



Seagate® BarraCuda® 515 FIPS SSD

Product Manual

User Capacity	SED FIPS/Common Criteria M.2 2280-D2-M Models
256 GB	ZP256MC30012
512 GB	ZP512MC30012
1024 GB	ZP1024MC30012
2048 GB	ZP2048MC30012

Revision History

Version and Date	Description of Changes
Rev C, October 2022	■ Updated Cigent user instructions.
Rev B, July 2022	■ Revised document throughout. ■ Added Cigent user instructions.
Rev A, February 2022	First document release.

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When referring to drive capacity, one gigabyte, or GB, equals one billion bytes and one terabyte, or TB, equals one trillion bytes. Your computer's operating system may use a different standard of measurement and report a lower capacity. In addition, some of the listed capacity is used for formatting and other functions, and thus will not be available for data storage. Actual quantities will vary based on various factors, including file size, file format, features and application software. Actual data rates may vary depending on operating environment and other factors. The export or re-export of hardware or software containing encryption may be regulated by the U.S. Department of Commerce, Bureau of Industry and Security (for more information, visit www.bis.doc.gov), and controlled for import and use outside of the U.S. Seagate reserves the right to change, without notice, product offerings or specifications.

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Support

For Internal SSD Support, visit: <https://www.seagate.com/support/products/>

For Firmware Download and Tools Download for Secure Erase, visit: <https://www.seagate.com/support/downloads/>

For information regarding online support and services, visit: <http://www.seagate.com/contacts/>

For information regarding Warranty Support, visit: <http://www.seagate.com/support/warranty-and-replacements/>

For information regarding data recovery services, visit:

<http://www.seagate.com/services-software/seagate-recovery-services/recover/>

For Seagate OEM and Distribution partner and Seagate reseller portal, visit: <http://www.seagate.com/partners>

1. Introduction

The Seagate® BarraCuda® 515 FIPS SSD is a versatile M.2 NVMe SSD with integrated advanced data security. This SSD meets the strict encryption and security requirements set by the US Government to keep sensitive data protected and secure.

Table 1 BarraCuda 515 FIPS SSD Features

Feature	Description	
Capacity (User)	<ul style="list-style-type: none"> ■ 256 GB, 512 GB, 1024 GB, 2048 GB 	
Certifications, Eco-Compliance	<ul style="list-style-type: none"> ■ CE, UL, FCC, BSMI, KCC, Microsoft WHQL, VCCI, CB ■ RoHS 	
Dimensions	<ul style="list-style-type: none"> ■ Length, Max (mm/in): 80.15 mm/3.156 in ■ Width, Max (mm/in): 22.15 mm/0.872 in ■ Height, Max (mm/in): 4.78mm/0.188 in 	
Form Factor	<ul style="list-style-type: none"> ■ M.2 2280-D2-M 	
Weight	<ul style="list-style-type: none"> ■ 256 GB: 8.5g ■ 512 GB: 8.5g ■ 1024 GB: 8.9g ■ 2048 GB: 9.2g 	
Endurance	Total Bytes Written <ul style="list-style-type: none"> ■ 256 GB: 245 TB ■ 512 GB: 545 TB ■ 1024 GB: 1140 TB ■ 2048 GB: 2310 TB 	See Section 2.5, Reliability/Endurance .
Interface Compliance	<ul style="list-style-type: none"> ■ NVMe 1.3 ■ PCI Express Base 3.1 	
NAND	<ul style="list-style-type: none"> ■ 3D TLC 	
Operating Systems	<ul style="list-style-type: none"> ■ Windows® 10 (64 bit) ■ Ubuntu® 18.04, 20.04 ■ CentOS® versions 7 	
Performance Random	<ul style="list-style-type: none"> ■ Read: Up to 640,000 IOPS ■ Write: Up to 640,000 IOPS 	Actual performance might vary depending on use conditions and environment. See Section 2.2, Performance .
Performance Sequential	<ul style="list-style-type: none"> ■ Read: Up to 3400MB/s ■ Write: Up to 3100MB/s 	Actual performance might vary depending on the capacity, use conditions and environment. See Section 2.2, Performance .
Power Consumption	<ul style="list-style-type: none"> ■ Active Power (W): <5.7 ■ Idle Power PS3 (mW): <21 ■ Low Power L1.2 PS4 (mW): <2 	See Section 2.3, Power Consumption .
Power Management	<ul style="list-style-type: none"> ■ Supports ActiveStatePower Management (ASPM) ■ Supports Autonomous Power StateTransition (APST) ■ Supports L1.2 	

