Ultrastar® SS300

2.5-inch Serial-attached (SCSI) (SAS)

Solid State Drive Product Manual



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Model Numbers

Ultrastar SS300 Model Numbers	
HUSMM3232ASS200	HUSMR3232ASS204
HUSMM3232ASS201	HUSMR3232ASS205
HUSMM3232ASS204	HUSMR3216ASS200
HUSMM3232ASS205	HUSMR3216ASS201
HUSMM3216ASS200	HUSMR3216ASS204
HUSMM3216ASS201	HUSMR3216ASS205
HUSMM3216ASS204	HUSMR3280ASS200
HUSMM3216ASS205	HUSMR3280ASS201
HUSMM3280ASS200	HUSMR3280ASS204
HUSMM3280ASS201	HUSMR3280ASS205
HUSMM3280ASS204	HUSMR3240ASS200
HUSMM3280ASS205	HUSMR3240ASS201
HUSMM3240ASS200	HUSMR3240ASS204
HUSMM3240ASS201	HUSMR3240ASS205
HUSMM3240ASS204	HUSMM3232ASS200
HUSMM3240ASS205	HUSMM3232ASS201
HUSMR3232ASS200	HUSMM3232ASS204
HUSMR3232ASS201	HUSMM3232ASS205

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Convention

The following icon and text conventions are used throughout this document to identify additional information of which the reader should be aware.

Conventions		Description
SHOCK HAZARD		*This icon indicates the danger of an electrical shock that may harm or otherwise prove fatal to the user*.
ESD		This icon indicates the possible presence of Electrostatic Discharge (ESD or "static electricity") that may harm the internal electronic components. The user is advised to handle the device only after discharging any possible electrostatic buildup that may be present.
CAUTION		This icon indicates the existence of a hazard that could result in equipment or property damage, or equipment failure if the safety instructions are not observed.
NOTE		This icon identifies information that relates to the safe operation of the equipment or related items.
Bold	**Text**	Used to indicate **important technical notes**.
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Revision History

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Nov. 8, 2017	1.0	All	Initial release
Apr. 4, 2018	1.1	All	Interim release

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1.0 General Description

1.1 Introduction

This document describes the specifications of the following HGST 2.5-inch SAS drives.

Table 1 - 1: Product Identification Table

Market Name	Long Model #	Encryption	Capacity (GB)	Interface and Endurance
Ultrastar SS300	HUSMM3232ASS200	Crypto enabled	3200	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3232ASS201	TCG encryption	3200	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3232ASS204	Crypto disabled	3200	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3232ASS205	TCG encryption & FIPs certified	3200	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3216ASS200	Crypto enabled	1600	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3216ASS201	TCG encryption	1600	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3216ASS204	Crypto disabled	1600	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3216ASS205	TCG encryption & FIPs certified	1600	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3280ASS200	Crypto enabled	800	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3280ASS201	TCG encryption	800	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3280ASS204	Crypto disabled	800	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3280ASS205	TCG encryption & FIPs certified	800	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3240ASS200	Crypto enabled	400	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3240ASS201	TCG encryption	400	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3240ASS204	Crypto disabled	400	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMM3240ASS205	TCG encryption & FIPs certified	400	2.5" 12Gb/s SAS 10 DW/D
Ultrastar SS300	HUSMR3232ASS200	Crypto enabled	3200	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3232ASS201	TCG encryption	3200	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3232ASS204	Crypto disabled	3200	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3232ASS205	TCG encryption & FIPs certified	3200	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3216ASS200	Crypto enabled	1600	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3216ASS201	TCG encryption	1600	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3216ASS204	Crypto disabled	1600	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3216ASS205	TCG encryption & FIPs certified	1600	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3280ASS200	Crypto enabled	800	2.5" 12Gb/s SAS 3 DW/D

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Market Name	Long Model #	Encryption	Capacity (GB)	Interface and Endurance
Ultrastar SS300	HUSMR3280ASS201	TCG encryption	800	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3280ASS204	Crypto disabled	800	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3280ASS205	TCG encryption & FIPs certified	800	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3240ASS200	Crypto enabled	400	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3240ASS201	TCG encryption	400	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3240ASS204	Crypto disabled	400	2.5" 12Gb/s SAS 3 DW/D
Ultrastar SS300	HUSMR3240ASS205	TCG encryption & FIPs certified	400	2.5" 12Gb/s SAS 3 DW/D

Table 1 - 2: **Drive Writes per Day for Each Product Family**

Model	Family	Drive Writes per Day
ME	Mainstream endurance	10
RI-3	Read-intensive	3

Notes:

1. The specifications in this document are subject to change without notice.

1.2 Glossary

Table 1 - 3: **Acronym Definitions**

Word	Meaning
BMS	Background Media Scan
GB	Gigabyte = 1,000,000,000 bytes
Gbps	Gigabits per second
Kb	Kilobit = 1000 bits
KB	Kilobyte = 1000 bytes
Mb	Megabit = 1,000,000 bits
MB	Megabyte = 1,000,000 bytes
SAS	Serial Attached SCSI
SED	Self-encrypting Drive
SFF	Small Form Factor
SMART	Self-monitoring and Reporting Technology
SSD	Solid State Drive
TB	Terabyte = 1,000,000,000,000 bytes

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1.3 Caution - Electrostatic Discharge

This drive can be damaged by ESD (Electrostatic Discharge). Any damage incurred to the drive after its removal from the shipping package and the ESD protective bag is the responsibility of the user.

1.4 Byte Ordering Conventions

In this manual, where it is not explicitly stated, all multi-byte values are stored with the most significant byte first. For example, in a 4-byte field, byte 0 will contain the MSB and byte 3 the LSB. A sample table is shown below.

Table 1 - 4: Byte Ordering Conventions

<table>
<tr><th></th><th colspan="8">Bit</th></tr>
<tr><th>Byte</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td></td><td colspan="8">Defect List Header</td></tr>
<tr><td>0</td><td colspan="8">1-Byte Field</td></tr>
<tr><td>1</td><td>Bit 7</td><td colspan="3">Bits 6-4 of Byte 1</td><td colspan="4">Bits 3-0 of Byte 1</td></tr>
<tr><td>2-3</td><td colspan="8">MSB
2-Byte Field
LSB</td></tr>
<tr><td>4-7</td><td colspan="8">MSB
3- or More Byte Field
LSB</td></tr>
</table>

Notes:

1. All fields marked Reserved are expected to be 0 as inputs/requests to the drive and will be 0 as outputs/responses from the drive. To allow for future expansion, user codes should avoid dependencies on Reserved fields.
2. All fields marked Obsolete or Ignored will not be processed or examined by the drive. It is recommended that these be treated as Reserved fields.

1.5 Control Electronics

The drive is electronically controlled by a microprocessor, logic modules, digital/analog modules, and various drivers and receivers. The control electronics perform the following major functions:

- Monitoring incoming power to insure safe writes
- Providing temporary back-up power in the event of a power loss
- Maintaining data integrity through CRC, ECC, and Power Loss Imminent detection

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2.0 Features

2.1 Features

- Storage capacities for MLC: 3.2TB, 1.6TB, 800GB, 400GB
- 6 Gbps and 12 Gbps SAS-3 interface
- Supports single-port operations
- Supports dual-ported operations
- Supports wide-port operations
- Supports full duplex operations
- Variable sector sizes: 512B, 520B, 528B, 4096B, 4160B, and 4224B
- Pin 3 disable
- Ready LED signaling
- Tagged command queuing support
- Automatic read/write data rransfer
- Adaptive read-ahead algorithm
- Write cache via PLI protection.
- XOR function
- ECC on-the-fly correction
- Automatic defect reallocation
- Self-diagnostics at power on
- MLC NAND flash
- SMART
- ANSI T10 protection information (end-to-end)
- TCG revert
- FIPS 140-2 Level 2-compliant models
- Sanitize (block erase, crypto erase)
- UNMAP
- Fast format
- Atomic write support
- For MLC: mainstream endurance, 3 D/W read-intensive models

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3.0 Control Electronics

3.1 Control Electronics

The drive is electronically controlled by a microprocessor, logic modules, digital/analog modules, and various drivers and receivers. The control electronics perform the following major functions:

- Monitoring incoming power to ensure safe writes
- Providing temporary back-up power in the event of a power loss
- Maintaining data integrity through CRC, ECC, and Power Loss Imminent detection

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4.0 Drive Characteristics

4.1 Formatted Capacity

Table 4 - 1: Formatted Capacities Listed in Blocks

Description	Label Capacity (GB)	Encryption Model	Default Capacity[1]
HUSMH4020ASS200	200	Crypto enabled	390,721,968 (1749F1B0h)
HUSMH4020ASS201	200	TCG encryption	390,721,968 (1749F1B0h)
HUSMH4020ASS204	200	Crypto disabled	390,721,968 (1749F1B0h)
HUSMH4020ASS205	200	TCG encryption & FIPS certified	390,721,968 (1749F1B0h)
HUSMH4040ASS200	400	Crypto enabled	781,422,768 (2E9390B0h)
HUSMH4040ASS201	400	TCG encryption	781,422,768 (2E9390B0h)
HUSMH4040ASS204	400	Crypto disabled	781,422,768 (2E9390B0h)
HUSMH4040ASS205	400	TCG encryption & FIPS certified	781,422,768 (2E9390B0h)
HUSMM3216ASS200	1600	Crypto enabled	3,125,627,568 (BA4D4AB0h)
HUSMM3216ASS201	1600	TCG encryption	3,125,627,568 (BA4D4AB0h)
HUSMM3216ASS204	1600	Crypto disabled	3,125,627,568 (BA4D4AB0h)
HUSMM3216ASS205	1600	TCG encryption & FIPS certified	3,125,627,568 (BA4D4AB0h)
HUSMM3232ASS200	3200	Crypto enabled	6,251,233,968 (1749A42B0h)
HUSMM3232ASS201	3200	TCG encryption	6,251,233,968 (1749A42B0h)
HUSMM3232ASS204	3200	Crypto disabled	6,251,233,968 (1749A42B0h)
HUSMM3232ASS205	3200	TCG encryption & FIPS certified	6,251,233,968 (1749A42B0h)
HUSMM3240ASS200	400	Crypto enabled	781,422,768 (2E9390B0h)
HUSMM3240ASS201	400	TCG encryption	781,422,768 (2E9390B0h)

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Description	Label Capacity (GB)	Encryption Model	Default Capacity[1]
HUSMM3240ASS204	400	Crypto disabled	781,422,768 (2E9390B0h)
HUSMM3240ASS205	400	TCG encryption & FIPS certified	781,422,768 (2E9390B0h)
HUSMM3280ASS200	800	Crypto enabled	1,562,824,368 (5D26CEB0h)
HUSMM3280ASS201	800	TCG encryption	1,562,824,368 (5D26CEB0h)
HUSMM3280ASS204	800	Crypto disabled	1,562,824,368 (5D26CEB0h)
HUSMM3280ASS205	800	TCG encryption & FIPS certified	1,562,824,368 (5D26CEB0h)
HUSMR3216ASS200	1600	Crypto enabled	3,125,627,568 (BA4D4AB0h)
HUSMR3216ASS201	1600	TCG encryption	3,125,627,568 (BA4D4AB0h)
HUSMR3216ASS204	1600	Crypto disabled	3,125,627,568 (BA4D4AB0h)
HUSMR3216ASS205	1600	TCG encryption & FIPS certified	3,125,627,568 (BA4D4AB0h)
HUSMR3232ASS200	3200	Crypto enabled	6,251,233,968 (1749A42B0h)
HUSMR3232ASS201	3200	TCG encryption	6,251,233,968 (1749A42B0h)
HUSMR3232ASS204	3200	Crypto disabled	6,251,233,968 (1749A42B0h)
HUSMR3232ASS205	3200	TCG encryption & FIPS certified	6,251,233,968 (1749A42B0h)
HUSMR3240ASS200	400	Crypto enabled	781,422,768 (2E9390B0h)
HUSMR3240ASS201	400	TCG encryption	781,422,768 (2E9390B0h)
HUSMR3240ASS204	400	Crypto disabled	781,422,768 (2E9390B0h)
HUSMR3240ASS205	400	TCG encryption & FIPS certified	781,422,768 (2E9390B0h)
HUSMR3280ASS200	800	Crypto enabled	1,562,824,368 (5D26CEB0h)
HUSMR3280ASS201	800	TCG encryption	1,562,824,368 (5D26CEB0h)
HUSMR3280ASS204	800	Crypto disabled	1,562,824,368 (5D26CEB0h)

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Description	Label Capacity (GB)	Encryption Model	Default Capacity[1]
HUSMR3280ASS205	800	TCG encryption & FIPS certified	1,562,824,368 (5D26CEB0h)

Notes:

1. Default Capacity refers to the size to which a drive will format, using 0xFFFFFFFF for the requested number of blocks in a mode select block descriptor.
2. Refer to Block Descriptor and FORMAT UNIT (04) for details.

4.2 Datasheet

Table 4 - 2: Datasheet

Host Interface Transfer Rate	6.0Gbps and 12.0 Gbps SAS
Flash Media	3D, 32 Layer Multi-Level Cell (MLC)
SDRAM Size	1024 MB (all 200GB, 400GB, 480GB, 800GB drives) 2048MB (all 960GB, 1600GB drives) 4096MB (all 1920GB, 3200GB drives) 6144MB (all 3840GB drives) 8192MB (all 7680GB drives)

4.3 Product IDs

The Product IDs in Table 16.4.2 “Inquiry Data - EVPD = 0, Page Code = 00h - Standard Inquiry Data Page” are as follows:

Table 4 - 3: Product ID in Inquiry Command Worldwide ID – Block Assignment

Endurance	Marketing Name	Description	Label Capacity (GB)	Encryption Model
Mainstream: 10 DW/D	Ultrastar SS300	HUSMM3232ASS204	3200GB	Crypto disabled
	Ultrastar SS300	HUSMM3232ASS200	3200GB	Crypto enabled
	Ultrastar SS300	HUSMM3232ASS201	3200GB	TCG encryption
	Ultrastar SS300	HUSMM3232ASS205	3200GB	TCG encryption & FIPs certified
	Ultrastar SS300	HUSMM3216ASS204	1600GB	Crypto disabled
	Ultrastar SS300	HUSMM3216ASS200	1600GB	Crypto enabled
	Ultrastar SS300	HUSMM3216ASS201	1600GB	TCG encryption

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Endurance	Marketing Name	Description	Label Capacity (GB)	Encryption Model
	Ultrastar SS300	HUSMM3216ASS205	1600GB	TCG encryption & FIPs certified
	Ultrastar SS300	HUSMM3280ASS204	800GB	Crypto disabled
	Ultrastar SS300	HUSMM3280ASS200	800GB	Crypto enabled
	Ultrastar SS300	HUSMM3280ASS201	800GB	TCG encryption
	Ultrastar SS300	HUSMM3280ASS205	800GB	TCG encryption & FIPs certified
	Ultrastar SS300	HUSMM3240ASS204	400GB	Crypto disabled
	Ultrastar SS300	HUSMM3240ASS200	400GB	Crypto enabled
	Ultrastar SS300	HUSMM3240ASS201	400GB	TCG encryption
	Ultrastar SS300	HUSMM3240ASS205	400GB	TCG encryption & FIPs certified
Read	Ultrastar SS300	HUSMR3232ASS204	3200GB	Crypto disabled
	Ultrastar SS300	HUSMR3232ASS200	3200GB	Crypto enabled
	Ultrastar SS300	HUSMR3232ASS201	3200GB	TCG encryption
	Ultrastar SS300	HUSMR3232ASS205	3200GB	TCG encryption & FIPs Certified
	Ultrastar SS300	HUSMR3216ASS204	1600GB	Crypto disabled
	Ultrastar SS300	HUSMR3216ASS200	1600GB	Crypto enabled
	Ultrastar SS300	HUSMR3216ASS201	1600GB	TCG encryption
	Ultrastar SS300	HUSMR3216ASS205	1600GB	TCG encryption & FIPs certified
	Ultrastar SS300	HUSMR3280ASS204	800GB	Crypto disabled
	Ultrastar SS300	HUSMR3280ASS200	800GB	Crypto enabled
	Ultrastar SS300	HUSMR3280ASS201	800GB	TCG encryption
	Ultrastar SS300	HUSMR3280ASS205	800GB	TCG encryption & FIPs certified
	Ultrastar SS300	HUSMR3240ASS204	400GB	Crypto disabled
	Ultrastar SS300	HUSMR3240ASS200	400GB	Crypto enabled
	Ultrastar SS300	HUSMR3240ASS201	400GB	TCG encryption
	Ultrastar SS300	HUSMR3240ASS205	400GB	TCG encryption & FIPs certified

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- Block assignment of Worldwide IDs is as follows:

Table 4 - 4: Block Assignment of Worldwide IDs in the INQUIRY Command

Manufacturing Site	Product	Block Assignment[1]
China	HUSMM3232ASS201	001h
	HUSMM3216ASS201	001h
	HUSMM3280ASS201	001h
	HUSMM3240ASS201	001h
	HUSMR3232ASS201	001h
	HUSMR3216ASS201	001h
	HUSMR3280ASS201	001h
	HUSMR3240ASS201	001h

Notes:

1. Additional block assignments will be issued as needed according to actual production volume.

4.4 Performance Characteristics

Drive performance is characterized by the following parameters:

- Command overhead
- Data transfer speed
- Buffering operation (read ahead/write cache)

Notes:

1. All the above parameters contribute to drive performance, while other parameters contribute to the performance of the overall system. This manual defines the basic drive characteristics, not system throughput, which depends on the system and the application.

