrected by designated algorithms.

3.3 Global Wear Leveling

Flash memory devices differ from Hard Disk Drives (HDDs) in terms of how blocks are utilized. For HDDs, when a change is made to stored data, like erase or update, the controller mechanism on HDDs will perform overwrites on blocks. Unlike HDDs, flash blocks cannot be overwritten and each P/E cycle wears down the lifespan of blocks gradually. Repeatedly program/erase cycles performed on the same memory cells will eventually cause some blocks to age faster than others. This would bring flash storages to their end of service term sooner. Global wear leveling is an important mechanism that levels out the wearing of all blocks so that the wearing-down of all blocks can be almost evenly distributed. This will increase the lifespan of SSDs.

3.4 Power Failure Management

Power Failure Management plays a crucial role when power supply becomes unstable. Power disruption may occur when users are storing data into the SSD, leading to instability in the drive. However, with Power Failure Management, a firmware protection mechanism will be activated to scan pages and blocks once power is resumed. Valid data will be transferred to new blocks for merging and the mapping table will be rebuilt. Therefore, data reliability can be reinforced, preventing damage to data stored in the NAND Flash.

3.5 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 which blocks of data are no longer in use and can be removed permanently. Thus, the SSD will perform the erase action, which prevents unused data from occupying blocks all the time.

3.6 Flash Translation Layer – Page Mapping

Page mapping is an advanced flash management technology whose essence lies in the ability to gather data, distribute the data into flash pages automatically, and then schedule the data to be evenly written. Page-level mapping uses one page as the unit of mapping. The most important characteristic is that each logical page can be mapped to any physical page on the flash memory device. This mapping algorithm allows different sizes of data to be written to a block as if the data is written to a data pool and it does not need to take extra operations to process a write command. Thus, page mapping is adopted to increase random access speed and improve SSD lifespan, reduce block erase frequency, and achieve optimized performance and lifespan.

3.7 Hyper Cache Technology

Apacer proprietary Hyper Cache technology uses a portion of the available capacity as SLC (1bit-per-cell) NAND flash memory, called Hyper cache mode. When data is written to SSD, the firmware will direct the data to Hyper Cache mode, providing excellent performance to handle various scenarios in industrial use.

3.8 SMART Read Refresh™

Apacer's SMART Read Refresh plays a proactive role in avoiding read disturb errors from occurring to ensure health status of all blocks of NAND flash. Developed for read-intensive applications in particular, SMART Read Refresh is employed to make sure that during read operations, when the read operation threshold is reached, the data is refreshed by re-writing it to a different block for subsequent use.

4. NVMe Support Features

4.1 Host Memory Buffer

Host Memory Buffer (HMB) allows HOST to allocate system memory for SSD's exclusive use in order to provide better performance and endurance, especially for DRAMless solutions.

5. Reliability Features

5.1 Thermal Throttling

Thermal throttling can monitor the temperature of the SSD equipped with a built-in thermal sensor via S.M.A.R.T. commands. This method can ensure the temperature of the device stays within temperature limits by drive throttling, i.e. reducing the speed of the drive when the device temperature reaches the threshold level, so as to prevent overheating, guarantee data reliability, and prolong product lifespan. When the temperature exceeds the maximum threshold level, thermal throttling will be triggered to reduce performance step by step to prevent hardware components from being damaged. Performance is only permitted to drop to the extent necessary for recovering a stable temperature to cool down the device's temperature. Once the temperature decreases to the minimum threshold value, transfer speeds will rise back to its optimum performance level.

5.2 Heat Spreader

In many applications, SSDs are subject to challenging conditions. If the working environment is already hot, and the SSD's operation causes it to increase in temperature as well, the result could be damage to the hardware or corrupted data. For this reason, Apacer's graphene heat spreader is developed for heat dissipation to cool both the NAND Flash and the Controller IC, while still allowing an SSD to deliver high-speed performance, as well as prevent heat-related damage from occurring.

6. S.M.A.R.T.

SMART, an acronym for Self-Monitoring, Analysis and Reporting Technology, is an open standard that allows a hard disk 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 of impending failures while there is still time to perform proactive actions, such as copy data to another device.