Table 1 BarraCuda 515 FIPS SSD Features (continued)

Feature	Description	
Security	<ul style="list-style-type: none"> ■ FIPS 140-2 Iv2 (NIST certificate #4294) ■ NIAP Common Criteria FDE_EE Product In Evaluation (VID 11322) ■ Includes perpetual Cigent® software license ■ AES-XTS 256-bit hardware encryption ■ RSA-2048 digital signature verification ■ On-chip deterministic random number generator ■ Tamper-evidence protection ■ TCG Opal SSC 2.0 support ■ TAA compliant 	<p>See Section 7.1, Advanced Device Security Features See Section 7.2, About FIPS</p>
Reliability	<ul style="list-style-type: none"> ■ End-to-end data path protection ■ MTBF: 1.8 million hours ■ UBER: 1 error in 10¹⁶ bits read 	
Shock and Vibration	Shock <ul style="list-style-type: none"> ■ Non-Operating: 1,500 G, at 0.5 ms 	<p>See Section 2.4, Environmental Conditions.</p>
	Vibration <ul style="list-style-type: none"> ■ Non-Operating: 1.52 G_{RMS}, (20 to 80 Hz, Frequency) 	
Temperature Range	<ul style="list-style-type: none"> ■ Operating: 0°C to 70°C ■ Non-operating: -40°C to 85°C 	
Voltage	<ul style="list-style-type: none"> ■ 3.3 V±5% 	
Warranty	<p>Five years, or when the device reaches Host TBW, whichever happens first. Endurance rating valid for SSD Life Remaining > 1%.</p>	

2. Specifications

2.1 Models and Capacity

Table 2 Models and Capacity

User Capacity	SED FIPS M.2 2280-D2-M
256 GB	ZP256MC30012
512 GB	ZP512MC30012
1024 GB	ZP1024MC30012
2048 GB	ZP2048MC30012

NOTE About capacity:

- Sector Size: 512 Bytes
- User-addressable LBA count = $(97696368) + (1953504 \times (\text{Desired Capacity in Gb}-50.0))$ From International Disk Drive Equipment and Materials Association (IDEMA) (*LBA1-03_standard.doc*)

2.2 Performance

Table 3 Random and Sequential Read and Write Performance

Parameter	2048 GB	1024 GB	512 GB	256 GB
Sequential Read (Max, MB/s), 128KB	3400	3400	3400	3300
Sequential Write (Max, MB/s), 128KB	3000	3100	2500	1300
Random Read (Max, IOPS), 4KB QD32 T8	640,000	640,000	420,000	210,000
Random Write (Max, IOPS), 4KB QD32 T8	640,000	640,000	625,000	320,000

NOTE About performance:

- Fresh out of box (FOB) performance obtained on newly formatted drive. Performance may vary based on the SSD's firmware version, system hardware, and configuration.
- CrystalDiskMark V6.0:
 - Sequential Read/Write: 1GB range, QD=32, Thread=1
 - Random Read/Write: 1GB range, QD=32, Thread=8

2.3 Power Consumption

Table 4 Power Consumption

Parameter	2048 GB	1024 GB	512 GB	256 GB
Max. Average Read (mW)	5300	5300	5100	5000
Max. Average Write (mW)	5700	5200	4500	3100
Idle PS3 (mW)	22	21	16	16
L1.2 (mW)	2	2	2	2

NOTE

About power consumption:

- The measured power voltage is 3.3 V.
- Measured under ambient temperature.
- Power Consumption can vary based on system hardware.
- Power consumption is measured during the sequential read and write (128KB) operations for 5 times using CrystalDiskMark 6.0.0 with the test size range 1GiB.

2.4 Environmental Conditions

Table 5 Temperature, Humidity, Shock

Specification	Value
Temperature Operating (case temperature at specific airflow) Non-operating	0°C to 70°C -40°C to 85°C
Humidity Operating Non-operating (storage)	90% 93%
Shock Non-operating	1,500 G, duration 0.5 ms
Vibration Non-operating	1.52 G _{RMS} , (20Hz to 80Hz, Frequency)

NOTE

Temperature is measured without condensation. Operating mode temperature is measured by temperature sensor, SMART Attribute.

Airflow is suggested. Airflow allows the device to be operated at the appropriate temperature for each component during heavy workloads environments.