4.4.1 Drive Ready Time

Table 4 - 5: Drive Ready Time

Model	Unsafe Power Cycle Time
All models	< ~30 seconds to data ops (3.2TB and above) < ~1 second to interface response

Notes:

1. Power On to Drive Ready Time assumes proper shutdown. The drive Ready Time varies if the previous shutdown was not preceded by a non-immediate START STOP UNIT command (START=0 and IMMED=0).

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4.4.2 SSD Response Time

Table 4 - 6: **SSD Response Time**

Model	Typical (Seconds)	Maximum (Seconds)
All models	100µs	15ms

4.4.3 Data Transfer Speed

Table 4 - 7: **6Gbps Single Port 9W Mode, ME**

Description / Access Type (QD is at the drive)	400GB Mbps	800GB Mbps	1.6TB Mbps	3.2TB Mbps
Sequential write 128KB, aligned, QD=1	460	460	460	460
Sequential read 128KB, aligned, QD=1	490	490	490	490
Sequential write 128KB, aligned, QD=32	530	530	530	530
Sequential read 128KB, aligned, QD=32	540	540	540	540
Sequential write 4KB, aligned, QD=1	130	120	120	120
Sequential read 4KB, aligned, QD=1	140	140	140	140
Sequential write 4KB, aligned, QD=32	380	380	380	380
Sequential read 4KB, aligned, QD=32	470	470	470	470
Sequential write 0.5KB, aligned, QD=1	20	20	20	20
Sequential read 0.5KB, aligned, QD=1	20	20	20	20
Sequential write 0.5KB, aligned, QD=32	120	120	120	120
Sequential read 0.5KB, aligned, QD=32	210	200	200	200
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 1	31000	30000	30000	30000
Random write, 4KB, aligned, QD = 4	83000	78000	79000	78000
Random write, 4KB, aligned, QD = 16	98000	98000	98000	97000
Random write, 4KB, aligned, QD = 32	98000	98000	98000	97000
Random write, 4KB, aligned, QD = 128	98000	98000	98000	97000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 1	11000	11000	11000	12000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	35000	36000	40000	43000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	87000	92000	109000	121000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	123000	129000	145000	149000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	151000	150000	151000	151000
Random read, 4KB, aligned, QD = 1	10000	10000	10000	10000

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Random read, 4KB, aligned, QD = 4	37000	38000	38000	39000
Random read, 4KB, aligned, QD = 16	114000	118000	120000	121000
Random read, 4KB, aligned, QD = 32	122000	122000	122000	122000
Random read, 4KB, aligned, QD = 128	122000	122000	122000	122000
Random write, 8KB, aligned, QD = 1	24000	24000	24000	23000

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Table 4-7: 6Gbps Single Port 9W Mode, ME (**cont'd**)

Description / Access Type (QD is at the drive)	400GB Mbps	800GB Mbps	1.6TB Mbps	3.2TB Mbps
Random write, 8KB, aligned, QD = 4	52000	51000	51000	48000
Random write, 8KB, aligned, QD = 16	57000	57000	57000	48000
Random write, 8KB, aligned, QD = 32	57000	57000	57000	48000
Random write, 8KB, aligned, QD = 128	57000	57000	57000	48000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	8000	8000	8000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	24000	24000	27000	30000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	52000	52000	62000	69000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	68000	66000	76000	79000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	83000	83000	83000	83000
Random read, 8KB, aligned, QD = 1	7000	7000	7000	7000
Random read, 8KB, aligned, QD = 4	27000	27000	28000	28000
Random read, 8KB, aligned, QD = 16	64000	64000	65000	65000
Random read, 8KB, aligned, QD = 32	65000	65000	65000	65000
Random read, 8KB, aligned, QD = 128	65000	65000	65000	65000
Random write, 64KB, aligned, QD = 1	6000	6000	6000	6000
Random write, 64KB, aligned, QD = 4	8000	8000	8000	6000
Random write, 64KB, aligned, QD = 16	8000	8000	8000	6000
Random write, 64KB, aligned, QD = 32	8000	8000	8000	6000
Random write, 64KB, aligned, QD = 128	8000	8000	8000	6000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 1	2000	2000	3000	3000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	6000	6000	7000	8000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	11000	10000	11000	11000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	11000	11000	11000	11000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	11000	11000	11000	11000
Random read, 64KB, aligned, QD = 1	2000	2000	2000	2000
Random read, 64KB, aligned, QD = 4	8000	8000	8000	8000
Random read, 64KB, aligned, QD = 16	8000	8000	8000	8000
Random read, 64KB, aligned, QD = 32	8000	8000	8000	8000
Random read, 64KB, aligned, QD = 128	8000	8000	8000	8000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=1	460	460	460	460
Sequential read 128KB, aligned, QD=1	490	490	490	490
Sequential write 128KB, aligned, QD=32	530	530	530	530
Sequential read 128KB, aligned, QD=32	540	540	540	540
Sequential write 4KB, aligned, QD=1	120	120	120	120
Sequential read 4KB, aligned, QD=1	140	140	140	140
Sequential write 4KB, aligned, QD=32	380	380	380	380
Sequential read 4KB, aligned, QD=32	470	470	470	470
Sequential write 0.5KB, aligned, QD=1	20	20	20	20
Sequential read 0.5KB, aligned, QD=1	20	20	20	20
Sequential write 0.5KB, aligned, QD=32	120	120	120	120
Sequential read 0.5KB, aligned, QD=32	200	200	200	200
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 1	30000	29000	29000	29000
Random write, 4KB, aligned, QD = 4	81000	76000	74000	74000
Random write, 4KB, aligned, QD = 16	98000	98000	98000	85000
Random write, 4KB, aligned, QD = 32	98000	98000	98000	85000
Random write, 4KB, aligned, QD = 128	98000	98000	98000	85000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 1	11000	11000	11000	12000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	32000	34000	38000	42000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	75000	83000	98000	116000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	106000	115000	132000	143000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	150000	149000	150000	143000
Random read, 4KB, aligned, QD = 1	10000	10000	10000	10000
Random read, 4KB, aligned, QD = 4	37000	38000	38000	39000
Random read, 4KB, aligned, QD = 16	112000	117000	119000	120000
Random read, 4KB, aligned, QD = 32	122000	122000	122000	122000
Random read, 4KB, aligned, QD = 128	122000	122000	122000	122000
Random write, 8KB, aligned, QD = 1	24000	23000	23000	23000
Random write, 8KB, aligned, QD = 4	51000	49000	49000	42000
Random write, 8KB, aligned, QD = 16	55000	51000	49000	42000
Random write, 8KB, aligned, QD = 32	55000	51000	49000	42000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 8KB, aligned, QD = 128	55000	51000	50000	42000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	7000	8000	8000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	21000	22000	25000	29000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	44000	44000	52000	65000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	58000	56000	65000	76000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	82000	81000	82000	82000
Random read, 8KB, aligned, QD = 1	7000	7000	7000	7000
Random read, 8KB, aligned, QD = 4	27000	27000	28000	28000
Random read, 8KB, aligned, QD = 16	63000	63000	64000	64000
Random read, 8KB, aligned, QD = 32	64000	64000	65000	65000
Random read, 8KB, aligned, QD = 128	65000	65000	65000	65000
Random write, 64KB, aligned, QD = 1	6000	6000	6000	5000
Random write, 64KB, aligned, QD = 4	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 16	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 32	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 128	7000	6000	6000	5000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 1	2000	2000	2000	3000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	5000	5000	6000	7000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	10000	10000	10000	11000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	11000	11000	11000	11000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	11000	11000	11000	11000
Random read, 64KB, aligned, QD = 1	2000	2000	3000	3000
Random read, 64KB, aligned, QD = 4	8000	8000	8000	8000
Random read, 64KB, aligned, QD = 16	8000	8000	8000	8000
Random read, 64KB, aligned, QD = 32	8000	8000	8000	8000
Random read, 64KB, aligned, QD = 128	8000	8000	8000	8000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=32	990	930	860	660
Sequential read 128KB, aligned, QD=32	1090	1090	1090	1090
Sequential write 4KB, aligned, QD=32	760	760	760	660
Sequential read 4KB, aligned, QD=32	730	710	720	730
Sequential write 0.5KB, aligned, QD=32	250	250	250	250
Sequential read 0.5KB, aligned, QD=32	60	70	70	70
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 4	95000	90000	90000	88000
Random write, 4KB, aligned, QD = 16	173000	129000	127000	96000
Random write, 4KB, aligned, QD = 32	173000	130000	127000	96000
Random write, 4KB, aligned, QD = 128	173000	130000	127000	96000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	35000	37000	40000	43000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	88000	95000	113000	129000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	129000	140000	171000	153000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	217000	206000	199000	153000
Random read, 4KB, aligned, QD = 4	37000	38000	38000	38000
Random read, 4KB, aligned, QD = 16	123000	131000	137000	143000
Random read, 4KB, aligned, QD = 32	190000	213000	228000	205000
Random read, 4KB, aligned, QD = 128	244000	245000	244000	205000
Random write, 8KB, aligned, QD = 4	70000	65000	63000	48000
Random write, 8KB, aligned, QD = 16	87000	65000	63000	48000
Random write, 8KB, aligned, QD = 32	87000	65000	63000	48000
Random write, 8KB, aligned, QD = 128	87000	65000	63000	48000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	25000	25000	29000	31000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	58000	59000	71000	82000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	81000	81000	99000	91000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	127000	124000	120000	91000
Random read, 8KB, aligned, QD = 4	28000	28000	29000	29000
Random Read, 8KB, Aligned, QD = 16	85000	87000	93000	98000
Random Read, 8KB, Aligned, QD = 32	118000	122000	127000	129000
Random Read, 8KB, Aligned, QD = 128	130000	130000	130000	130000
Random Write, 64KB, Aligned, QD = 4	11000	8000	8000	6000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random Write, 64KB, Aligned, QD = 16	11000	8000	8000	6000
Random Write, 64KB, Aligned, QD = 32	11000	8000	8000	6000
Random Write, 64KB, Aligned, QD = 128	11000	8000	8000	6000
Random 70% Read / 30% Write, 64KB, Aligned, QD = 4	7000	7000	8000	9000
Random 70% Read / 30% Write, 64KB, Aligned, QD = 16	14000	14000	16000	14000
Random 70% Read / 30% Write, 64KB, Aligned, QD = 32	18000	18000	19000	14000
Random 70% Read / 30% Write, 64KB, Aligned, QD = 128	20000	19000	19000	14000
Random Read, 64KB, Aligned, QD = 4	10000	10000	10000	10000
Random Read, 64KB, Aligned, QD = 16	17000	17000	17000	17000
Random Read, 64KB, Aligned, QD = 32	17000	17000	17000	17000
Random Read, 64KB, Aligned, QD = 128	17000	17000	17000	17000

Table 4 - 10: **6Gbps Dual Port 9W Mode, RI-3**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=32	820	920	850	660
Sequential read 128KB, aligned, QD=32	1090	1090	1090	1090
Sequential write 4KB, aligned, QD=32	760	760	760	660
Sequential read 4KB, aligned, QD=32	690	710	720	730
Sequential write 0.5KB, aligned, QD=32	250	250	250	250
Sequential read 0.5KB, aligned, QD=32	60	70	70	70
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random Write, 4KB, Aligned, QD = 4	95000	90000	90000	88000
Random Write, 4KB, Aligned, QD = 16	173000	129000	127000	96000
Random Write, 4KB, Aligned, QD = 32	173000	130000	127000	96000
Random Write, 4KB, Aligned, QD = 128	173000	130000	127000	96000
Random 70% Read / 30% Write, 4KB, Aligned, QD = 4	35000	37000	40000	43000
Random 70% Read / 30% Write, 4KB, Aligned, QD = 16	88000	95000	113000	129000
Random 70% Read / 30% Write, 4KB, Aligned, QD = 32	129000	140000	171000	153000
Random 70% Read / 30% Write, 4KB, Aligned, QD = 128	217000	206000	199000	153000
Random Read, 4KB, Aligned, QD = 4	37000	38000	38000	38000
Random Read, 4KB, Aligned, QD = 16	123000	131000	137000	143000
Random Read, 4KB, Aligned, QD = 32	190000	213000	228000	205000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random Read, 4KB, Aligned, QD = 128	244000	245000	244000	205000
Random Write, 8KB, Aligned, QD = 4	70000	65000	63000	48000
Random Write, 8KB, Aligned, QD = 16	87000	65000	63000	48000
Random Write, 8KB, Aligned, QD = 32	87000	65000	63000	48000
Random Write, 8KB, Aligned, QD = 128	87000	65000	63000	48000
Random 70% Read / 30% Write, 8KB, Aligned, QD = 4	25000	25000	29000	31000
Random 70% Read / 30% Write, 8KB, Aligned, QD = 16	58000	59000	71000	82000
Random 70% Read / 30% Write, 8KB, Aligned, QD = 32	81000	81000	99000	91000
Random 70% Read / 30% Write, 8KB, Aligned, QD = 128	127000	124000	120000	91000
Random Read, 8KB, Aligned, QD = 4	28000	28000	29000	29000
Random Read, 8KB, Aligned, QD = 16	85000	87000	93000	98000
Random Read, 8KB, Aligned, QD = 32	118000	122000	127000	129000
Random Read, 8KB, Aligned, QD = 128	130000	130000	130000	130000
Random Write, 64KB, Aligned, QD = 4	11000	8000	8000	6000
Random Write, 64KB, Aligned, QD = 16	11000	8000	8000	6000
Random Write, 64KB, Aligned, QD = 32	11000	8000	8000	6000
Random Write, 64KB, Aligned, QD = 128	11000	8000	8000	6000
Random 70% Read / 30% Write, 64KB, Aligned, QD = 4	7000	7000	8000	9000
Random 70% Read / 30% Write, 64KB, Aligned, QD = 16	14000	14000	16000	14000
Random 70% Read / 30% Write, 64KB, Aligned, QD = 32	18000	18000	19000	14000
Random 70% Read / 30% Write, 64KB, Aligned, QD = 128	20000	19000	19000	14000
Random Read, 64KB, Aligned, QD = 4	10000	10000	10000	10000
Random Read, 64KB, Aligned, QD = 16	17000	17000	17000	17000
Random Read, 64KB, Aligned, QD = 32	17000	17000	17000	17000
Random Read, 64KB, Aligned, QD = 128	17000	17000	17000	17000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=1	810	810	800	640
Sequential read 128KB, aligned, QD=1	890	890	890	890
Sequential write 128KB, aligned, QD=32	990	930	860	660
Sequential read 128KB, aligned, QD=32	1070	1070	1070	1070
Sequential write 4KB, aligned, QD=1	150	150	150	150
Sequential read 4KB, aligned, QD=1	170	170	170	170
Sequential write 4KB, aligned, QD=32	660	660	660	660
Sequential read 4KB, aligned, QD=32	930	930	930	930
Sequential write 0.5KB, aligned, QD=1	20	20	20	20
Sequential read 0.5KB, aligned, QD=1	20	20	20	20
Sequential write 0.5KB, aligned, QD=32	170	170	170	170
Sequential read 0.5KB, aligned, QD=32	200	210	200	210
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 1	36000	35000	35000	35000
Random write, 4KB, aligned, QD = 4	107000	99000	99000	96000
Random write, 4KB, aligned, QD = 16	165000	129000	127000	97000
Random write, 4KB, aligned, QD = 32	167000	129000	127000	97000
Random write, 4KB, aligned, QD = 128	165000	129000	127000	97000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 1	11000	12000	12000	12000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	36000	38000	42000	45000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	90000	97000	117000	133000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	129000	141000	175000	153000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	216000	205000	199000	153000
Random read, 4KB, aligned, QD = 1	10000	10000	10000	10000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	126000	135000	142000	149000
Random read, 4KB, aligned, QD = 32	193000	217000	231000	205000
Random read, 4KB, aligned, QD = 128	239000	239000	239000	205000
Random write, 8KB, aligned, QD = 1	30000	29000	29000	29000
Random write, 8KB, aligned, QD = 4	79000	64000	63000	48000
Random write, 8KB, aligned, QD = 16	86000	64000	63000	48000
Random write, 8KB, aligned, QD = 32	86000	64000	63000	48000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 8KB, aligned, QD = 128	86000	64000	63000	48000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	8000	8000	9000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	25000	25000	29000	32000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	55000	54000	67000	78000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	76000	74000	92000	92000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	121000	122000	121000	92000
Random read, 8KB, aligned, QD = 1	8000	7000	8000	7000
Random read, 8KB, aligned, QD = 4	29000	29000	29000	30000
Random read, 8KB, aligned, QD = 16	84000	84000	90000	96000
Random read, 8KB, aligned, QD = 32	114000	117000	124000	127000
Random read, 8KB, aligned, QD = 128	128000	128000	129000	129000
Random write, 64KB, aligned, QD = 1	10000	8000	8000	6000
Random write, 64KB, aligned, QD = 4	11000	8000	8000	6000
Random write, 64KB, aligned, QD = 16	11000	8000	8000	6000
Random write, 64KB, aligned, QD = 32	11000	8000	8000	6000
Random write, 64KB, aligned, QD = 128	11000	8000	8000	6000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 1	3000	3000	3000	3000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	7000	7000	8000	9000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	14000	14000	16000	15000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	18000	18000	20000	15000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	20000	19000	19000	14000
Random read, 64KB, aligned, QD = 1	3000	3000	3000	3000
Random read, 64KB, aligned, QD = 4	10000	10000	10000	11000
Random read, 64KB, aligned, QD = 16	17000	16000	17000	17000
Random read, 64KB, aligned, QD = 32	17000	17000	17000	17000
Random read, 64KB, aligned, QD = 128	17000	17000	17000	17000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=1	800	810	810	660
Sequential read 128KB, aligned, QD=1	890	890	890	890
Sequential write 128KB, aligned, QD=32	830	930	850	660
Sequential read 128KB, aligned, QD=32	1070	1070	1070	1070
Sequential write 4KB, aligned, QD=1	150	150	150	150
Sequential read 4KB, aligned, QD=1	170	170	170	170
Sequential write 4KB, aligned, QD=32	650	650	650	660
Sequential read 4KB, aligned, QD=32	930	930	930	930
Sequential write 0.5KB, aligned, QD=1	20	20	20	20
Sequential read 0.5KB, aligned, QD=1	20	20	20	20
Sequential write 0.5KB, aligned, QD=32	170	170	170	170
Sequential read 0.5KB, aligned, QD=32	200	190	200	200
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 1	35000	34000	34000	34000
Random write, 4KB, aligned, QD = 4	101000	91000	90000	84000
Random write, 4KB, aligned, QD = 16	110000	101000	99000	84000
Random write, 4KB, aligned, QD = 32	110000	101000	99000	84000
Random write, 4KB, aligned, QD = 128	110000	102000	100000	84000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 1	11000	11000	12000	12000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	33000	36000	39000	44000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	77000	87000	103000	127000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	109000	123000	150000	143000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	173000	181000	174000	143000
Random read, 4KB, aligned, QD = 1	10000	10000	10000	10000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	121000	133000	141000	149000
Random read, 4KB, aligned, QD = 32	179000	213000	229000	205000
Random read, 4KB, aligned, QD = 128	239000	239000	240000	204000
Random write, 8KB, aligned, QD = 1	29000	28000	28000	28000
Random write, 8KB, aligned, QD = 4	55000	50000	49000	42000
Random write, 8KB, aligned, QD = 16	55000	50000	49000	42000
Random write, 8KB, aligned, QD = 32	55000	50000	49000	42000