Table 6-1 SMART (02h)

Byte	Length	Description
0	1	Critical Warning
1-2	2	Composite Temperature
3	1	Available Spare
4	1	Available Spare Threshold
5	1	Percentage Used
6-31	26	Reserved
32-47	16	Data Units Read
48-63	16	Data Units Written
64-79	16	Host Read Commands
80-95	16	Host Write Commands
96-111	16	Controller Busy Time
112-127	16	Power Cycles
128-143	16	Power On Hours
144-159	16	Unsafe Shutdowns
160-175	16	Media and Data Integrity Errors
176-191	16	Number of Error Information Log Entries
192-195	4	Warning Composite Temperature Time
196-199	4	Critical Composite Temperature Time
200-201	2	Temperature Sensor 1
202-203	2	Temperature Sensor 2
204-205	2	Temperature Sensor 3
206-207	2	Temperature Sensor 4
208-209	2	Temperature Sensor 5
210-211	2	Temperature Sensor 6
212-213	2	Temperature Sensor 7
214-215	2	Temperature Sensor 8
216-511	296	Reserved

Note: Temperature display of the Temperature Sensor from 1 to 8 (corresponding bytes from 200 to 215) is not supported if the return value is 0h.

7. Electrical Specifications

7.1 Operating Voltage

Table 7-1 lists the supply voltage for Apacer Professional PB4480-R.

Table 7-1 Operating Range

Item	Range
Supply Voltage	3.3V ± 5%

7.2 Power Consumption

Table 7-2 lists the power consumption for Apacer Professional PB4480-R.

Table 7-2 Power Consumption

Capacity / Mode	Unit	512 GB	1 TB	2 TB	4 TB
Active (Max.)	mA	1,525	1,455	1,450	1,400
Idle		420	435	420	415

Notes:
- All values are typical and may vary depending on flash configurations or host system settings.
- Power consumption is measured using CrystalDiskMark 8.0.4 with file size 1,000MB.

8. Mechanical Specifications

Table 8-1 Physical Dimensions

Parameter	Unit	512 GB	1 TB	2 TB	4 TB
Length	mm	80.00 ± 0.15			
Width		22.00 ± 0.15			
Height (Max.)		2.43			