Storage: The drive can be stored for a maximum of 180 days in the original unopened Seagate shipping package or 60 days, unpackaged, in the defined non-operating limits. Storage can be extended to 1 year packaged or unpackaged under optimal environmental conditions (<40°C, <40% relative humidity non-condensing, and non-corrosive environment).

Shock and vibration results assume that the SSD is mounted securely with the input vibration applied to the SSD mounting. These specifications do not cover connection issues that may result from testing at this level. The measured specification is in root mean square (RMS) form.

- **Non-operating Shock.** The limits of non-operating shock applies to all conditions of handling and transportation. This includes both isolated SSD and integrated SSDs. Shock may be applied in the X, Y, or Z-axis.
- **Non-Operating Vibration.** The limits of non-operating vibration shall apply to all conditions of handling and transportation. This includes both isolated SSD and integrated SSDs. Vibration may be applied in the X, Y, or Z-axis.

2.5 Reliability/Endurance

Table 6 Reliability/Endurance

Specification	Value
Mean time between failures (MTBF)	1.8 million hours
Bit Error Rate	1 error in 10^{16} bits read
Endurance	Total Bytes Written <ul style="list-style-type: none"> ■ 256 GB: 245 TB ■ 512 GB: 545 TB ■ 1024 GB: 1140 TB ■ 2048 GB: 2310 TB

NOTE

About endurance:

- The SSD achieves the specified MTBF in an operational environment that complies with the operational temperature range specified in this manual. Operating temperatures are measured by temperature sensor.
- Endurance rating valid for SSD Life Remaining > 1%.
- Endurance is characterized while running Client JESD219A workload (per JESD218A specification).

3. Mechanical Information

Weight: 8.5 g (256 GB), 8.5g (512 GB)

8.9 g (1024 GB, 2048 GB)