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Table 4-12: 12Gbps Single Port 9W Mode, RI-3 (**cont'd**)

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 8KB, aligned, QD = 128	55000	51000	49000	42000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	8000	8000	9000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	22000	23000	26000	31000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	45000	45000	53000	71000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	62000	61000	71000	83000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	95000	102000	101000	83000
Random read, 8KB, aligned, QD = 1	7000	7000	8000	8000
Random read, 8KB, aligned, QD = 4	28000	29000	29000	30000
Random read, 8KB, aligned, QD = 16	78000	81000	87000	95000
Random write, 8KB, aligned, QD = 32	55000	50000	49000	42000
Random write, 8KB, aligned, QD = 128	55000	51000	49000	42000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	8000	8000	9000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	22000	23000	26000	31000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	45000	45000	53000	71000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	62000	61000	71000	83000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	95000	102000	101000	83000
Random read, 8KB, aligned, QD = 1	7000	7000	8000	8000
Random read, 8KB, aligned, QD = 4	28000	29000	29000	30000
Random read, 8KB, aligned, QD = 16	78000	81000	87000	95000
Random read, 8KB, aligned, QD = 32	104000	113000	121000	126000
Random read, 8KB, aligned, QD = 128	127000	128000	128000	129000
Random write, 64KB, aligned, QD = 1	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 4	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 16	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 32	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 128	7000	6000	6000	5000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 1	2000	2000	3000	3000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	6000	6000	7000	9000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	12000	12000	13000	12000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	14000	15000	15000	12000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	14000	15000	14000	12000
Random read, 64KB, aligned, QD = 1	3000	3000	3000	3000

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Table 4 - 12: 12Gbps Single Port 9W Mode, RI-3 **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random read, 64KB, aligned, QD = 4	9000	10000	10000	11000
Random read, 64KB, aligned, QD = 16	16000	16000	16000	17000
Random read, 64KB, aligned, QD = 32	17000	17000	17000	17000
Random read, 64KB, aligned, QD = 128	17000	17000	17000	17000

Table 4 - 13: **12Gbps Dual Port 9W Mode, ME**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=32	870	920	860	660
Sequential read 128KB, aligned, QD=32	2070	2130	2150	2150
Sequential write 4KB, aligned, QD=32	990	920	850	660
Sequential read 4KB, aligned, QD=32	680	680	670	710
Sequential write 0.5KB, aligned, QD=32	270	270	280	270
Sequential read 0.5KB, aligned, QD=32	70	70	70	70
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 4	109000	102000	101000	96000
Random write, 4KB, aligned, QD = 16	166000	129000	127000	96000
Random write, 4KB, aligned, QD = 32	167000	129000	127000	96000
Random write, 4KB, aligned, QD = 128	167000	129000	127000	96000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	36000	38000	42000	45000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	90000	97000	117000	135000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	130000	141000	177000	153000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	217000	206000	199000	153000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	127000	136000	144000	151000
Random read, 4KB, aligned, QD = 32	196000	225000	249000	205000
Random read, 4KB, aligned, QD = 128	288000	279000	265000	205000
Random write, 8KB, aligned, QD = 4	84000	64000	63000	48000
Random write, 8KB, aligned, QD = 16	84000	64000	63000	48000
Random write, 8KB, aligned, QD = 32	84000	64000	63000	48000
Random write, 8KB, aligned, QD = 128	84000	64000	63000	48000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	25000	26000	30000	33000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	59000	60000	73000	86000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	83000	83000	104000	91000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	128000	125000	120000	91000
Random read, 8KB, aligned, QD = 4	29000	29000	30000	31000
Random read, 8KB, aligned, QD = 16	89000	91000	99000	106000
Random read, 8KB, aligned, QD = 32	129000	136000	154000	146000
Random read, 8KB, aligned, QD = 128	176000	201000	189000	145000
Random write, 64KB, aligned, QD = 4	10000	8000	8000	6000
Random write, 64KB, aligned, QD = 16	10000	8000	8000	6000
Random write, 64KB, aligned, QD = 32	10000	8000	8000	6000
Random write, 64KB, aligned, QD = 128	10000	8000	8000	6000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	7000	7000	9000	10000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	15000	15000	18000	14000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	19000	19000	19000	14000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	20000	19000	19000	14000
Random read, 64KB, aligned, QD = 4	10000	10000	11000	12000
Random read, 64KB, aligned, QD = 16	22000	22000	24000	30000
Random read, 64KB, aligned, QD = 32	27000	26000	29000	32000
Random read, 64KB, aligned, QD = 128	30000	29000	31000	32000

Table 4 - 14: **12Gbps Dual Port 9W Mode, RI-3**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=32	700	830	850	660
Sequential read 128KB, aligned, QD=32	2020	2140	2030	2150
Sequential write 4KB, aligned, QD=32	830	920	850	660
Sequential read 4KB, aligned, QD=32	700	680	670	730
Sequential write 0.5KB, aligned, QD=32	270	270	260	260
Sequential read 0.5KB, aligned, QD=32	60	70	70	70
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 4	104000	94000	93000	83000
Random write, 4KB, aligned, QD = 16	110000	102000	99000	83000
Random write, 4KB, aligned, QD = 32	110000	102000	99000	83000
Random write, 4KB, aligned, QD = 128	110000	102000	100000	83000

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Table 4-14: 12Gbps Dual Port 9W Mode, RI-3 (**cont'd**)

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	33000	36000	39000	44000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	33000	36000	39000	44000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	77000	87000	104000	128000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	109000	124000	151000	142000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	173000	181000	175000	142000
Random read, 4KB, aligned, QD = 4	38000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	122000	134000	142000	150000
Random read, 4KB, aligned, QD = 32	180000	219000	245000	205000
Random read, 4KB, aligned, QD = 128	247000	279000	265000	205000
Random write, 8KB, aligned, QD = 4	55000	51000	49000	41000
Random write, 8KB, aligned, QD = 16	55000	51000	49000	41000
Random write, 8KB, aligned, QD = 32	55000	51000	49000	41000
Random write, 8KB, aligned, QD = 128	55000	51000	50000	41000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	22000	24000	27000	32000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	49000	51000	61000	79000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	67000	68000	82000	82000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	97000	104000	100000	82000
Random read, 8KB, aligned, QD = 4	29000	29000	30000	31000
Random read, 8KB, aligned, QD = 16	83000	88000	96000	106000
Random read, 8KB, aligned, QD = 32	114000	129000	145000	140000
Random read, 8KB, aligned, QD = 128	147000	186000	179000	139000
Random write, 64KB, aligned, QD = 4	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 16	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 32	7000	6000	6000	5000
Random write, 64KB, aligned, QD = 128	7000	6000	6000	5000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	6000	6000	7000	10000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	12000	13000	14000	12000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	14000	15000	15000	12000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	14000	15000	14000	12000
Random read, 64KB, aligned, QD = 4	10000	10000	11000	12000
Random read, 64KB, aligned, QD = 16	19000	21000	22000	27000
Random read, 64KB, aligned, QD = 32	23000	25000	26000	27000

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Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random read, 64KB, aligned, QD = 128	25000	29000	28000	28000

Table 4 - 15: **12Gbps Single Port 11W Mode, ME**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=1	810	810	810	810
Sequential read 128KB, aligned, QD=1	890	890	890	890
Sequential write 128KB, aligned, QD=32	990	1050	1050	1010
Sequential read 128KB, aligned, QD=32	1070	1070	1070	1070
Sequential write 4KB, aligned, QD=1	150	150	150	150
Sequential read 4KB, aligned, QD=1	170	170	170	170
Sequential write 4KB, aligned, QD=32	650	660	660	660
Sequential read 4KB, aligned, QD=32	930	930	930	930
Sequential write 0.5KB, aligned, QD=1	20	20	20	20
Sequential read 0.5KB, aligned, QD=1	20	20	20	20
Sequential write 0.5KB, aligned, QD=32	170	170	170	170
Sequential read 0.5KB, aligned, QD=32	200	210	200	210
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 1	36000	35000	35000	35000
Random write, 4KB, aligned, QD = 4	107000	99000	99000	97000
Random write, 4KB, aligned, QD = 16	165000	161000	160000	148000
Random write, 4KB, aligned, QD = 32	165000	167000	167000	148000
Random write, 4KB, aligned, QD = 128	166000	167000	167000	148000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 1	11000	12000	12000	12000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	36000	38000	42000	45000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	90000	97000	117000	133000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	129000	141000	175000	199000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	216000	237000	269000	234000
Random read, 4KB, aligned, QD = 1	10000	10000	10000	10000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	126000	135000	142000	149000
Random read, 4KB, aligned, QD = 32	193000	218000	231000	236000
Random read, 4KB, aligned, QD = 128	239000	239000	239000	239000

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Table 4 - 15: 12Gbps Single Port 11W Mode, ME **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 8KB, aligned, QD = 1	30000	29000	29000	29000
Random write, 8KB, aligned, QD = 4	79000	72000	73000	71000
Random write, 8KB, aligned, QD = 4	79000	72000	73000	71000
Random write, 8KB, aligned, QD = 16	86000	88000	96000	74000
Random write, 8KB, aligned, QD = 32	86000	88000	96000	74000
Random write, 8KB, aligned, QD = 128	86000	88000	96000	74000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	8000	8000	9000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	25000	25000	29000	32000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	55000	54000	67000	78000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	76000	74000	92000	107000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	121000	122000	144000	141000
Random read, 8KB, aligned, QD = 1	8000	7000	7000	7000
Random read, 8KB, aligned, QD = 4	29000	29000	29000	30000
Random read, 8KB, aligned, QD = 16	84000	84000	90000	96000
Random read, 8KB, aligned, QD = 32	114000	117000	124000	127000
Random read, 8KB, aligned, QD = 128	128000	128000	129000	129000
Random write, 64KB, aligned, QD = 1	10000	9000	9000	9000
Random write, 64KB, aligned, QD = 4	11000	11000	12000	9000
Random write, 64KB, aligned, QD = 16	11000	11000	12000	9000
Random write, 64KB, aligned, QD = 32	11000	11000	12000	9000
Random write, 64KB, aligned, QD = 128	11000	11000	12000	9000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 1	3000	3000	3000	3000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	7000	7000	8000	9000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	14000	14000	16000	19000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	18000	18000	20000	21000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	20000	19000	22000	22000
Random read, 64KB, aligned, QD = 1	3000	3000	3000	3000
Random read, 64KB, aligned, QD = 4	10000	10000	10000	11000
Random read, 64KB, aligned, QD = 16	17000	16000	17000	17000
Random read, 64KB, aligned, QD = 32	17000	17000	17000	17000
Random read, 64KB, aligned, QD = 128	17000	17000	17000	17000

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Table 4-16: **12Gbps Single Port 11W Mode, RI-3**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=1	800	810	810	800
Sequential read 128KB, aligned, QD=1	890	890	890	890
Sequential write 128KB, aligned, QD=32	830	1050	1050	1010
Sequential read 128KB, aligned, QD=32	1070	1070	1070	1070
Sequential write 4KB, aligned, QD=1	150	150	150	150
Sequential read 4KB, aligned, QD=1	170	170	170	170
Sequential write 4KB, aligned, QD=32	650	650	660	660
Sequential read 4KB, aligned, QD=32	930	930	930	930
Sequential write 0.5KB, aligned, QD=1	20	20	20	20
Sequential read 0.5KB, aligned, QD=1	20	20	20	20
Sequential write 0.5KB, aligned, QD=32	170	170	170	170
Sequential read 0.5KB, aligned, QD=32	200	200	200	210
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 1	35000	34000	34000	34000
Random write, 4KB, aligned, QD = 4	101000	91000	91000	91000
Random write, 4KB, aligned, QD = 16	110000	123000	142000	129000
Random write, 4KB, aligned, QD = 32	110000	123000	148000	129000
Random write, 4KB, aligned, QD = 128	109000	123000	150000	129000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 1	11000	11000	12000	12000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	33000	36000	39000	44000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	77000	87000	103000	127000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	109000	124000	150000	188000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	173000	205000	241000	218000
Random read, 4KB, aligned, QD = 1	10000	10000	10000	10000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	121000	133000	141000	149000
Random read, 4KB, aligned, QD = 32	178000	213000	229000	236000
Random read, 4KB, aligned, QD = 128	239000	239000	240000	239000
Random write, 8KB, aligned, QD = 1	29000	28000	28000	28000
Random write, 8KB, aligned, QD = 4	55000	63000	65000	64000
Random write, 8KB, aligned, QD = 16	55000	63000	75000	64000

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Table 4-16: 12Gbps Single Port 11W Mode, RI-3 **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 8KB, aligned, QD = 32	55000	63000	75000	64000
Random write, 8KB, aligned, QD = 128	55000	63000	75000	64000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	8000	8000	9000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	22000	23000	26000	31000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	45000	45000	53000	71000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	62000	61000	71000	95000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	95000	102000	119000	127000
Random read, 8KB, aligned, QD = 1	7000	7000	8000	8000
Random read, 8KB, aligned, QD = 4	28000	29000	29000	30000
Random read, 8KB, aligned, QD = 16	78000	81000	87000	95000
Random read, 8KB, aligned, QD = 32	104000	113000	121000	126000
Random read, 8KB, aligned, QD = 128	127000	128000	128000	129000
Random write, 64KB, aligned, QD = 1	7000	8000	9000	8000
Random write, 64KB, aligned, QD = 4	7000	8000	9000	8000
Random write, 64KB, aligned, QD = 16	7000	8000	9000	8000
Random write, 64KB, aligned, QD = 32	7000	8000	9000	8000
Random write, 64KB, aligned, QD = 128	7000	8000	9000	8000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 1	2000	2000	3000	3000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	6000	6000	7000	9000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	12000	12000	13000	18000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	14000	15000	16000	19000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	14000	15000	17000	19000
Random read, 64KB, aligned, QD = 1	3000	3000	3000	3000
Random read, 64KB, aligned, QD = 4	9000	10000	10000	11000
Random read, 64KB, aligned, QD = 16	16000	16000	16000	17000
Random read, 64KB, aligned, QD = 32	17000	17000	17000	17000
Random read, 64KB, aligned, QD = 128	17000	17000	17000	17000