Top View

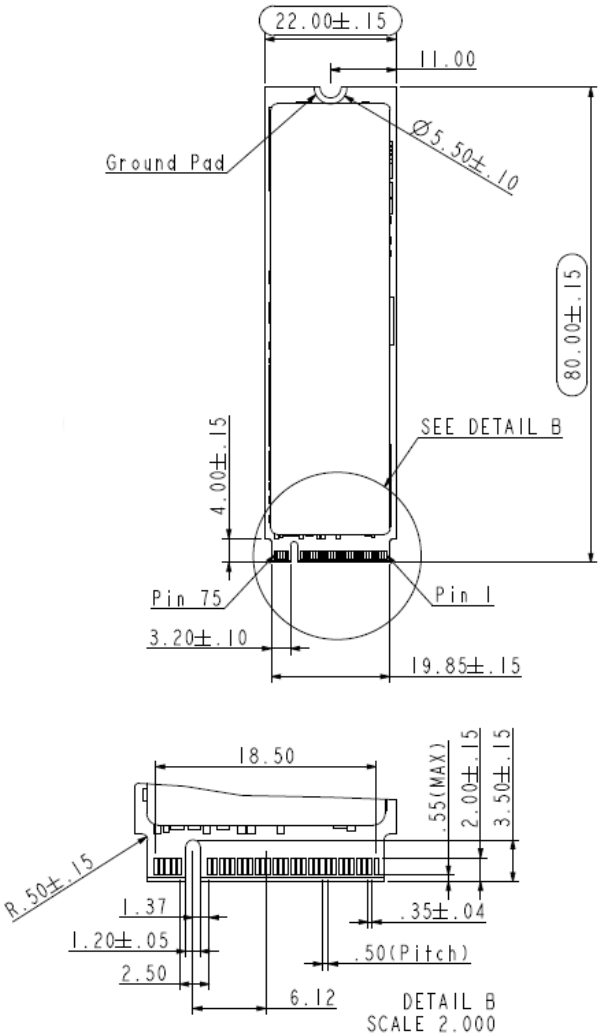


Figure 8-1 Top View

Bottom View

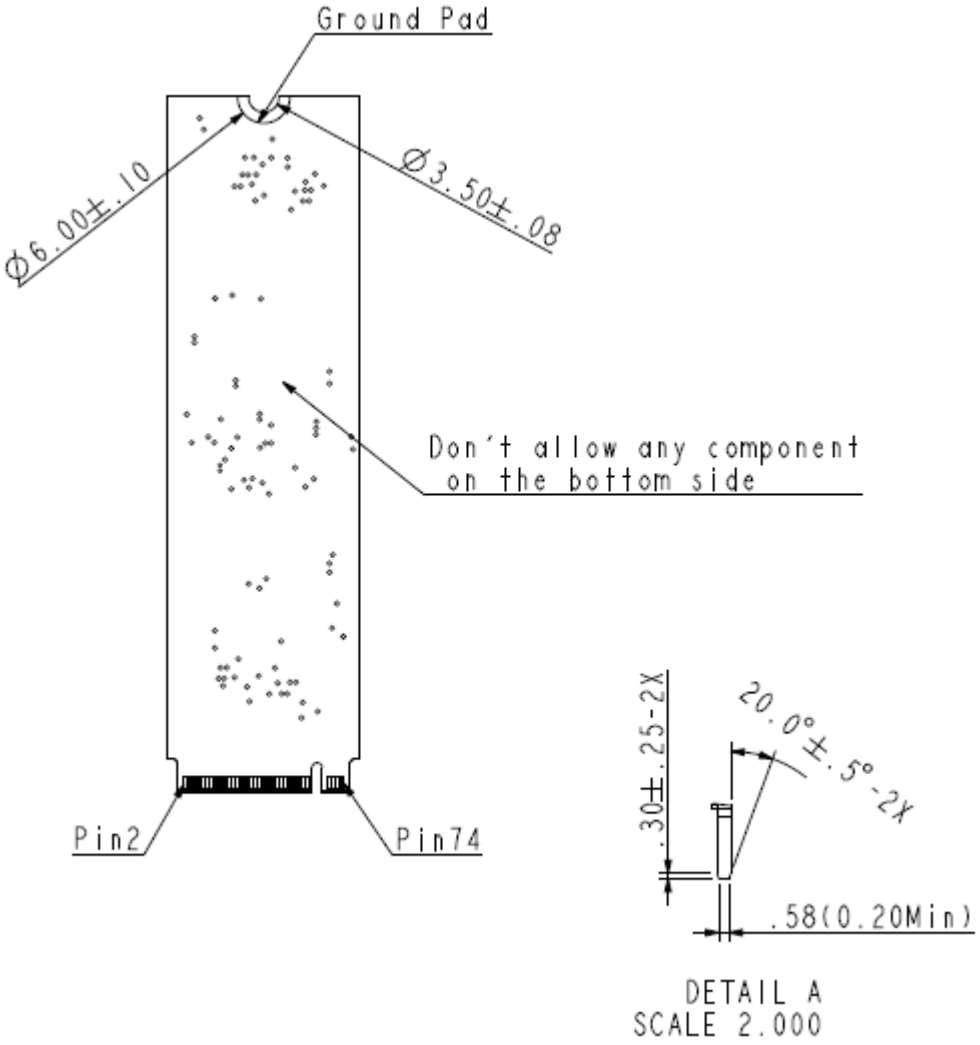


Figure 8-2 Bottom View

Side View

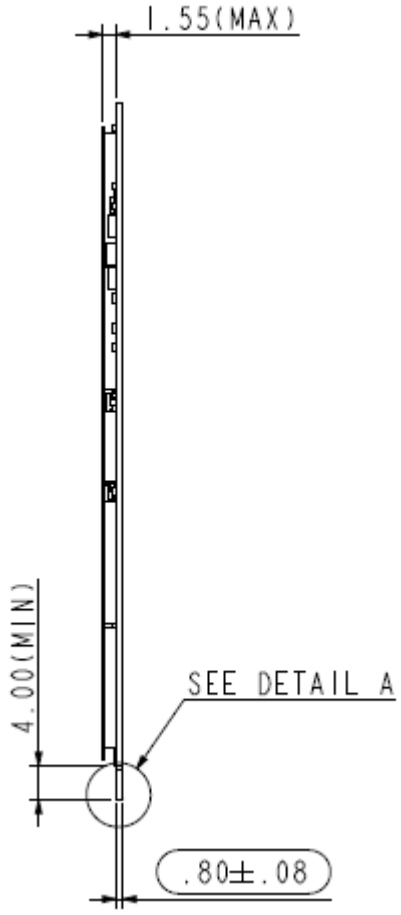


Figure 8-3 Side View

9. Product Ordering Information

The following table lists the available models of Apacer Professional PB4480-R series which are in mass production or will be in mass production. Consult your Apacer sales representative to confirm availability of valid combinations and to determine availability of new combinations.

Capacity	Bulk P/N
512GB	AP512GPB4480-R
1TB	AP1TPB4480-R
2TB	AP2TPB4480-R
4TB	AP4TPB4480-R

Revision History

Revision	Description	Date
1.0	Initial release	7/24/2023
1.1	Renamed heatsink to heat spreader	9/26/2023
1.2	Corrected the pin assignments table at 2.1 Pin Assignments	2/1/2024
1.3	- Updated vibration and shock spec at Table 1-2 - Removed 6.1 Command Set from 6. Software Interface and renamed the chapter title to 6. S.M.A.R.T.	2/5/2024
1.4	Added a note regarding temperature at Table 1-2	4/1/2024

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