Height: 4.7 mm±0.08 mm

Width: 22 mm±0.15 mm

Length: 80 mm±0.15 mm

Figure 1 BarraCuda 515 FIPS SSD Top Side View

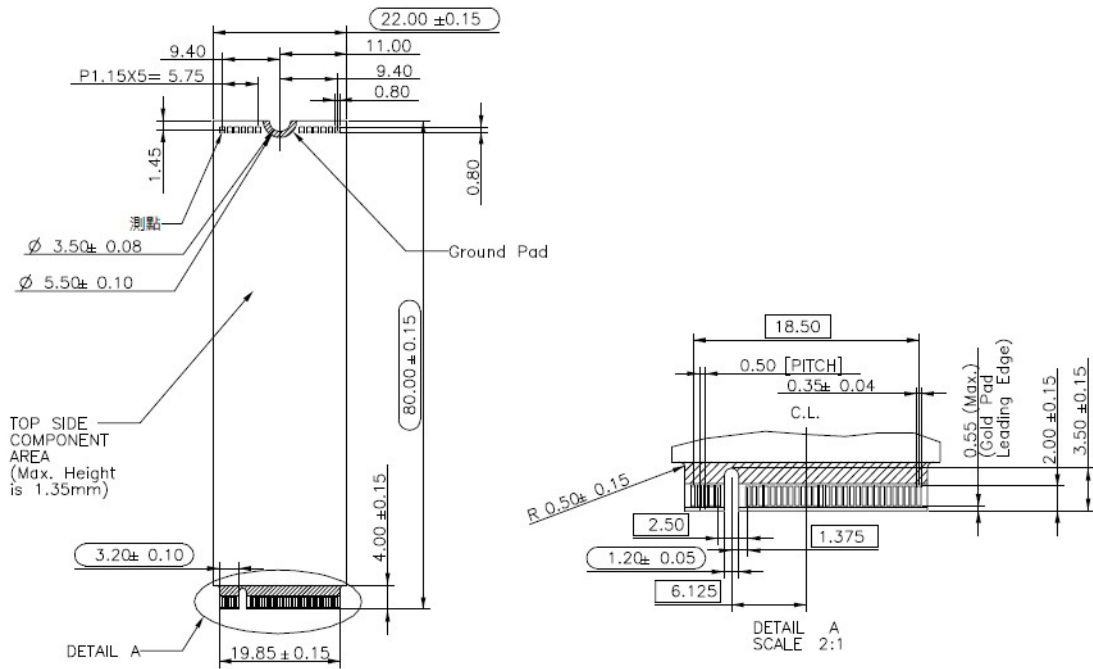


Figure 2 BarraCuda 515 FIPS SSD Bottom Side View

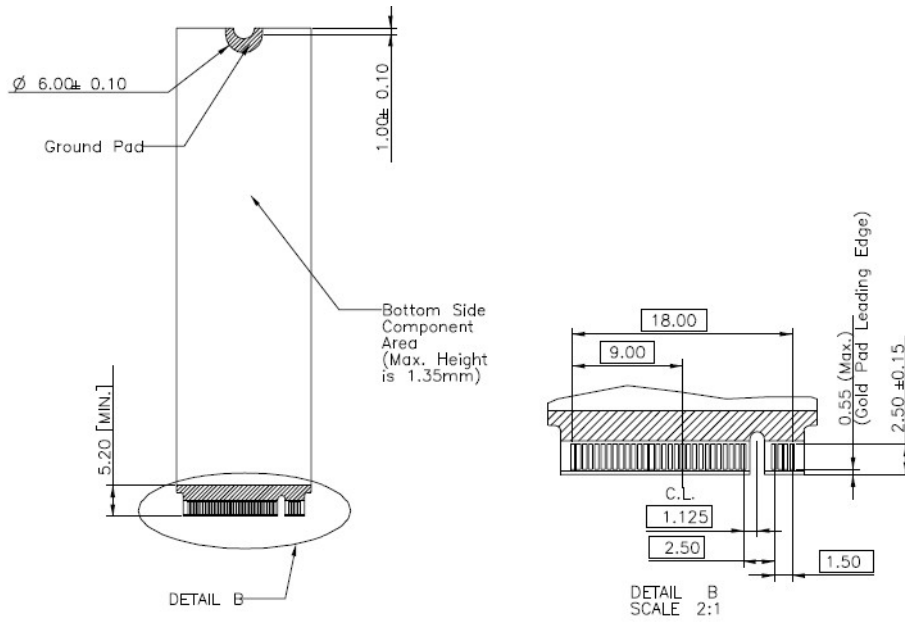


Figure 3 BarraCuda 515 FIPS SSD Side View 1

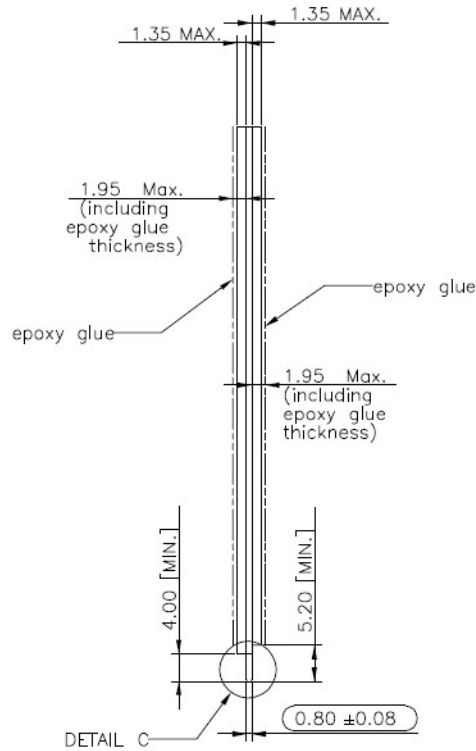
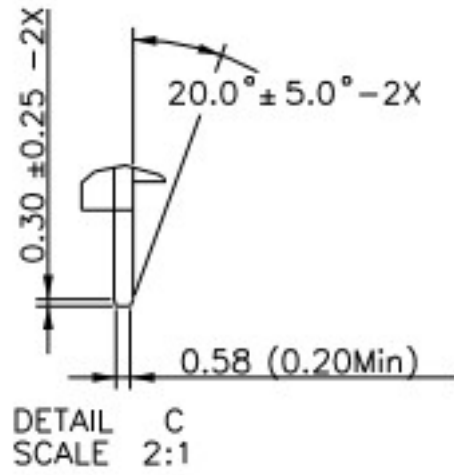


Figure 4 BarraCuda 515 FIPS SSD Side View 2



Notes

- Notes :
1. = Max Component Height
 2. = No Component
 3. = No Component / Signal Vias / Signal Copper / Printing
 4. General Tolerance ±0.15mm
 5. are critical dimensions

4. Pin and Signal Descriptions

Table 7 Pin Descriptions

Pin No.	PCIe Pin	Description
1	GND	CONFIG_3 = GND
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 signal 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
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

Table 7 Pin Descriptions (continued)