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Table 4-17: **12Gbps Dual Port 11W Mode, ME**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=32	770	1500	1290	1010
Sequential read 128KB, aligned, QD=32	2060	2130	2150	2150
Sequential write 4KB, aligned, QD=32	990	1300	1290	1010
Sequential read 4KB, aligned, QD=32	690	680	670	710
Sequential write 0.5KB, aligned, QD=32	270	270	260	270
Sequential read 0.5KB, aligned, QD=32	70	70	70	70
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 4	109000	102000	101000	99000
Random write, 4KB, aligned, QD = 16	167000	170000	187000	147000
Random write, 4KB, aligned, QD = 32	166000	170000	193000	147000
Random write, 4KB, aligned, QD = 128	166000	169000	193000	147000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	36000	38000	42000	45000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	90000	97000	117000	135000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	130000	141000	177000	205000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	217000	240000	280000	233000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	127000	136000	144000	151000
Random read, 4KB, aligned, QD = 32	196000	225000	249000	268000
Random read, 4KB, aligned, QD = 128	288000	383000	401000	312000
Random write, 8KB, aligned, QD = 4	84000	79000	79000	73000
Random write, 8KB, aligned, QD = 16	84000	88000	96000	73000
Random write, 8KB, aligned, QD = 32	84000	88000	96000	73000
Random write, 8KB, aligned, QD = 128	84000	88000	96000	74000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	25000	26000	30000	33000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	59000	60000	73000	86000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	83000	83000	104000	122000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	128000	133000	161000	139000
Random read, 8KB, aligned, QD = 4	29000	29000	30000	31000
Random read, 8KB, aligned, QD = 16	89000	91000	99000	107000
Random read, 8KB, aligned, QD = 32	129000	136000	154000	174000
Random read, 8KB, aligned, QD = 128	176000	201000	232000	222000
Random write, 64KB, aligned, QD = 4	10000	11000	12000	9000

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Table 4-17: 12Gbps Dual Port 11W Mode, ME **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 64KB, aligned, QD = 16	10000	11000	12000	9000
Random write, 64KB, aligned, QD = 32	10000	11000	12000	9000
Random write, 64KB, aligned, QD = 128	10000	11000	12000	9000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	7000	7000	9000	10000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	15000	15000	19000	22000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	19000	19000	23000	22000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	20000	20000	24000	21000
Random read, 64KB, aligned, QD = 4	10000	10000	11000	12000
Random read, 64KB, aligned, QD = 16	22000	22000	24000	30000
Random read, 64KB, aligned, QD = 32	27000	26000	29000	34000
Random read, 64KB, aligned, QD = 128	30000	29000	32000	34000

Table 4 - 18: **12Gbps Dual Port 11W Mode, RI-3**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=32	610	910	1280	1010
Sequential read 128KB, aligned, QD=32	2010	2140	2030	2150
Sequential write 4KB, aligned, QD=32	830	1300	1280	1010
Sequential read 4KB, aligned, QD=32	690	680	670	730
Sequential write 0.5KB, aligned, QD=32	260	260	260	260
Sequential read 0.5KB, aligned, QD=32	70	70	70	70
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 4	104000	94000	94000	93000
Random write, 4KB, aligned, QD = 16	110000	123000	149000	128000
Random write, 4KB, aligned, QD = 32	110000	122000	151000	128000
Random write, 4KB, aligned, QD = 128	110000	122000	151000	128000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	33000	35000	39000	44000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	77000	87000	104000	128000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	109000	124000	151000	191000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	173000	206000	245000	217000
Random read, 4KB, aligned, QD = 4	38000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	122000	134000	142000	150000
Random read, 4KB, aligned, QD = 32	180000	219000	245000	268000

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Table 4-18: 12Gbps Dual Port 11W Mode, RI-3 **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random read, 4KB, aligned, QD = 128	247000	366000	401000	312000
Random write, 8KB, aligned, QD = 4	55000	62000	69000	64000
Random write, 8KB, aligned, QD = 16	55000	63000	75000	64000
Random write, 8KB, aligned, QD = 32	55000	63000	75000	64000
Random write, 8KB, aligned, QD = 128	55000	62000	76000	64000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	22000	24000	27000	32000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	49000	51000	61000	79000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	67000	68000	82000	108000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	98000	109000	130000	125000
Random read, 8KB, aligned, QD = 4	29000	29000	30000	31000
Random read, 8KB, aligned, QD = 16	83000	88000	96000	106000
Random read, 8KB, aligned, QD = 32	114000	129000	145000	172000
Random read, 8KB, aligned, QD = 128	147000	186000	207000	213000
Random write, 64KB, aligned, QD = 4	7000	8000	9000	8000
Random write, 64KB, aligned, QD = 16	7000	8000	9000	8000
Random write, 64KB, aligned, QD = 32	7000	8000	9000	8000
Random write, 64KB, aligned, QD = 128	7000	8000	9000	7000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	6000	6000	7000	10000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	12000	13000	15000	19000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	14000	15000	17000	19000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	14000	16000	18000	18000
Random read, 64KB, aligned, QD = 4	10000	10000	11000	12000
Random read, 64KB, aligned, QD = 16	19000	21000	22000	30000
Random read, 64KB, aligned, QD = 32	23000	25000	26000	34000
Random read, 64KB, aligned, QD = 128	25000	29000	28000	34000

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Table 4 - 19: **12Gbps Single Port 14W Mode, ME**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=1	810	810	810	810
Sequential read 128KB, aligned, QD=1	890	890	890	890
Sequential write 128KB, aligned, QD=32	990	1050	1050	1050
Sequential read 128KB, aligned, QD=32	1070	1070	1070	1070
Sequential write 4KB, aligned, QD=1	150	150	150	150
Sequential read 4KB, aligned, QD=1	170	170	170	170
Sequential write 4KB, aligned, QD=32	650	660	660	660
Sequential read 4KB, aligned, QD=32	930	930	930	930
Sequential write 0.5KB, aligned, QD=1	20	20	20	20
Sequential read 0.5KB, aligned, QD=1	20	20	20	20
Sequential write 0.5KB, aligned, QD=32	170	170	170	170
Sequential read 0.5KB, aligned, QD=32	200	210	200	200
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 1	36000	35000	35000	35000
Random write, 4KB, aligned, QD = 4	107000	99000	99000	97000
Random write, 4KB, aligned, QD = 16	165000	162000	159000	156000
Random write, 4KB, aligned, QD = 32	167000	167000	168000	165000
Random write, 4KB, aligned, QD = 128	166000	167000	167000	167000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 1	11000	12000	12000	12000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	36000	38000	42000	45000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	89000	97000	117000	133000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	129000	141000	175000	199000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	216000	237000	269000	278000
Random read, 4KB, aligned, QD = 1	10000	10000	10000	10000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	126000	135000	142000	149000
Random read, 4KB, aligned, QD = 32	193000	218000	231000	236000
Random read, 4KB, aligned, QD = 128	239000	239000	239000	239000
Random write, 8KB, aligned, QD = 1	30000	29000	29000	29000
Random write, 8KB, aligned, QD = 4	79000	72000	73000	71000
Random write, 8KB, aligned, QD = 16	86000	88000	101000	98000

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Table 4-19: 12Gbps Single Port 14W Mode, ME **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 8KB, aligned, QD = 16	86000	88000	101000	98000
Random write, 8KB, aligned, QD = 32	86000	88000	102000	101000
Random write, 8KB, aligned, QD = 128	86000	88000	102000	101000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	8000	8000	9000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	25000	25000	29000	32000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	55000	54000	67000	78000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	76000	74000	92000	107000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	121000	122000	144000	153000
Random read, 8KB, aligned, QD = 1	8000	7000	7000	7000
Random read, 8KB, aligned, QD = 4	29000	29000	29000	30000
Random read, 8KB, aligned, QD = 16	84000	84000	90000	96000
Random read, 8KB, aligned, QD = 32	114000	117000	124000	127000
Random read, 8KB, aligned, QD = 128	128000	128000	129000	129000
Random write, 64KB, aligned, QD = 1	10000	9000	9000	9000
Random write, 64KB, aligned, QD = 4	11000	11000	15000	15000
Random write, 64KB, aligned, QD = 16	11000	11000	16000	15000
Random write, 64KB, aligned, QD = 32	11000	11000	16000	15000
Random write, 64KB, aligned, QD = 128	11000	11000	16000	15000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 1	3000	3000	3000	3000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	7000	7000	8000	9000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	14000	14000	16000	19000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	18000	18000	20000	21000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	20000	19000	22000	22000
Random read, 64KB, aligned, QD = 1	3000	3000	3000	3000
Random read, 64KB, aligned, QD = 4	10000	10000	10000	11000
Random read, 64KB, aligned, QD = 16	17000	16000	17000	17000
Random read, 64KB, aligned, QD = 32	17000	17000	17000	17000
Random read, 64KB, aligned, QD = 128	17000	17000	17000	17000

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Table 4 - 20: **12Gbps Single Port 14W Mode, RI-3**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=1	800	810	810	810
Sequential read 128KB, aligned, QD=1	890	890	890	890
Sequential write 128KB, aligned, QD=32	830	1050	1050	1050
Sequential read 128KB, aligned, QD=32	1070	1070	1070	1070
Sequential write 4KB, aligned, QD=1	150	150	150	150
Sequential read 4KB, aligned, QD=1	170	170	170	170
Sequential write 4KB, aligned, QD=32	660	660	660	660
Sequential read 4KB, aligned, QD=32	930	930	930	930
Sequential write 0.5KB, aligned, QD=1	20	20	20	20
Sequential read 0.5KB, aligned, QD=1	20	20	20	20
Sequential write 0.5KB, aligned, QD=32	170	170	170	170
Sequential read 0.5KB, aligned, QD=32	200	190	210	210
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 1	35000	34000	34000	34000
Random write, 4KB, aligned, QD = 4	101000	91000	91000	92000
Random write, 4KB, aligned, QD = 16	110000	123000	143000	143000
Random write, 4KB, aligned, QD = 32	110000	123000	155000	156000
Random write, 4KB, aligned, QD = 128	110000	123000	154000	167000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 1	11000	11000	12000	12000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	33000	36000	39000	44000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	77000	87000	103000	127000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	109000	123000	150000	188000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	173000	205000	242000	262000
Random read, 4KB, aligned, QD = 1	10000	10000	10000	10000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	121000	133000	141000	149000
Random read, 4KB, aligned, QD = 32	179000	213000	229000	236000
Random read, 4KB, aligned, QD = 128	239000	239000	240000	239000
Random write, 8KB, aligned, QD = 1	29000	28000	27000	28000
Random write, 8KB, aligned, QD = 4	55000	62000	65000	66000
Random write, 8KB, aligned, QD = 16	55000	63000	85000	91000

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Table 4-20: 12Gbps Single Port 14W Mode, RI-3 **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 8KB, aligned, QD = 32	55000	63000	85000	98000
Random write, 8KB, aligned, QD = 128	55000	63000	86000	101000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 1	8000	8000	9000	9000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	22000	23000	26000	31000
Random write, 8KB, aligned, QD = 32	55000	63000	85000	98000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	45000	45000	53000	71000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	61000	61000	71000	95000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	95000	102000	119000	145000
Random read, 8KB, aligned, QD = 1	7000	7000	8000	8000
Random read, 8KB, aligned, QD = 4	28000	29000	29000	30000
Random read, 8KB, aligned, QD = 16	77000	81000	87000	95000
Random read, 8KB, aligned, QD = 32	104000	113000	121000	126000
Random read, 8KB, aligned, QD = 128	127000	128000	128000	129000
Random write, 64KB, aligned, QD = 1	7000	8000	9000	9000
Random write, 64KB, aligned, QD = 4	7000	8000	10000	13000
Random write, 64KB, aligned, QD = 16	7000	8000	10000	13000
Random write, 64KB, aligned, QD = 32	7000	8000	11000	13000
Random write, 64KB, aligned, QD = 128	7000	8000	11000	13000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 1	2000	2000	3000	3000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	6000	6000	7000	9000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	12000	12000	13000	18000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	14000	15000	17000	21000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	14000	15000	18000	22000
Random read, 64KB, aligned, QD = 1	3000	3000	3000	3000
Random read, 64KB, aligned, QD = 4	9000	10000	10000	11000
Random read, 64KB, aligned, QD = 16	16000	16000	16000	17000
Random read, 64KB, aligned, QD = 32	17000	17000	17000	17000
Random read, 64KB, aligned, QD = 128	17000	17000	17000	17000

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Table 4 - 21: **12Gbps Dual Port 14W Mode, ME**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=32	750	1510	1990	1700
Sequential read 128KB, aligned, QD=32	2060	2130	2150	2150
Sequential write 4KB, aligned, QD=32	990	1300	1300	1300
Sequential read 4KB, aligned, QD=32	680	680	670	710
Sequential write 0.5KB, aligned, QD=32	260	270	260	260
Sequential read 0.5KB, aligned, QD=32	70	70	70	70
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 4	109000	102000	102000	99000
Random write, 4KB, aligned, QD = 16	167000	170000	187000	175000
Random write, 4KB, aligned, QD = 32	166000	170000	204000	194000
Random write, 4KB, aligned, QD = 128	167000	169000	203000	195000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	36000	38000	42000	45000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	90000	97000	117000	135000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	130000	141000	176000	205000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	217000	240000	280000	286000
Random read, 4KB, aligned, QD = 4	39000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	127000	136000	144000	151000
Random read, 4KB, aligned, QD = 32	196000	225000	249000	268000
Random read, 4KB, aligned, QD = 128	288000	383000	417000	425000
Random write, 8KB, aligned, QD = 4	84000	79000	78000	76000
Random write, 8KB, aligned, QD = 16	84000	88000	120000	114000
Random write, 8KB, aligned, QD = 32	84000	88000	122000	120000
Random write, 8KB, aligned, QD = 128	84000	88000	121000	118000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	25000	26000	30000	33000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	59000	60000	73000	86000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	83000	83000	104000	122000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	128000	133000	161000	173000
Random read, 8KB, aligned, QD = 4	29000	29000	30000	31000
Random read, 8KB, aligned, QD = 16	89000	91000	99000	107000
Random read, 8KB, aligned, QD = 32	128000	136000	154000	174000
Random read, 8KB, aligned, QD = 128	176000	201000	232000	252000

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Table 4-21: 12Gbps Dual Port 14W Mode, ME **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random write, 64KB, aligned, QD = 4	10000	11000	16000	15000
Random write, 64KB, aligned, QD = 16	10000	11000	16000	15000
Random write, 64KB, aligned, QD = 32	10000	11000	16000	15000
Random write, 64KB, aligned, QD = 128	10000	11000	16000	15000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	7000	7000	9000	10000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	15000	15000	19000	23000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	19000	19000	23000	29000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	20000	20000	25000	30000
Random read, 64KB, aligned, QD = 4	10000	10000	11000	12000
Random read, 64KB, aligned, QD = 16	22000	22000	24000	30000
Random read, 64KB, aligned, QD = 32	27000	26000	29000	34000
Random read, 64KB, aligned, QD = 128	30000	29000	32000	34000

Table 4 - 22: **12Gbps Dual Port 14W Mode, RI-3**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Sequential write 128KB, aligned, QD=32	610	960	1960	1700
Sequential read 128KB, aligned, QD=32	2010	2140	2030	2150
Sequential write 4KB, aligned, QD=32	830	1300	1300	1300
Sequential read 4KB, aligned, QD=32	690	680	700	730
Sequential write 0.5KB, aligned, QD=32	270	280	260	270
Sequential read 0.5KB, aligned, QD=32	70	70	70	70
	IOPS	**IOPS**	**IOPS**	**IOPS**
Random write, 4KB, aligned, QD = 4	104000	94000	94000	93000
Random write, 4KB, aligned, QD = 16	110000	123000	152000	154000
Random write, 4KB, aligned, QD = 32	110000	123000	158000	171000
Random write, 4KB, aligned, QD = 128	110000	122000	157000	172000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 4	33000	36000	39000	44000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	77000	87000	104000	128000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	109000	124000	151000	191000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 128	173000	206000	245000	268000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 16	77000	87000	104000	128000
Random mix: 70% read / 30% write, 4KB, aligned, QD = 32	109000	124000	151000	191000

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Table 4-22: 12Gbps Dual Port 14W Mode, RI-3 **(cont'd)**

Description / Access Type (QD is at the drive)	400GB Mbps	800G Mbps	1.6T Mbps	3.2T Mbps
Random read, 4KB, aligned, QD = 4	38000	39000	40000	40000
Random read, 4KB, aligned, QD = 16	122000	134000	142000	150000
Random read, 4KB, aligned, QD = 32	180000	219000	245000	267000
Random read, 4KB, aligned, QD = 128	247000	367000	413000	426000
Random write, 8KB, aligned, QD = 4	55000	62000	69000	70000
Random write, 8KB, aligned, QD = 16	55000	63000	86000	98000
Random write, 8KB, aligned, QD = 32	55000	63000	86000	103000
Random write, 8KB, aligned, QD = 128	55000	62000	86000	102000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 4	22000	24000	27000	32000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 16	49000	51000	61000	79000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 32	67000	68000	82000	108000
Random mix: 70% read / 30% write, 8KB, aligned, QD = 128	97000	109000	130000	158000
Random read, 8KB, aligned, QD = 4	29000	29000	30000	31000
Random read, 8KB, aligned, QD = 16	82000	88000	96000	106000
Random read, 8KB, aligned, QD = 32	113000	129000	145000	172000
Random read, 8KB, aligned, QD = 128	147000	185000	207000	246000
Random write, 64KB, aligned, QD = 4	7000	8000	10000	13000
Random write, 64KB, aligned, QD = 16	7000	8000	10000	13000
Random write, 64KB, aligned, QD = 32	7000	8000	11000	13000
Random write, 64KB, aligned, QD = 128	7000	8000	11000	13000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 4	6000	6000	7000	10000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 16	12000	13000	15000	21000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 32	14000	15000	18000	26000
Random mix: 70% read / 30% write, 64KB, aligned, QD = 128	14000	16000	18000	26000
Random read, 64KB, aligned, QD = 4	10000	10000	11000	12000
Random read, 64KB, aligned, QD = 16	19000	21000	22000	30000
Random read, 64KB, aligned, QD = 32	23000	25000	26000	34000
Random read, 64KB, aligned, QD = 128	25000	29000	28000	34000

Notes:

1. Drive performance varies with model capacity and actual drive use.
2. For this table, '1 MB / Sec' should be interpreted as 1024 x 1024 Bytes per Second.
3. Ongoing FW improvement may slightly change the performance.