Pin No.	PCIe Pin	Description
31	PETp1	PCIe TX Differential signal defined by the PCI Express M.2 spec
32	N/C	No connect
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	N/C	No connect
39	GND	Ground
40	SMB_CLK (I/O)(0/1.8V)	SMBus Clock; Open Drain with pull-up on platform
41	PETn0	PCIe TX Differential signal defined by the PCI Express M.2 spec
42	SMB_DATA (I/O)(0/1.8V)	SMBus Data; Open Drain with pull-up on platform.
43	PETp0	PCIe TX Differential signal defined by the PCI Express M.2 spec
44	ALERT#(O) (0/1.8V)	Alert notification to master; Open Drain with pull-up on platform; Active low.
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 defined by the PCIe Mini CEM specification.
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 Sub-states.
53	REFCLKn	PCIe Reference Clock signals (100 MHz) defined by the PCI Express M.2 spec.
54	PEWAKE#(I/O)(0/3.3V)	PCIe PME Wake. Open Drain with pull up on platform; Active Low.
55	REFCLKp	PCIe Reference Clock signals (100 MHz) defined by the PCI Express M.2 spec.
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 7 Pin Descriptions (continued)

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 M	Module Key
60	Module Key M	
61	Module Key M	
62	Module Key M	
63	Module Key M	
64	Module Key M	
65	Module Key M	
66	Module Key M	
67	N/C	No connect
68	SUSCLK(32KHz) (I)(0/3.3V)	32.768 kHz clock supply input that is provided by the platform chipset to reduce power and cost for the module.
69	N/C	PEDET (NC-PCIe)
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	Ground

5. SMART Support

The BarraCuda 515 FIPS SSD supports the SMART command set.

5.1 SMART Attributes

The following table lists SMART Attributes and Descriptions.

Table 8 SMART Attributes (Log Identifier 02h)

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 (Current Temperature)
[203:202]	2	Temperature Sensor 2 (N/A)
[205:204]	2	Temperature Sensor 3 (N/A)
[207:206]	2	Temperature Sensor 4 (N/A)

Table 8 SMART Attributes (Log Identifier 02h)

[209:208]	2	Temperature Sensor 5 (N/A)
[211:210]	2	Temperature Sensor 6 (N/A)
[213:212]	2	Temperature Sensor 7 (N/A)
[215:214]	2	Temperature Sensor 8 (N/A)
[511:216]	296	Reserved

6. NVMe Commands

Table 9 Admin Commands

Identifier	O/M	Command Description	Support
00h	M	Delete I/O Submission Queue	Y
01h	M	Create I/O Submission Queue	Y
02h	M	Get Log Page	Y
04h	M	Delete I/O Completion Queue	Y
05h	M	Create I/O Completion Queue	Y
06h	M	Identify	Y
08h	M	Abort	Y
09h	M	Set Feature	Y
0Ah	M	Get Feature	Y
0Ch	M	Asynchronous Event Request	Y
0Dh	O	Namespace management	N
10h	O	Firmware Commit	Y
11h	O	Firmware Image Download	Y
14h	O	Device Self-test	N
15h	O	Namespace Attachment	N
18h	O	Keep Alive	N
19h	O	Directive Send	N
1Ah	O	Directive receive	N
1Dh	O	NVMe-MI Send	N
1Eh	O	NVMe-Mi Receive	N
80h	O	Format NVM	N
81h	O	Security Send	Y
82h	O	Security Receive	Y
84h	O	Sanitize	N

Table 10 I/O Commands

Identifier	O/M	Command Description	Support
00h	O	Flush	Y
01h	O	Write	N* / Y **
02h	O	Read	N* / Y **
04h	O	Write Uncorrectable	N
05h	O	Compare	N* / Y **
08h	O	Write Zeroes	N* / Y **
09h	O	Dataset Management	N* / Y **

*when in FIPS-approved mode

**only available when in FIPS mode + unlocked state

Table 11 Set Feature Commands

Identifier	O/M	Command Description	Support
00h		Reserved	-
01h	M	Arbitration	Y
02h	M	Power Management	Y
03h	O	LBA Range Type	N
04h	M	Temperature Threshold	Y
05h	M	Error Recovery	Y
06h	O	Volatile Write Cache	Y
07h	M	Number Of Queues	Y
08h	M	Interrupt Coalescing	Y
09h	M	Interrupt Vector Configuration	Y
0Ah	M	Write Atomicity Normal	Y
0Bh	M	Asynchronous Event Configuration	Y
0Ch	O	Autonomous Power State Transition	Y
0Dh	O	Host Memory Buffer	N
0Eh	O	Timestamp	Y
10h	O	Host Controlled Thermal Management	Y
11h	O	Non-Operational Power State Config	Y
0Eh - 7Dh		Reserved	-
80h	O	Software Progress Marker	Y

Table 12 Get Log Page Commands

Identifier	O/M	Command Description	Support
00h		Reserved	-
01h	M	Error Information	Y
02h	M	SMART / Health Information	Y
03h	M	Firmware Slot Information	Y
04h	O	Changed Namespace List	N
06h	O	Device Self-test	N
09h - 7Fh		Reserved	-
81h	-	Sanitize Status (not supported)	N
82h - FFh		Reserved	-

7. Security

7.1 Advanced Device Security Features

7.1.1 Physical Presence SID (PSID)

The Physical Presence SID (PSID) is defined by TCG OPAL as a 32-character string and its purpose is to revert the SSD back to its manufacturing setting when the drive is set through TCG Opal (SED). The PSID code is printed on the SSD's label. All user data will be erased when reverting the drive back to manufacturing settings.

7.1.2 Manufacturer's Secure ID (MSID)

The Manufacturer's Secure ID (MSID) is defined by TCG OPAL as a 32-character string and is assigned during the manufacturing process, which is a password that cannot be changed by the host system. MSID can be obtained electronically from the drive across the interface. On acquiring the SSD, the user must set a new password. If a new password is not set the SSD might be potentially taken control by anyone who can reset the MSID. Such an attack on the drive is known as Denial of Service (DoS) since the rightful owner has been locked out.

7.1.3 Instant Secure Erase

Instant Secure Erase erases all the data of the SED drive with the Opal-activated encrypted data structure by resetting the SSD with the PSID. Since the key is reset, the previously encrypted data cannot be accessed.

Table 13 Supported Sanitize Operations

Drive Security Type	TCG Commands	
	PSID Revert Process	Instant Security Erase
SED - FIPS (TCG Opal)	Yes	Yes, Via TCG Revert (PSID)

7.2 About FIPS

The Federal Information Processing Standard (FIPS) Publication 140-2 is a U.S. Government Computer Security Standard used to accredit cryptographic modules. It is titled 'Security Requirements for Cryptographic Modules (FIPS PUB 140-2)' and is issued by the National Institute of Standards and Technology (NIST).

7.2.1 Purpose

This standard specifies the security requirements that will be satisfied by a cryptographic module utilized within a security system protecting sensitive but unclassified information. The standard provides four increasing, qualitative levels of security: Level 1, Level 2, Level 3, and Level 4. These levels are intended to cover the wide range of potential applications and environments in which cryptographic modules may be employed.

7.2.2 Validation Program

Products that claim conformance to this standard are validated by the Cryptographic Module Validation Program (CMVP) which is a joint effort between National Institute of Standards and Technology (NIST) and the Communications Security Establishment (CSE) of the Government of Canada. Products validated as conforming to FIPS 140-2 are accepted by the Federal agencies of both countries for the protection of sensitive information (United States) or Designated Information (Canada).

In the CMVP, vendors of cryptographic modules use independent, accredited testing laboratories to have their modules tested. National Voluntary Laboratory Accreditation Program (NVLAP) accredited laboratories perform cryptographic module compliance/conformance testing.

7.2.3 Seagate SED

The SEDs referenced in this Product Manual are in the process of being validated by CMVP and will be thoroughly tested by a NVLAP accredited lab to satisfy FIPS 140-2 Level 2 requirements. In order to operate in FIPS Approved Mode of Operation, these SEDs require security initialization. For more information, refer to *Security Rules* section in the *Security Policy* document uploaded on the NIST website. To reference the product certification visit: <http://csrc.nist.gov/groups/STM/cmvp/documents/140-1/1401vend.htm>, and search for certificate number 4294.

7.2.4 Security Level 2

Security Level 2 enhances the physical security mechanisms of a Security Level 1 cryptographic module by adding the requirement for tamper-evidence, which includes the use of tamper-evident epoxy resin that covers the module.

The complete module is covered with an opaque epoxy resin, leaving only the host interface connector (data and power ports) exposed and preventing physical access to the critical security parameters (CSP) within the module.

A tamper-evident epoxy resin protects the SSD's circuitry and components from unauthorized physical access. See example in [Figure 5, Example of FIPS tamper-evident epoxy resin](#).

Security Level 2 also requires, at a minimum, role-based authentication in which a cryptographic module authenticates the authorization of an operator to assume a specific role and perform a corresponding set of services.