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4.4.4 Random Writes Over the Life of the Drive

Table 4 - 23: **Random Writes Over the Life of the Drive**

Model / Worst Case (TBW)	3200GB	1600GB	800GB	400GB
Mainstream Endurance (ME)	53161	26581	13290	7300
Read Intensive (RI-3)	15948	7974	3987	1994

Note:
1. Lifetime Random Endurance 4KB-aligned.

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5.0 Data Integrity

The SSD employs a *failsafe write cache* that insures customer data is committed to the media in the event of a power loss. This failsafe write cache cannot be disabled. On a given write command, if all data has been received by the SSD and the RESPONSE frame has been sent to the initiator with Good status, it is guaranteed that all write data will be committed to the media in the event of a power loss. If the RESPONSE frame was not sent and some (or all) of the data was received by the SSD, some (or all) of the data may be committed to the media in the event of a power loss. In this case, it is guaranteed that all affected blocks will be readable without error, but not all blocks may return the newly written data.

5.1 Equipment Status

Equipment status is available to the host system any time the drive is not ready to read or write. This status normally exists at power-on time and will be maintained until the following conditions are satisfied:

- Self-check of drive is complete. Appropriate error status is made available to the host system if any of the following conditions occur after the drive has become ready.
- A SMART error is detected.

5.2 Error Recovery Procedure

Errors occurring with the drive are handled by the error recovery procedure. Errors that are uncorrectable after application of the error recovery procedures are reported to the host system as non-recoverable errors.

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6.0 Electrical Interface

6.1 SAS Connector

The drive uses the 68-pin connector, which conforms to the mechanical requirements of SFF-8639. The mechanical dimension and signal assignment of this connector have been developed in accordance with SFF-8680. The connector is expected to be used in an environment that uses a common connector structure for racking drives in a cabinet. The connector allows for plugging a drive directly into a backplane by providing the necessary electrical connection. Mechanical stability and device retention must be provided by a mechanism outside the drive.

6.1.1 68-Pin SFF8639 Connector

Figure 6 - 1: **Connector Pinout**

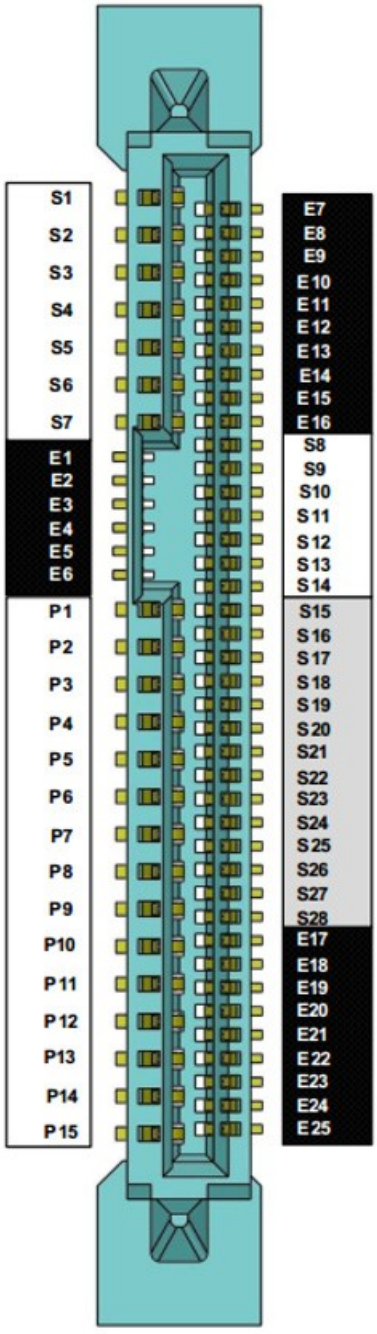

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Table 6 - 1: **68-Pin Connector Signal Definition**

Pin Number	Signal	Description
S1	GND	Ground
S2	S0T+	SAS Port 0 Transmit (positive) signal
S3	S0T-	SAS Port 0 Transmit (negative) signal
S4	GND	Ground
S5	S0R-	SAS Port 0 Receive (positive) signal
S6	S0R+	SAS Port 0 Receive (negative) signal
S7	GND	Ground
S8	GND	Ground
S9	S1T+	SAS Port 1 Transmit (positive) signal
S10	S1T-	SAS Port 1 Transmit (negative) signal
S11	GND	Ground
S12	S1R-	SAS Port 1 Receive (positive) signal
S13	S1R+	SAS Port 1 Receive (negative) signal
S14	GND	Ground
S15	Reserved	Reserved
S16	GND	Ground
S17	S2T+	SAS Port 2 Transmit (positive) signal
S18	S2T-	SAS Port 2 Transmit (negative) signal
S19	GND	Ground
S20	S2R-	SAS Port 2 Receive (positive) signal
S21	S2R+	SAS Port 2 Receive (negative) signal
S22	GND	Ground
S23	S3T+	SAS Port 3 Transmit (positive) signal
S24	S3T-	SAS Port 3 Transmit (negative) signal
S25	GND	Ground
S26	S3R-	SAS Port 3 Receive (positive) signal
S27	S3R+	SAS Port 3 Receive (negative) signal
S28	GND	Ground
P1	Wake#	Reserved
P2	Dev_Reset	Device Reset
P3	DevSLP#	Device Sleep

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Pin Number	Signal	Description
P4	IfDet#	Interface type detect
P5	GND	Ground
P6	GND	Ground
P7	+5V-Charge	Pre-charge pin for +5V
P8	+5V	+5V power supply input
P9	+5V	+5V power supply input
P10	PRSNT#	Device Present
P11	Activity	Activity/Ready LED
P12	GND	Ground
E3	+3.3Vaux	+3.3V for SM bus
E4	PCIe B RST	PCIe Reset (Port B)
E5	PCIe A RST	PCIe Reset (Port A)
E6	Reserved	Reserved
E7	PCIe A RefClk+	PCIe Reference Clock+ (Port A)
E8	PCIe A RefClk+	PCIe Reference Clock- (Port A)
E9	GND	Ground
E10	PETp0	PCIe 0 TX+
E11	PETn0	PCIe 0 TX-
E12	GND	Ground
E13	PERn0	PCIe 0 RX-
E14	PERp0	PCIe 0 RX+
E15	GND	Ground
E16	Reserved	Reserved
E17	PETp3	PCIe 3 TX+
E18	PETn3	PCIe 3 TX-
E19	GND	Ground
E20	PERn3	PCIe 3 RX-
E21	PERp3	PCIe 3 RX+
E22	GND	Ground
E23	SMCLK	SM Bus Clock
E24	SMDAT	SM Bus Data
E25	DualPortEn#	ePCIe Dual Port Enable

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- Voltage and Ground Signals: The 12V and 5V contacts provide all the voltages required by the drive. The two voltages share a common ground plane to which all the ground contacts are connected.

6.2 READY LED Output

The drive provides an open-drain driver to the Ready LED Output signal, with 15mA of current sink capability. The cathode of the LED should be connected to this signal. The LED and the current-limiting resistor must be provided by the enclosure.

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7.0 Environment

7.1 Temperature and Humidity

Table 7 - 1: Operating and Non-Operating Conditions

Operating Conditions	
Temperature[1]	0°C to 75ºC (drive-reported; see Cooling Requirements)
Relative humidity[1]	5 to 90%, non-condensing
Maximum wet bulb temperature	29.4ºC, non-condensing
Maximum ambient temperature gradient	20ºC/hour
Altitude	-305 to 3,048 m
Shipping Conditions	
Ambient temperature[1]	-55°C to 95ºC
Relative humidity[1]	5 to 95%, non-condensing
Maximum wet bulb temperature	35ºC, non-condensing
Maximum surface temperature gradient	30ºC/hour
Altitude	-305 to 12,192 m
Storage Conditions	
Ambient temperature[1]	0°C to 60ºC
Relative humidity[1]	5 to 95%, non-condensing
Maximum wet bulb temperature	35ºC, non-condensing
Altitude	-305 to 12,192 m

[1] Temperature and relative humidity limits are constrained by wet bulb temperature limits defined above.

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7.2 Storage Requirements

7.2.1 Packaging

The drive or option kit is shipped by HGST in a sealed ESD bag.

7.2.2 Storage Time

Cumulative storage time in the sealed ESD bag before initial power-on must not exceed one year.

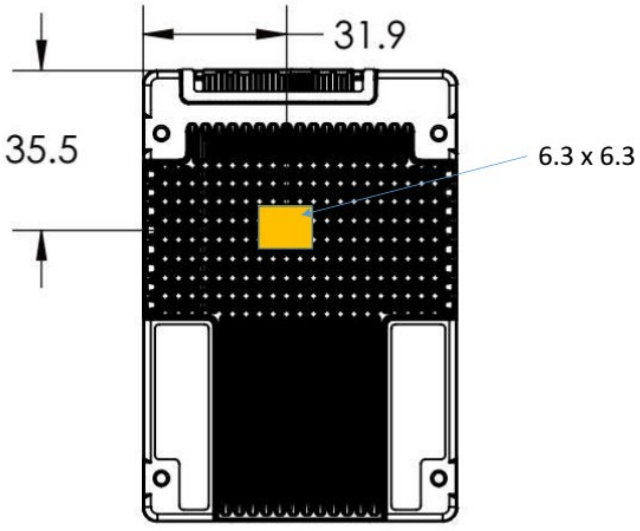
7.3 Cooling Requirements

The drive-reported temperature must not exceed 80ºC. Drive component temperatures will remain within the limits specified by their respective manufacturers, provided drive-reported, storage, and shipping temperatures are maintained within limits as specified in Operating and Non-operating Conditions. The drive will require forced air cooling to meet the specified maximum operating temperatures. See Table 7 - 1 for various ambient air temperatures required to maintain the drive within specified operating limits. Integrators should evaluate drive temperature behavior for their specific applications.

Table 7 - 2: Drive Reported Temperature Requirements

Module Name	Location	Maximum Allowable Temperature
Drive Reported Temperature	As noted in figure 7 - 1	75ºC

Figure 7 - 1: Location of temperature measurement sensor inside the drive



Notes:

1. The temperature measurement sensor is located inside the drive on the PCBA near the ASIC module, which is the hottest point in the drive.
2. All dimensions are in millimeters (mm).
3. Image is not to scale.

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8.0 DC Power Requirements

The following voltage specification applies to the drive power connector. Connections to the drive should be made using a Safety Extra Low Voltage (SELV) circuit. There is no power on or power off sequencing requirement. Adequate secondary over-current protection is the responsibility of the system.

Table 8 - 1: Input Voltage and Capacitance

Supply	Tolerance	Absolute Max. Spike Voltage	Supply Rise Time	Capacitance
5V	+10%/- 7%	7V (for 26ms)	0.1ms-200ms	47µF
12V	+10%/- 7%	15V (for 26ms)	0.1ms-400ms	47µF

8.1 Power Supply Current, Average and Peak

The following current and power requirements are typical when operating under normal 5V and 12V conditions.

Table 8 - 2: ME and RI-3 Models; Power Supply Current, Average and Peak (3.2TB, 1.6TB, 800GB, 400GB)

Capacity:	3.2 TB ME	3.2 TB RI	1.6 TB ME	1.6 TB RI	800 GB ME	800 GB RI	400 GB ME	400 GB RI
	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG
Startup: **14 watt, 6 Gbps, single port**								
12V (MAX A)	1.2	1.1	1.2	1.0	0.9	0.8	0.5	0.5
5V (MAX A)	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.5
256KB SeqWr QD128 **14 watt, 12 Gbps, dual port**								
12V (MEAN A)	0.87	0.85	0.87	0.88	0.73	0.67	0.55	0.50
12V (MAX A)	1.11	1.11	1.25	1.25	0.97	0.89	0.73	0.66
5V (MEAN A)	0.43	0.44	0.41	0.42	0.33	0.31	0.27	0.25
5V (MAX A)	0.91	0.94	0.78	0.80	0.73	0.71	0.65	0.66
Power (watts)	**12.6**	**12.4**	**12.4**	**12.7**	**10.4**	**9.6**	**7.9**	**7.2**
Performance (MBPS)	1760	1540	2060	1890	1580	1360	1030	870
256KB SeqWr QD128 **11 watt, 12 Gbps, dual port**								
12V (MEAN A)	0.64	0.62	0.66	0.66	0.59	0.68	0.56	0.49
12V (MAX A)	0.82	0.80	0.85	0.87	0.95	0.90	0.72	0.65
5V (MEAN A)	0.32	0.32	0.33	0.32	0.27	0.32	0.28	0.25
5V (MAX A)	0.77	0.75	0.72	0.75	0.64	0.70	0.64	0.62
Power (watts)	**9.3**	**9.1**	**9.5**	**9.5**	**8.5**	**9.7**	**8.1**	**7.2**
Performance (MBPS)	1050	1040	1340	1320	1230	1450	1060	860
256KB SeqWr QD128 **9 watt, 12 Gbps, dual port**								
12V (MEAN A)	0.52	0.52	0.51	0.53	0.55	0.53	0.55	0.50

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12V (MAX A)	0.67	0.67	0.71	0.70	0.71	0.68	0.71	0.66
5V (MEAN A)	0.26	0.26	0.26	0.27	0.26	0.26	0.28	0.25
5V (MAX A)	0.66	0.66	0.63	0.65	0.63	0.62	0.64	0.62
Power (watts)	**7.5**	**7.6**	**7.4**	**7.8**	**7.9**	**7.7**	**8.0**	**7.3**
Performance (MBPS)	680	680	870	880	960	960	1040	890
256KB SeqRd QD128 14 watt, 12 Gbps, dual port								
12V (MEAN A)	0.46	0.46	0.44	0.42	0.47	0.42	0.41	0.42
12V (MAX A)	0.64	0.73	0.62	0.63	0.65	0.62	0.61	0.60
5V (MEAN A)	0.38	0.38	0.40	0.35	0.38	0.33	0.33	0.36
5V (MAX A)	0.77	0.77	0.72	0.70	0.71	0.66	0.65	0.68
Power (Watts)	**7.4**	**7.4**	**7.3**	**6.8**	**7.5**	**6.7**	**6.6**	**6.9**
Performance (MBPS)	1870	1870	2210	1800	2210	1870	1870	2130
256KB SeqRd QD128 11 watt, 12 Gbps, dual port								
12V (MEAN A)	0.46	0.46	0.44	0.45	0.46	0.42	0.41	0.42
12V (MAX A)	0.63	0.74	0.63	0.68	0.66	0.65	0.61	0.59
5V (MEAN A)	0.38	0.38	0.40	0.39	0.38	0.33	0.33	0.36
5V (MAX A)	0.75	0.73	0.73	0.75	0.71	0.66	0.65	0.72
Power (Watts)	**7.4**	**7.4**	**7.3**	**7.3**	**7.4**	**6.7**	**6.6**	**6.8**
Performance (MBPS)	1870	1870	2210	2110	2210	1870	1870	2140
256KB SeqRd QD128 9 watt, 12 Gbps, dual port								
12V (MEAN A)	0.49	0.46	0.44	0.44	0.46	0.42	0.41	0.42
12V (MAX A)	0.73	0.74	0.64	0.66	0.66	0.61	0.61	0.60
5V (MEAN A)	0.42	0.38	0.40	0.39	0.38	0.33	0.33	0.36
5V (MAX A)	0.79	0.76	0.73	0.75	0.71	0.67	0.65	0.67
Power (watts)	**7.9**	**7.3**	**7.3**	**7.3**	**7.5**	**6.7**	**6.6**	**6.91**
Performance (MBPS)	2210	1870	2210	2100	2200	1870	1870	2130
4KB RanWr QD128 14 watt, 12 Gbps, dual port								
12V (MEAN A)	0.79	0.78	0.72	0.72	0.66	0.64	0.58	0.53
12V (MAX A)	1.15	1.13	1.20	1.18	0.95	0.86	0.74	0.68
5V (MEAN A)	0.46	0.47	0.40	0.42	0.34	0.35	0.30	0.27
5V (MAX A)	1.06	1.06	0.79	0.81	0.72	0.72	0.66	0.65
Power (watts)	**11.8**	**11.7**	**10.7**	**10.8**	**9.6**	**9.4**	**8.5**	**7.7**
Performance (IOPS)	198000	172000	199000	155000	153000	124000	161000	110000
4KB RanWr QD128 11 watt, 12 Gbps, dual port								
12V (MEAN A)	0.68	0.67	0.70	0.70	0.68	0.63	0.58	0.52
12V (MAX A)	0.84	0.82	0.92	0.94	0.94	0.87	0.75	0.67
5V (MEAN A)	0.38	0.38	0.39	0.41	0.35	0.34	0.30	0.27

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5V (MAX A)	0.89	0.91	0.78	0.78	0.71	0.71	0.66	0.64
Power (watts)	**10.1**	**9.9**	**10.4**	**10.5**	**10.0**	**9.3**	**8.5**	**7.6**
Performance (IOPS)	143000	126000	189000	147000	157000	118000	164000	101000
4KB RanWr QD128 9 watt, 12 Gbps, dual port								
12V (MEAN A)	0.57	0.56	0.57	0.58	0.60	0.58	0.58	0.52
12V (MAX A)	0.71	0.69	0.72	0.73	0.77	0.73	0.74	0.67
5V (MEAN A)	0.30	0.30	0.31	0.32	0.31	0.31	0.30	0.27
5V (MAX A)	0.79	0.80	0.70	0.73	0.71	0.69	0.67	0.64
Power (watts)	**8.4**	**8.2**	**8.4**	**8.6**	**8.7**	**8.5**	**8.5**	**7.6**
Performance (IOPS)	92000	83000	124000	97000	120000	98000	161000	99000
4KB Ran70Rd/30Wr QD128 14 watt, 12 Gbps, dual port								
12V (MEAN A)	0.70	0.70	0.64	0.66	0.63	0.60	0.55	0.51
12V (MAX A)	1.07	1.07	1.07	1.09	0.88	0.83	0.70	0.65
5V (MEAN A)	0.41	0.42	0.37	0.39	0.34	0.33	0.30	0.28
5V (MAX A)	0.84	0.88	0.72	0.74	0.67	0.66	0.64	0.61
Power (watts)	**10.5**	**10.5**	**9.6**	**9.8**	**9.3**	**8.9**	**8.1**	**7.5**
Performance (IOPS)	276000	262000	272000	245000	252000	217000	231000	178000
4KB Ran70Rd/30Wr QD128 11 watt, 12 Gbps, dual port								
12V (MEAN A)	0.65	0.64	0.64	0.65	0.63	0.60	0.55	0.51
12V (MAX A)	0.78	0.74	0.93	0.93	0.88	0.81	0.69	0.64
5V (MEAN A)	0.37	0.37	0.37	0.38	0.34	0.33	0.30	0.28
5V (MAX A)	0.78	0.77	0.71	0.74	0.69	0.67	0.62	0.62
Power (watts)	**9.7**	**9.5**	**9.6**	**9.7**	**9.3**	**8.9**	**8.1**	**7.5**
Performance (IOPS)	229000	221000	269000	239000	252000	213000	230000	179000
4K Ran70Rd/30Wr QD128 9 watt, 12 Gbps, dual port								
12V (MEAN A)	0.55	0.54	0.55	0.56	0.57	0.56	0.55	0.51
12V (MAX A)	0.63	0.63	0.68	0.68	0.71	0.68	0.71	0.64
5V (MEAN A)	0.29	0.29	0.31	0.32	0.30	0.31	0.30	0.27
5V (MAX A)	0.65	0.65	0.64	0.67	0.64	0.65	0.64	0.62
Power (watts)	**8.1**	**8.0**	**8.2**	**8.3**	**8.4**	**8.3**	**8.2**	**7.5**
Performance (IOPS)	148000	143000	192000	169000	201000	180000	232000	178000
4K RanRd QD128 14 watt, 12 Gbps, dual port								
12V (MEAN A)	0.69	0.69	0.63	0.63	0.62	0.58	0.54	0.50
12V (MAX A)	1.06	1.06	1.00	0.97	0.84	0.76	0.66	0.60
5V (MEAN A)	0.42	0.42	0.37	0.38	0.34	0.32	0.31	0.28
5V (MAX A)	0.78	0.75	0.68	0.70	0.65	0.63	0.59	0.58
Power (watts)	**10.4**	**10.4**	**9.4**	**9.5**	**9.1**	**8.6**	**8.0**	**7.4**
Performance (IOPS)	396000	403000	391000	389000	365000	344000	296000	252000

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4K RanRd QD128 11 watt, 12 Gbps, dual port								
12V (MEAN A)	0.62	0.61	0.63	0.63	0.62	0.59	0.54	0.50
12V (MAX A)	0.70	0.70	0.92	0.93	0.84	0.78	0.66	0.60
5V (MEAN A)	0.36	0.36	0.37	0.37	0.34	0.33	0.31	0.28
5V (MAX A)	0.68	0.67	0.68	0.70	0.65	0.62	0.59	0.58
Power (Watts)	**9.2**	**9.1**	**9.4**	**9.4**	**9.1**	**8.7**	**8.0**	**7.4**
Performance (IOPS)	306000	306000	392000	388000	363000	345000	296000	252000
4K RanRd QD128 9 watt, 12 Gbps, dual port								
12V (MEAN A)	0.52	0.51	0.52	0.53	0.55	0.53	0.54	0.50
12V (MAX A)	0.59	0.58	0.61	0.62	0.66	0.62	0.66	0.62
5V (MEAN A)	0.29	0.29	0.30	0.30	0.29	0.29	0.31	0.28
5V (MAX A)	0.61	0.58	0.59	0.62	0.59	0.58	0.59	0.56
Power (Watts)	**7.7**	**7.6**	**7.7**	**7.8**	**8.0**	**7.8**	**8.0**	**7.4**
Performance (IOPS)	201000	201000	261000	261000	274000	274000	297000	237000
4K RanRd QD128 14 watt, 12 Gbps, single port								
12V (MEAN A)	0.541	0.534	0.491	0.497	0.506	0.488	0.446	0.473
12V (MAX A)	0.863	0.888	0.776	0.777	0.736	0.69	0.607	0.605
5V (MEAN A)	0.298	0.3	0.275	0.28	0.264	0.263	0.244	0.258
5V (MAX A)	0.655	0.625	0.579	0.613	0.576	0.563	0.536	0.567
Power (Watts)	**7.991**	**7.919**	**7.279**	**7.37**	**7.406**	**7.175**	**6.574**	**6.979**
Performance (IOPS)	226000	226000	226000	228000	226000	228000	187000	221000
Drive idle 14 watt, 12 Gbps, single port								
12V (MEAN A)	0.28	0.28	0.23	0.24	0.26	0.24	0.23	0.23
12V (MAX A)	0.45	0.50	0.50	0.47	0.44	0.43	0.42	0.45
5V (MEAN A)	0.14	0.15	0.13	0.14	0.13	0.13	0.13	0.13
5V (MAX A)	0.46	0.45	0.42	0.44	0.41	0.42	0.40	0.42
Power (Watts)	**4.1**	**4.0**	**3.4**	**3.5**	**3.7**	**3.5**	**3.4**	**3.4**
Drive Standby 14 watt, 12 Gbps, single port								
12V (MEAN A)	0.34	0.33	0.30	0.30	0.32	0.29	0.28	0.29
12V (MAX A)	0.36	0.37	0.35	0.35	0.37	0.35	0.34	0.34
5V (MEAN A)	0.14	0.14	0.13	0.14	0.13	0.13	0.13	0.13
5V (MAX A)	0.43	0.42	0.40	0.42	0.41	0.41	0.40	0.42
Power (watts)	**4.8**	**4.6**	**4.2**	**4.3**	**4.5**	**4.2**	**4.1**	**4.1**

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Table 8 - 3: Allowable Power Supply Noise Limits at Drive Power Connector

Description	Noise Voltage (mVpp)	Frequency Range
+5V DC	250	100Hz-20MHz
+12V DC	450	100Hz-100KHz
	250	100KHz-20MHz

8.2 Power Consumption Efficiency Index

Table 8 - 4: Power Consumption Efficiency Index

Description	3.2TB ME	1.6TB ME	800GB ME	400GB ME	3.2TB RI-3	1.6TB RI-3	800GB RI-3	400GB RI-3
Power consumption; Efficiency index idle mode (W/GB)	0.0013	0.0021	0.0046	0.0085	0.0013	0.0022	0.0046	0.0084

8.3 Power Slew Requirements During Power Loss

Table 8 - 5: Supply Voltage Fall Times During Power Loss

Fall Time	Result
5V Fall Time	1ms to 5s for 5V input power dropping to 0V
12V Fall Time	1ms to 5s for 12V input power dropping 0V

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9.0 Reliability

9.1 Data Reliability

- Intel second-generation LDPC
- LBA seeded 32-bit CRC for ECC detection
- Probability of uncorrectable data error is 1 in $1x10^{17}$ bits read.

9.2 Data Retention

The device, after being placed into service and until the end of its rated design life (as per Enterprise JESD218), is designed to retain data for three months when powered off and stored at 40°C.

9.3 Failure Prediction (SMART)

A recoverable equipment error is an error other than a read error that is detected and corrected by the drive error recovery procedure. Examples are Drive Not Ready and internal drive errors.

SMART Monitoring Parameters are checked to predict drive failure conditions before they occur. The primary parameters monitored for the SSD include:

1. **Remaining Reserves**: This ensures that the remaining spare erase blocks are at a sufficient level to guarantee proper operation of device.
2. **Volatile Memory Backup**: Self-tests measure the capacitance of the Power Loss Imminent circuitry to guarantee the drive can commit data to media during unsafe power loss operations.
3. **Wear Indicator**: This is an endurance tracking mechanism based on the maximum number of NAND erase operations performed on any band over the life of the device.

See Log Sense (4D) for tracking the percentage of failure threshold for these parameters. Non-recoverable equipment errors indicate a defective drive.

9.4 Mean Time To Failure

The estimated Mean Time To Failure (MTTF) for the SSD is 2.5M (million) hours. The MTTF target is derived from a sample population and is estimated by statistical measurements and acceleration algorithms under nominal operating conditions. MTTF ratings are not intended to predict reliability for an individual drive. The MTTF does not constitute a warranty.

MTTF values are based on drive/sensor-reported operating temperature of 40°C. For drive/sensor-reported operating temperatures above 40°C, an MTTF derating chart can be provided upon request.

9.5 Preventive Maintenance

No preventive maintenance is required. There are no parts, assemblies or subassemblies that can be repaired by the user.
***Important: Unauthorized repairs to the SSD will void the warranty*.**

9.6 Temperature Warning

Temperature Warning is enabled by setting the EWASC (Enable Warning Additional Sense Code) bit to 1 and setting DEXCPT (Disable Exception Control) bit to 0 in Mode Page 1C. For mode page settings, refer to Mode Page 1Ch - Informational Exceptions Control. The warning is issued as sense data (Sense Key 01h, Code 0Bh, Qual 01h).

The drive temperature is reported in Log Sense Page 2Fh.

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10.0 Mechanical Specifications

10.1 Outline

Figure 10 - 1: **Enclosure Outline**



Table 10 - 1: **Physical Dimensions**

Dimension	Value
Height	15.00+0.00 / -0.50
Width	69.85±0.25
Length (Base)	100.45 Max
Length (Including Connector)	100.75 Max

10.2 Weight (Grams)

Table 10 - 2: **Drive Weight**

Model	Capacity (GB)	Weight (Grams)
ME	400	125
	800	140
	1600	140
	3200	135
RI3	400	125
	800	125
	1600	140
	3200	135

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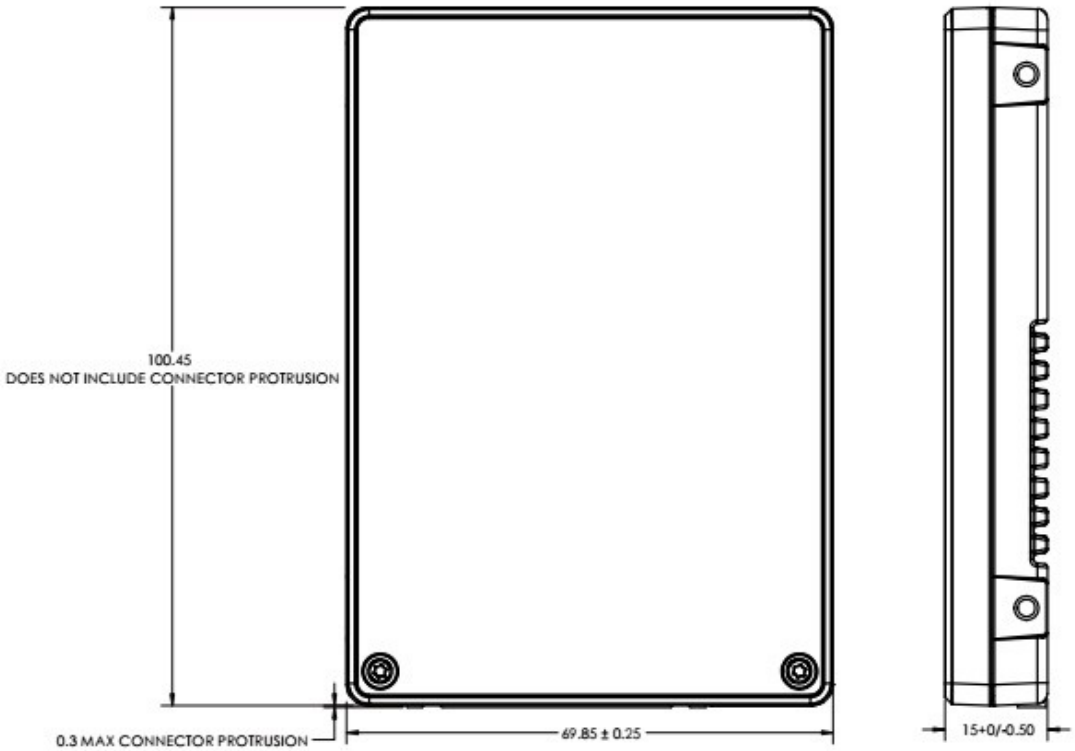
Figure 10 - 2: Mechanical Dimensions