Figure 5 Example of FIPS tamper-evident epoxy resin



8. Cigent Instructions

8.1 Introduction

The advanced cyber security defenses built into the operating firmware of BarraCuda 515 FIPS SSD repels ransomware attacks and prevents data theft even when all other cybersecurity protections fail or are bypassed. The BarraCuda 515 FIPS SSD comes with the perpetual Cigent software license for this cybersecurity. This license includes Cigent Windows and PBA Software:

- When combined with Cigent’s pre-boot authentication (PBA) the native cyber security protects systems against unauthorized access.
- When used with Cigent for Windows, it protect data for the entire device lifecycle—from provisioning through end-of-life—defending against numerous threat vectors.

For Cigent Windows and PBA software download, and installation and user manuals visit www.cigent.com/support/Seagate

9. SSD Features

9.1 Flash Management

9.1.1 Error Correction Code (ECC)

Flash memory cells will deteriorate with use, which might generate random bit errors in the stored data. Therefore, the BarraCuda 515 FIPS SSD applies the LDPC(Low Density Parity Check) of ECC algorithm, which can detect and correct errors that occur during read process, ensure data has been read correctly, as well as protect data from corruption.

9.1.2 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.

BarraCuda 515 FIPS SSD features provide 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.

9.1.3 Bad Block Management

Bad blocks are blocks that do not function properly or contain more invalid bits causing stored data to become 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”. BarraCuda 515 FIPS SSD features provide 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.

9.1.4 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.

9.1.5 SMART

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.

9.1.6 Firmware Upgrade

Firmware can be considered as a set of instructions on how the device communicates with the host. Firmware upgrades are typically available with added features, fixed compatibility issues, and improved read/write performance.

9.1.7 Thermal Throttling

Thermal throttling prevents components in an SSD from over-heating during read and write operations. The device is designed with an on-die thermal sensor, and with its accuracy, firmware can apply different levels of throttling to achieve the purpose of protection efficiently and proactively through SMART reading.

Table 14 Current version: Thermal Throttling 2.0

Item	Content
Smart reporting temperature	Flash normalized case temperature
Reference of temp. reading	On-board thermal sensor, Controller on-die thermal sensor
tmt1 threshold	68°C per Smart reported
tmt2 threshold	70°C per Smart reported
Protect threshold	80°C per Smart reported
Protect controller threshold	115°C from on-die thermal sensor
Fatal threshold	120°C from on-die thermal sensor
Resume performance threshold	64°C per Smart reported
Temperature polling frequency	Every 1 sec
TMT1_state impact	±10% CE
TMT2_state impact	-20% CE

9.2 SSD Lifetime Management

9.2.1 Total Bytes Written (TBW)

TBW (Total Bytes Written) is a measurement of the SSDs' expected lifespan, which represents the amount of data written to the device. To calculate the TBW of a SSD, the following equation is applied:

$$\text{TBW} = [(\text{NAND Endurance}) \times (\text{SSD Capacity})] / \text{WAF}$$

NAND Endurance: NAND endurance refers to the P/E (Program/Erase) cycle of a NAND flash. SSD Capacity: The SSD capacity is the specific capacity in total of a SSD.

WAF: Write Amplification Factor (WAF) 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 1, guarantees better endurance and lower frequency of data written to flash memory.

TBW in this document is based on JEDEC 219 workload.

9.2.2 Media Wear Indicator

Actual life indicator reported by SMART Attribute byte index [5], Percentage Used, recommends User to replace drive when reaching to 100%.

9.2.3 Read Only Mode (End of Life)

When drive is aged by cumulated program/erase cycles, media worn-out may cause increasing numbers of later bad block. When the number of available spare is less the threshold(5%, SMART attribute log ID 02h Byte4), the drive will notify Host through AER event and Critical Warning to enter Read Only Mode to prevent further data corruption. User should start to replace the drive with another one immediately.

9.3 An Adaptive Approach to Performance Tuning

9.3.1 Throughput

Based on the available space of the disk, the SSD regulates the read/write speed and manage the performance of throughput. When there still remains a lot of space, the firmware will continuously perform read/write action. There is still no need to implement garbage collection to allocate and release memory, which will accelerate the read/write processing to improve the performance. Contrarily, when the space is being used up, the drive will slow down the read/write processing, and implement garbage collection to release memory. Hence, read/write performance will become slower.