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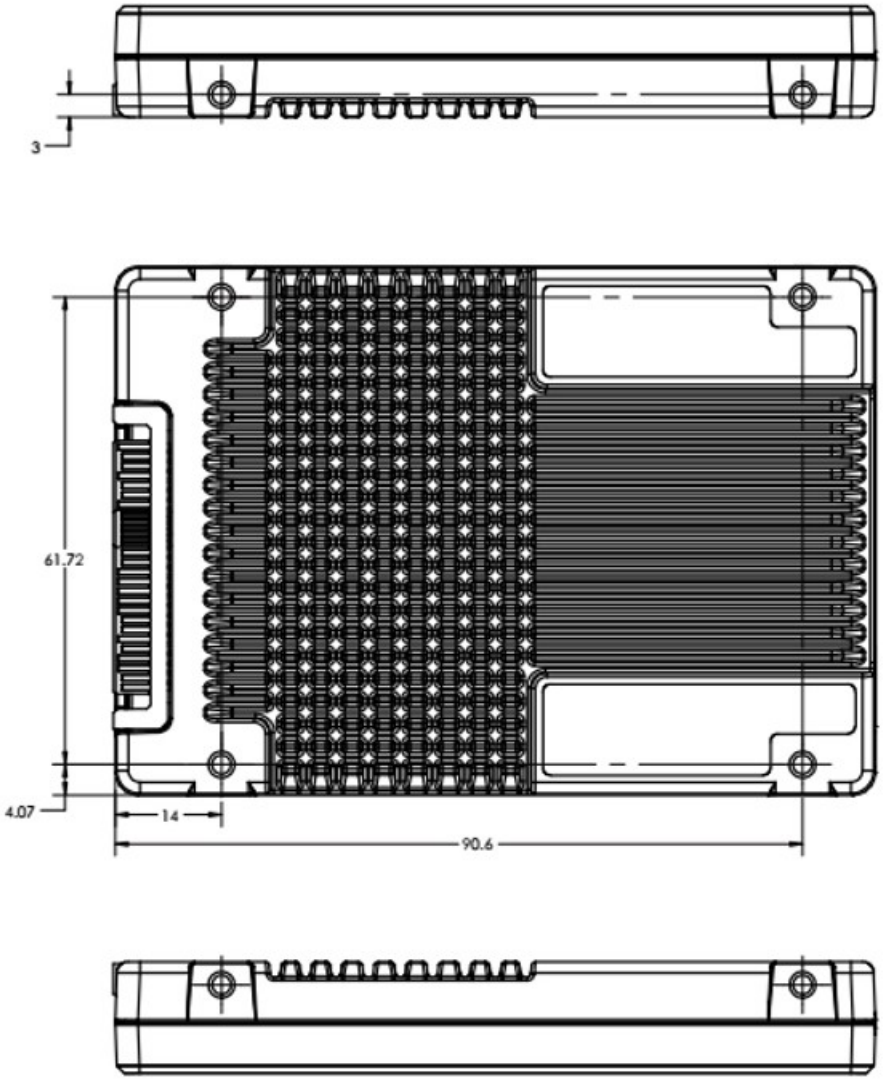
10.3 Mounting Positions and Mounting Holes

Figure 10 - 3: **Mounting Positions and Mounting Holes**



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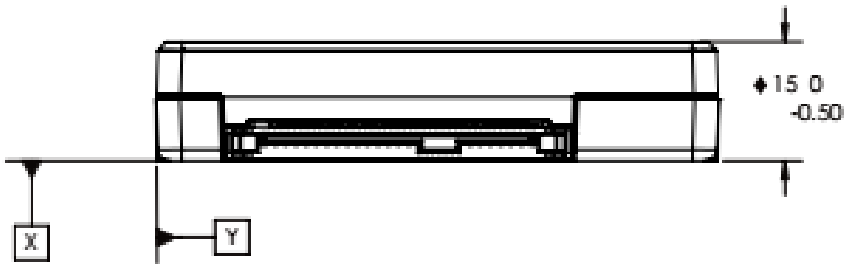
10.4 Interface Connector

The interface conforms to the specification SFF-8223, 2.5-inch Drive Form Factor with Serial Connector.

Figure 10 - 4: Interface Connector



10.5 Drive Mounting

The drive operates in all axes (6 directions). Performance and error rate will stay within specification limits if the drive is operated in the other orientations from which it was formatted.

The recommended mounting screw torque is 0.45 Nm (4.5 Kgf-cm). The recommended mounting screw depth is 2.5 mm maximum for bottom mounting and 3.0 mm maximum for horizontal mounting. Drive-level vibration tests and shock tests should be conducted with the drive mounted to a table, using the four side screws.

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11.0 Acoustics, Vibration, and Shock

11.1 Acoustics

All SSD models have no acoustics (0dB).

11.2 Operating Vibration

The drive is designed to operate without unrecoverable errors, while being subjected to the vibration levels defined below.

Table 11 - 1: Operating Vibration

Profile	G	Hz-Low	Hz-High	Duration/Axis	Axis
Flat PSD	2.17	5	700	10	x,y,z
Swept Sine	2.17	5	700	10	x,y,z

11.3 Non-Operating Vibration

The drive will not sustain permanent damage or loss of recorded data after being subjected to the range of conditions described below.

Table 11 - 2: Non-operating Vibration

Profile	G	Hz-Low	Hz-High	Duration/Axis	Axis
Flat PSD	3.13	5	800	10	x,y,z
Swept Sine	3.13	10	800	10	x,y,z

11.4 Operating Shock

The drive is designed to operate without unrecoverable errors while being subjected to the shock conditions defined below.

Table 11 - 3: Operating Shock

Amplitude	Pulse Width	Shock Profile	Pulse Count/Axis	Axis
1000 G	0.5 ms	Half-sine	1	+/-X,+/-Y,+/-Z
500 G	2.0 ms	Half-sine	1	+/-X,+/-Y,+/-Z

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11.5 Non-operating Shock

The drive will not sustain permanent damage or loss of data after being subjected to the conditions described in the following table.

Table 11 - 4: Non-operating Shock

Amplitude	Pulse Width	Shock Profile	Pulse Count/Axis	Axis
1000 G	0.5 ms	Half-sine	1	+/-X,+/-Y,+/-Z
500 G	2.0 ms	Half-sine	1	+/-X,+/-Y,+/-Z
150G*	11.0 ms	Half-sine	1	+/-X,+/-Y,+/-Z

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12.0 Label Specification

12.1 Overview

The certification marks described below may appear on the labels that are affixed to every drive shipped from the manufacturing location in accordance with the appropriate drive assembly drawing. These labels may be integrated with other labels.

12.2 Manufacturer Identification

The manufacturer identification label contains the “HGST, a Western Digital Company” logo, HGST model number, and the statement “Made by HGST,” or an HGST- approved equivalent.

12.3 Product Identification

The product label consists of the following elements:

- A label with the drive model number, manufacturing date, formatted capacity, and country of origin; or HGST-approved equivalent
- Certification Marks: UL, TUV, CE, FCC, BSMI, RCM, KCC, EIP, VCCI and WEEE
- A bar code label symbolizing the drive serial number
- If per agreement, a user-designed label.
- Interface definition mark: SAS.

Below are product identification examples:



BSMI (Taiwan)



CE Mark (EU/EEA)



UL(USA, Canada)



EIP (China RoHS)



FCC Mark (USA)



KCC (Korea)



RCM (Australia)



TUV (Europe)



VCCI (Japan)



WEEE Directive



SAS

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13.0 Electromagnetic Compatibility

The drive, when installed in a suitable enclosure and exercised with a random-access routine at a maximum data rate, will comply with the worldwide EMC requirements listed below. The drive is designed for system integration and installation into a suitable enclosure for use. As such, the drive is supplied as a subassembly and is not subject to Subpart B of Part 15 of the FCC Rules and Regulations.

The drive design minimizes radiated emissions when the drive is installed in an enclosure that provides reasonable shielding. As such, the drive is capable of meeting FCC Class B limits; however, it is the user's responsibility to assure that the drive meets the appropriate EMC requirements in their system. Shielded I/O cables may be required if the enclosure does not provide adequate shielding, with the shields grounded to the enclosure and to the host computer.

13.1 Radiated and Conducted RF

Table 13 - 1: Radiated and Conducted RF

Certification	Region
CISPR32: 2012	Australia, New Zealand
CNS 13438: 2010	Taiwan
EN 55032: 2012/AC: 2013	European Union
FCC Title 47 Part 15	USA
GB9254-2008	China
ICES-003, Issue 6, 2016	Canada
VCCI V-3/2015-04	Japan
KN 32: 2015-27 (RRA Notice)	Korea
KN 32: 2015-110 (RRA Notice)	Korea

13.2 ITE Immunity

Table 13 - 2: ITE Immunity

Certification	Region
EN 55024: 2010/A1: 2015	European Union
KN 35: 2015-27 (RRA Notice)	Korea
KN 35: 2015-110 (RRA Notice)	Korea

13.3 Power Line Harmonic Emissions

Table 13 - 3: Power Line Harmonic Emissions

Certification	Region
EN61000-3-2: 2006/A1: 2009/A2: 2009	European Union
GB17625.1 2003	China

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13.4 Voltage Fluctuations and Flicker

Table 13 - 4: Voltage Fluctuations and Flicker

Certification	Region
EN 61000-3-3: 2013	European Union
GB 17625.2 1999	China

13.5 Immunity Specifications

Table 13 - 5: Immunity Specifications

Certification	Region
KN 61000-4-2: 2013-06	Electrostatic Discharge (ESD) Immunity
KN 61000-4-3: 2011-10	Radiated RF Immunity
KN 61000-4-4: 2011-10	Electrical Fast Transient/Burst (EFT/B) Immunity
KN 61000-4-5: 2008-05	Surge Immunity
KN 61000-4-6: 2013-06	Conducted RF Immunity
KN 61000-4-8: 2013-06	Power Frequency Magnetic Field Immunity
KN 61000-4-11: 2008-05	Voltage Dips and Interruptions Immunity

13.6 Class B Regulatory Notices

13.6.1 European Union

The product conforms with the protection requirements of EU Council Directive 2014/30/EU on the approximation of the laws of the Member States relating to electromagnetic compatibility. HGST cannot accept responsibility for any failure to satisfy the protection requirements resulting from a non-recommended modification of the product, including the fitting of non-HGST option cards.
This product has been tested and found to comply with the limits for Class B Information Technology Equipment according to European Standard EN 55032. The limits for Class B equipment were derived for typical residential environments to provide reasonable protection against interference with licensed communication devices.

13.6.2 Canada

This Class B digital apparatus complies with Canadian ICES-003. Cetappareilnumérique de la classe B est conforme à la norme NMB-003 du Canada.

13.6.3 Germany

Deutschsprachiger EU Hinweis:

HinweisfürGeräte der Klasse B EU-RichtliniezurElektromagnetischenVerträglichkeit Dieses Produktentspricht den Schutzanforderungen der EU-Richtlinie 2014/30/EU zurAngleichung der Rechtsvorschriftenüber die elektromagnetischeVerträglichkeit in den EU-Mitgliedsstaaten. undhält die Grenzwerte der EN 55032 Klasse B ein. Um dieses sicherzustellen, sind die Gerätewie in den Handbüchernbeschriebenzuinstallieren und zubetreiben. Des Weiterendürfenauchnur von der HGST empfohleneKabelangeschlossenwerden. HGST übernimmtkeineVerantwortungfür die Einhaltung der Schutzanforderungen, wenn das ProduktohneZustimmung der HGST verändertbzw. wennErweiterungskomponenten von FremdherstellernohneEmpfehlung der HGST gesteckt/

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eingebautwerden.
Deutschland: Einhaltung des Gesetzesüber die elektromagnetischeVerträglichkeit von Geräten

Dieses Produktentsprichtdem "Gesetzüber die elektromagnetischeVerträglichkeit von Geräten (EMVG)". Dies ist die Umsetzung der EU-Richtlinie 2014/30/EU in der Bundesrepublik Deutschland.
ZulassungsbescheinigunglautdemDeutschenGesetzüber die elektromagneti-scheVerträglichkeit von Geräten (EMVG) vom 29 March 2014 (bzw. der EMC EG Richtlinie 2014/30/EU) fürGeräte der Klasse B Dieses Gerätistberechtigt, in ÜbereinstimmungmitdemDeutschen EMVG das EG-Konformitätszeichen - CE - zuführen. Verantwortlichfür die KonformitätserklärungnachParagraf 5 des EMVG ist die HGST, a Western Digital company, 3403 Yerba Buena Road, San Jose, California 95135. Informationen in Hinsicht EMVG Paragraf 4 Abs. (1) 4:
Das Geräterfüllt die Schutzanforderungennach EN 55024 und EN 55032 Klasse B

13.6.4 Korea (KCC)

이 기기는 가정용으로 전자파적합등록을 한 기기로서 주거 지역에서는 물론 모든 지역에서 사용할 수 있습니다.

13.6.5 Taiwan (BSMI)

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HGST Asia Pte. Ltd., Taiwan Branch 5F,No.167,Tun Hwa North Road, Taipei, Taiwan

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14.0 Standards

The following sections outline the safety standards for different countries.

14.1 UL and C-UL Standard Conformity

The product is certified under the following safety standards for use in Information Technology Equipment, including Electrical Business Equipment:

- EN 60950-1:2006 + A11: 2009 + A1: 2010 + A12: 2011 + A2:2013
- IEC 60950-1:2005, Second Edition; A1:2009, A2:2013
- UL 60950-1, Second Edition, 2011-12-19, U
- CSA C22.2 No. 60950-1-07, Second Edition, 2011-12, Canada

The cRUus safety mark is for both the United States of America and Canada. It is equivalent to, and replaces, the CSA Canadian safety mark, which is maintained for the duration of the product manufacturing life cycle. The cRUus component recognition mark is on the drive label.

14.1.1 European Standards Compliance

The product is certified to the EN 60950-1:2006 + A11: 2009 + A1: 2010 + A12: 2011 + A2:2013 safety standard for Europe.

14.1.2 German Safety Mark

The product is certified by TUV to meet EN 60950-1:2006 + A11: 2009 + A1: 2010 + A12: 2011 + A2:2013 safety standard under the Bauart Mark.

14.1.3 Flammability

The printed wiring boards, and connectors used in this product meet or exceed the UL minimum flammability classifications listed in the table below. The flammability ratings are marked on the printed wiring boards and flex cables.

Table 14 - 1: Component Flammability Rating

Component	Flammability Rating
Rigid printed wiring board	Min. V-1
2.5-Inch SAS connector	Min. V-2

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15.0 SAS Attachment

This section defines basic terminology and describes the behavior of the drive when attached to a Serial-Attached SCSI (SAS) domain.

15.1 General

This section introduces some of the terminology that is used in describing Serial Attached SCSI (i.e. SAS).

SAS is logically a bi-directional, point to point serial data channel that leverages the SCSI protocol set. Nodes are physically connected via ports. Ports may be connected point-to-point via SAS expanders, to form a complex switching network referred to as a SAS domain.

SAS is defined in terms of a hierarchy of functions or 'protocol layers'. This section focuses on SAS aspects of relevant to this product. All layers are defined in the following ANSI standard "SAS Protocol Layer - 4 (SPL-4)":

- SCSI Application Layer - Clause 9
- SSP Transport Layer (Serial SCSI Protocol) - Clause 8
- SAS Port Layer - Clause 7
- SSP Link Layer - Clause 6
- SAS PHY Layer - Clause 5

In addition, this drive claims compliance with the following ANSI standards:

- SCSI Architecture Model (SAM-5)
- SCSI Block Commands (SBC-4)

15.2 SAS Features

15.2.1 Supported SAS Features

The following SAS features are supported:

- SAS compliance
- Serial Attached SCSI - 4 (SAS-4)
- SAS protocol
- Serial SCSI Protocol (SSP)
- SAS dual-ported operation
- Single PHY ports (narrow ports) or optional wide ports
- Ports function independently with separate firmware controls.
- Multiple DMA engines capable of accessing either link
- Maximum outstanding credit of eight per link (default is four)
- Physical link rates
- G1 (1.5 Gbps), G2 (3.0 Gbps), G3 (6.0 Gbps), and G4 (12.0 Gbps) supported
- Largely automated OOB and speed negotiation sequences
- Optional support for the hot-plug timeout in hardware
- Spread spectrum clocking

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- Interface power management
- Partial Supported
- Slumber Supported
- Partial Support for Disconnect/Reconnect Mode Page 0x02
- Maximum Connect Time Limit is supported.
- Maximum Burst Size is supported.
- Other
- Connection Rate Matching
- Hard Reset primitive sequence detection and validation in hardware
- Support for NOTIFY (Power Loss Expected)
- NOTIFY (Enable Spin-up) is ignored
- Hashed WWN validation in hardware
- Extended CDB support
- Persistent Connections
- POWER DISABLE signal on the SAS connector

15.2.2 Unsupported SAS Features

The following SAS features are not supported:

- STP (Tunneled SATA) and SMP protocols (SAS dual-ported operation)
- Bus inactivity time limit (partial support for Disconnect/Reconnect Mode Page 0x02)
- First burst size (partial support for Disconnect/Reconnect Mode Page 0x02)

15.3 SAS Names and Identifiers

In SAS, device and port names are worldwide unique names within a transport protocol. Port identifiers are the values by which ports are identified within a domain and are used as SAS addresses. PHY identifiers are unique within a device.

Table 15 - 1: SAS Names and Identifiers

Object	SAS Implementation
Port identifier	SAS address
Port name	Not defined
Device name	SAS address
Physical identifier	PHY identifier

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The SAS Address format is defined by ANSI as follows:

Table 15 - 2: SAS Address Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	NAA (5h)				MSB of IEEE Company ID			
1	IEEE Company ID							
2								
3	LSB of IEEE Company ID				MSB of Vendor-specific Identifier			
4	Vendor-specific Identifier							
5								
6								
7								

The SAS Device Name is a unique SAS address worldwide name. This device name is reported via the SCSI Vital Products Data.