9.3.2 Predict & Fetch

Normally, when the Host tries to read data from the PCIe SSD, the PCIe SSD will only perform one read action after receiving one command. However, the drive applies Predict & Fetch to improve the read speed. When the host issues sequential read commands to the PCIe SSD, the PCIe SSD will automatically expect that the following will also be read commands. Thus, before receiving the next command, flash has already prepared the data. Accordingly, this accelerates the data processing time, and the host does not need to wait so long to receive data.

9.3.3 SLC Caching

The firmware design of the device currently adopts dynamic caching to deliver better performance for better endurance and consumer user experience. The SLC cache is set as 32 GB for 256 GB SSD and 64 GB across the capacities of 512/1024/2048 GB SSDs.

10. BarraCuda 515 Installation Precautions

10.1 BarraCuda 515 FIPS SSD Handling Instructions

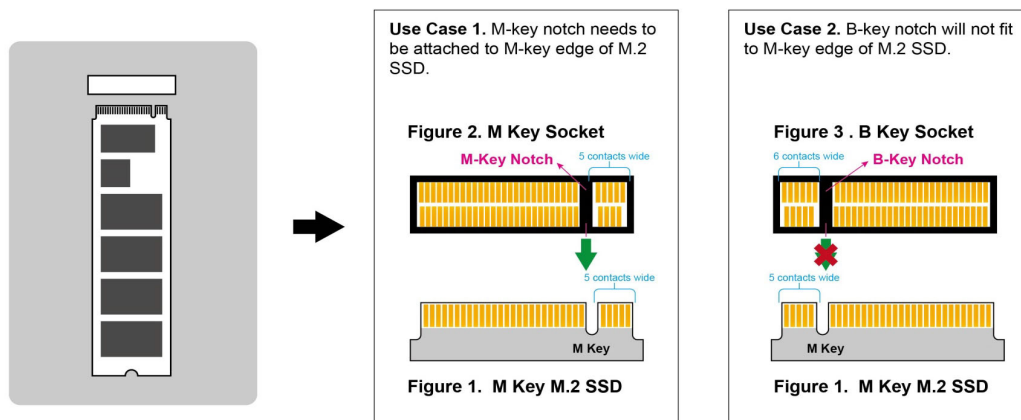
There are a lot of components assembled on a single SSD device. Handle the drive with care especially when it has any WLCSP (Wafer Level Chip Scale Packaging) components such as PMIC, thermal sensor or load switch. WLCSP is a packaging technology widely used for making smaller footprints. However, any bumps or scratches may damage those ultrasmall parts so you must handle with gentle care.

- CAUTION! DO NOT DROP SSD**
- CAUTION! INSTALL SSD WITH CARE**
- CAUTION! STORE SSD IN A PROPER PACKAGE**

10.2 BarraCuda 515 FIPS SSD Installation Instructions

The BarraCuda 515 FIPS SSD features the PCIe connector with M-key, which is compatible only with the M-key socket. See Use Case 1 in [Figure 6, M-Key M.2 Assembly Precautions](#). As shown in Use Case 2, misuse may cause severe damage to an SSD including burn-out.

Figure 6 M-Key M.2 Assembly Precautions



11. Safety, Standards, and Compliance

Each Hard Drive and Solid State Drive ("device") has a product label that includes certifications that are applicable to that specific drive. The following information provides an overview of requirements that may be applicable to the drive.

NOTE The most up to date information on Safety, Standards, and Compliance for this product is available in the Seagate HDD and SSD Regulatory Compliance and Safety document. You can find this document on the Seagate Support page (Scroll down to the Compliance section.): <https://www.seagate.com/support/>

11.1 Regulatory Model Numbers

The following regulatory model numbers represent the models in the BarraCuda 515 FIPS SSD Series:

- STA016

11.2 Reference Documents

In case of conflict between this document and the following reference document, this document takes precedence.

- PCIe Specifications
 - PCIe - PCI Express Electromechanical specification, revision 4.0
 - NVMe - Non Volatile Memory Express specification 1.3
 - PCIe CEM - PCI Express Card Electromechanical specification, revision 1.1
 - PCI Express M.2 Specification, revision 1.1
- Trusted Computing Group (TCG) Documents
 - Storage Work Group Security Subsystem Class: Opal, Version 2.00
- Solid State Drive Requirements and Endurance Test Methods
 - JESD218
 - JESD219
- Seagate Documentation
 - SeaTools™ SSD GUI User Guide - Publication Number: 100837824
 - SeaChest for SSD User Guide - Publication Number: 100847684



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