Each of the two SAS ports also has a unique SAS address worldwide name. These port identifiers are reported in the IDENTIFY address frame and are used as source and destination addresses in the OPEN address frame. They are also reported through the SCSI Vital Products Data.

Because this drive is one device with two ports, it has three SAS addresses. All SAS Addresses are in 64-bit IEEE Registered Name format, as shown in the following table.

Notes:
1. If configured for wide port, this drive will be considered as one device with one port.

Table 15 - 3: IEEE Registered Name Format

Bit				
63-60	59-36	35-24	23-2	1-0
0101	OUI in Canonical Form	Block Assignment	S/N	Object

The Name Address Authority field (5h) specifies the format used for the rest of the name as follows:

Table 15 - 4: Name Address Authority

Field	Description
OUI	Organizationally Unique Identifier (24 bits). Canonical form means that each byte is stored in “bit reversed” order.
Block Assignment	Block assignment within HGST, a Western Digital Company
Object	Device Name/Port Identifier 00b Device 01b Port 1 10b Port 2 11b Not assigned
S/N	Sequentially increasing drive serial number assigned at manufacturing

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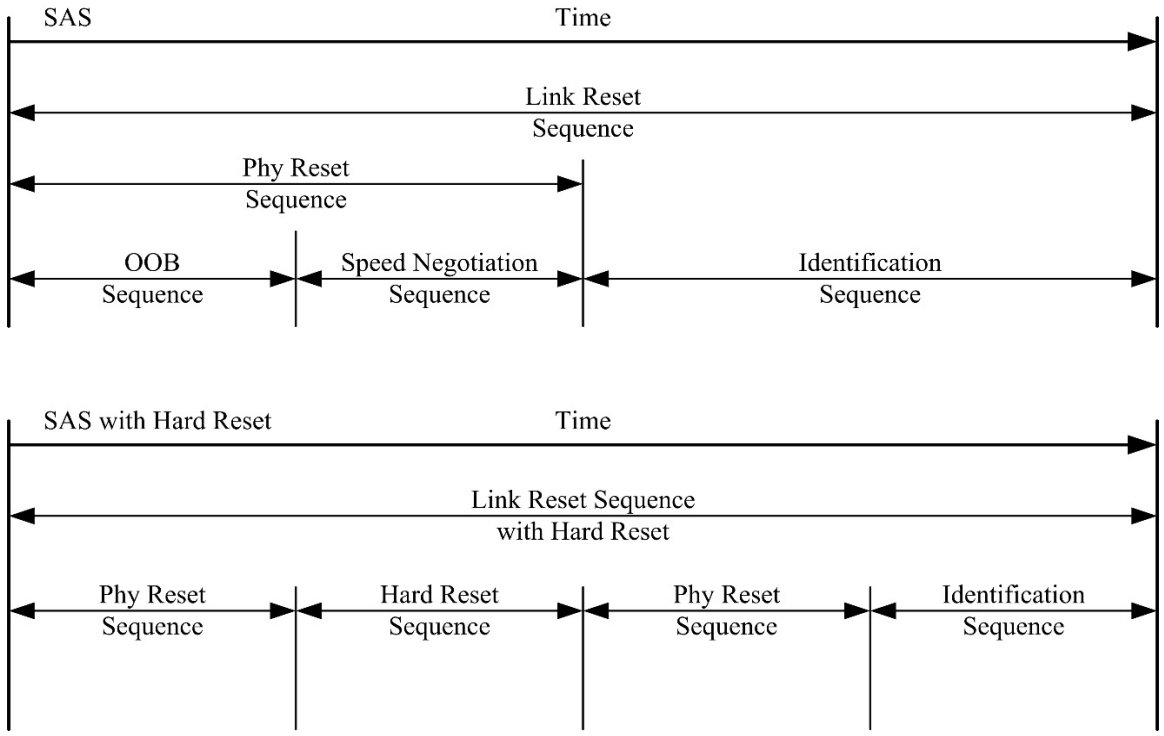
15.4 PHY Layer

The PHY layer defines 8b10b encoding and OOB signals. The PHY Layer is the interface between the link layer and the physical layer. This section describes PHY layer behaviors of the drive. For a complete description of SAS PHY layer, see the American National Standards Institute (ANSI) specification, SPL-2 on the web at **Ansi.org**.

15.4.1 Link Reset Sequence

The Link Reset sequences for SAS are defined in the SPL-2 ANSI specification with a general overview shown below. The following figure shows, a PHY Reset sequence consisting of an OOB sequence followed by speed negotiation. Link Reset sequences will always include a PHY Reset sequence followed by an Identification sequence. Inclusion of a Hard Reset sequence is optional. If Hard Reset is performed, it will be preceded by a PHY Reset sequence and followed by a PHY Reset sequence and an Identification sequence.

Figure 15 - 1: Link Reset Sequence



15.4.2 Hard Reset

A hard reset sequence on a port will not affect the other port. However, the outstanding commands on the other port will be aborted due to the LUN reset associated with the hard reset. A hard reset has a similar effect to a power-on reset, resulting in the re-initialization of all drive resources. The first command issued from every initiator on the port that received the hard reset will result in a CHECK CONDITION, with a Sense Key of UNIT ATTENTION and an Additional Sense Code of SCSI BUS RESET OCCURRED. The first command issued from every initiator on the other port will result in a CHECK CONDITION and an Additional Sense Code of BUS DEVICE RESET OCCURRED.

A hard reset sequence is never issued by the drive. A link reset will be initiated by the drive on the affected port upon completion of hard reset processing.

15.4.3 SAS Out of Band (OOB)

Out Of Band (OOB) signals are low-speed signal patterns detected by the PHY that do not appear in normal data streams. They consist of defined amounts of idle time followed by defined amounts of burst time. During the idle time, D.C. idle is transmitted. During the burst time, ALIGN (0) primitives are transmitted repeatedly. The signals are differentiated by the length of idle time between the burst times.

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As a SAS-compliant device, the drive uses three OOB signals: COMINIT/COMRESET, COMWAKE, and COMSAS.OOB. These operations are beyond the scope of this manual. refer to the ANSI SPL-4 specification for more details.

The drive will initiate OOB by sending COMINITs, under the following conditions:

- POR
- Loss of sync
- Identify timeout

15.4.4 SAS Speed Negotiation

The drive supports G1 (1.5 Gbps), G2 (3 Gbps), G3 (6 Gbps), and G4 (12 Gbps) negotiation speeds, both with and without SSC (Spread Spectrum Clocking). The default maximum negotiation rate is G4 speed (per byte 32 in the PHY Control and Discover Mode Page 19 subpage 1). The drive is a SAS3 device and supports SNW-1, SNW-2, and SNW-3 speed negotiation with PHY capabilities exchange. It also supports transmitter training (Train_Tx-SNW, at 12Gbps only) and receiver training (Train_Rx-SNW or Train-SNW). The PHY capabilities of the drive are defined in the table below.

Table 15 - 5: PHY Capabilities

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Start =1b	TX SSC Type=0	Reserved		Requested Logical Link Rate = 0h			
1	G1 without SSC=1b	G1 with SSC=1b	G2 without SSC=1b	G2 with SSC=1b	G3 without SSC=1b	G3 with SSC=1b	G4 without SSC=1b	G4 with SCC=1b
2	Reserved							
3	Reserved							Parity=1b

- The start bit is set to 1 to indicate the beginning of the PHY capabilities.
- The TX SSC TYPE bit is set to 0 to indicate that PHY's transmitter uses down-spreading SSC when SSC is enabled.
- The Request Logical Link Rate Field is set to 0 to indicate that the drive does not support multiplexing.
- Parity is set to 1 for even parity; PHY capabilities must indicate an even number of '1' bits.

Training is based on the highest untried, commonly supported settings on the exchanged SNW-3 supported settings bits. If a Train-SNW is invalid, and there are additional, untried, commonly supported settings exchanged during SNW-3, then a new Train-SNW will be performed based on the next highest untried, commonly supported settings. The following table defines the priority of the supported settings bits.

Table 15 - 6: Supported Settings Bit Priorities

Priority	Bit
Highest	G4 With SSC bit
...	G4 Without SSC bit
...	G3 With SSC bit
...	G3 Without SSC bit
...	G2 With SSC bit
...	G2 Without SSC bit
...	G1 With SSC bit
Lowest	G1 Without SSC bit

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15.4.5 PHY Error Handling

This section defines the PHY layer error handling of the drive.

Table 15 - 7: **Drive Error Handling**

Error	Error Handling Procedure
Link Reset	After POR or hard reset, the drive initiates link reset by transmitting exactly 1 COMINIT. For other resets, the drive does not initiate link reset.
COMINIT Timeout	If COMINIT or COMSAS is not received before the "Hot Plug Timeout" period expires, the drive continues to transmit DC zero and waits for COMINIT/COMSAS. The firmware is notified. This timeout is not considered an error.
COMSAS Timeout	If COMINIT is detected, and COMSAS is transmitted but not received before the COMSAS Detect Timeout timer expires, the firmware is notified, the drive continues to transmit DC zero, and it waits for COMINIT.
Speed Negotiation Errors	If speed negotiation fails with no match, or if the drive fails retrying the matched link rate, the firmware is notified, and the drive continues to transmit DC zero and wait for COMINIT. If the match link rate retry fails, the Phy Reset Problem counter is incremented (Log Page 0x18).
Loss of Sync	If the drive loses DWORD sync long enough for the loss of sync timer to expire, the firmware is notified, and the drive transmits a COMINIT to initiate a new link reset. The Loss of DWORD sync counter is incremented (Log Page 0x18).
Disparity/Invalid DWORD Error	If a disparity error or an invalid DWORD is detected by the drive, the Invalid DWORD Count is incremented (Log Page 0x18). The Running Disparity Error Count in Log Page 0x18 is not used.

15.4.6 Power Management

This drive supports SAS Slumber Power Down and SAS Partial Power Down.

- Partial Capable - If enabled and supported by the host, the drive requests Partial after 500µs.
- Slumber Capable - If enabled and supported by the host, the drive requests Slumber after 1000ms.

More information on SAS Partial/Slumber Power Down can be found in SAS Protocol Layer 4 (SPL-4).

SAS Power Management Features can be enabled or disabled by the host via a Mode Select to Mode Page 0x19 subpage 0x3.

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15.4 Link Layer

The SAS link layer defines primitives, address frames, and connections. The Link layer is the interface between the Port layer and the PHY layer. This section describes Link Layer behaviors of the Drive. For a complete description of SAS Link Layer, see the American National Standards Institute (ANSI) specification, SPL-4 on the web at Ansi.org.

15.4.1 Address Frames

Address frames are used for the identification sequence and for connection requests and are only sent outside connections. The Address Frame format is defined below:

Table 15 - 8: Address Frame Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	RSVD	Device Type			Address Frame Type			
1-27	Frame Type Dependent Bytes							
28-31	CRC							

The ADDRESS FRAME TYPE indicates the type of address frame and is defined in the following table. This field determines the definition of the bytes dependent on the frame type.

Table 15 - 9: Frame Type

Value	Address Frame Type Description
0000b	IDENTIFY: Identification Sequence
0001b	OPEN: Connection Request
Others	Reserved

15.4.2 Identify Address Frame

The IDENTIFY address frame format is used for the identification sequence. The IDENTIFY address frame is sent after the PHY reset sequence completes. The Identify Address Frame format is defined as follows:

Table 15 - 10: Identify Address Frame

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	RSVD	Device Type = 1h			Address Frame Type = 0			
1	Reserved				Reason			
2	Reserved				SSP Initiator Port	STP Initiator Port	SMP Initiator Port	RSVD
3	Reserved				SSP Target Port	STP Target Port	SMP Target Port	RSVD
4-11	Device Name							

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12-19	SAS Address						
20	PHY Identifier						
21	Persistent Capable	Power Capable	Slumber Capable	Partial Capable	Inside ZPSDS Persistent	Requested Inside ZPSDS	Break_Reply Capable
22	Reserved				APTA Capable	SMP Priority Capable	PWR_DIS Capable
22-27	Reserved						
28-31	CRC						

- Device Type is set to 001b to indicate that this drive is an "End Device".
- Address Frame Type is set to 00b to indicate that this is an IDENTIFY.
- Reason indicates the reason for link reset sequence as defined in the following table
- Initiator Port bits are set to 000b, as this device is a target device only.
- Target Port bits are set to 100b, as this device is an SSP target device only.
- Device Name contains the target Device Identifier.
- SAS ADDRESS contains the port identifier of the SAS port transmitting this frame.
- PHY Identifier contains the PHY identifier of the PHY transmitting this frame.
- Persistent Capable is set to 1b to indicate the PHY can establish and maintain a persistent connection. See SPL-4 for further details.
- Power Capable is set to 00b to indicate the drive does not support device power modes.
- Slumber Capable is set to 1b to indicate the drive supports slumber power PHY mode.
- Partial Capable is set to 1b to indicate PHY supports break power mode.
- Inside ZPSDS Persistent is set to 0b, as this is an "End Device".
- Requested Inside ZPSDS is set to 0b, as this is an "End Device".
- Break_Reply Capable is set to 1b to indicate that this port can send a BREAK_REPLY primitive sequence in response to receiving BREAK primitive sequences.
- APTA Capable is set to 0b to indicate PHY does not support APTA.
- SMP Priority Capable is set to 0b to indicate PHY is not capable of determining SMP frame priority.
- PWR_DIS Capable is set to 1b to indicate that the drive is a power consumer device that can use the POWER DISABLE signal (see SAS-4).

Table 15 - 11: Reason Field

Value	Address Frame Type Description
00b	Power On
01b	OPEN: Connection Request
02b	Hard Reset (received a Hard Reset during hard reset sequence)
04b	Loss of DWord synchronization
07b	Break Timeout Timer Expired
08b	PHY Test Function Stopped
Other	Reserved

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15.4.3 OPEN Address Frame

The OPEN address frame format is used for the identification sequence. The OPEN address frame is sent after the PHY reset sequence completes. The OPEN Address Frame format is defined as follows:

Table 15 - 12: Open Address Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	initiator Port=0	Protocol = 1			Address Frame Type = 1			
1	Features = 0				Connection Rate = 8h or 9h or Ah or Bh			
2-3	initiator Connection Tag							
4-11	Destination SAS Address							
12-19	Source SAS Address							
20	Source Zone Group							
21	Pathway Blocked Count							
22-23	Arbitration Wait Time							
24-27	More Compatible Features							
28-31	CRC							

- Initiator Port is set to 0 when the drive is the source port acting as a SAS target.
- Protocol is set to 001b to indicate the SSP Protocol.
- Features is set to 0 and ignored by the drive per SPL-2.
- Connection Rate is set to 8h (1.5Gbps) or 9h (3Gbps) or Ah (6Gbps) or Bh (12Gbps), depending on requested link rate. Rate matching is supported by the drive: if the link to the drive is 3.0Gbps, and the Connection Rate is 1.5Gbps, the drive inserts ALIGNs between DWords, to match the Connection Rate.
- Initiator Connection Tag: The drive sets this value to the last value received from this initiator.
- Destination SAS Address contains the port identifier of the SAS port to which a connection is being requested.
- Source SAS Address contains the port identifier on the port that originated this frame (the drive's port address).
- Source Zone Group is set to 0 and ignored by the drive per SPL-2.
- Pathway Blocked Count indicates the number of times the port has retried this connection request due to receiving OPEN_REJECT (PATHWAY BLOCKED). The drive does not increment the PATHWAY BLOCKED COUNT value past FFh.
- Arbitration Wait Time indicates how long the port transmitting the OPEN address frame has been waiting for a connection request to be accepted. For values from 0000h to 7FFFh, the Arbitration Wait Time timer increments in one microsecond steps. For values from 8000h to FFFFh, the Arbitration Wait Time timer increments in one millisecond steps.
- More Compatible Features is set to 0 and ignored by the drive per SPL-2.

15.4.4 Persistent Connections

This drive supports SAS Persistent Connections. A persistent connection is an SSP connection that is established after an EXTEND_CONNECTION (NORMAL) has been transmitted and received inside the SSP connection. The connection persists as long as the connected PHYs transmit SSP frames or periodically exchange EXTEND_CONNECTION (NORMAL) primitives. A persistent connection ignores the bus inactivity timer, the maximum connection timer, and the maximum burst size field. A persistent connection ends after a DONE primitive is received, when the link goes down, or when the connection is aborted (e.g., via the BREAK primitive).

15.4.5 Link Layer Error Handling

This section defines the link layer error handling of the drive.

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Table 15 - 13: Link Layer Error Handling

Error	Error Handling Procedure
IDENTIFY Timeout	If IDENTIFY is not received before the IDENTIFY timer expires (1ms), the firmware is notified, and the drive transmits a COMINIT to initiate a new link reset.
BREAK Received	If BREAK is received while the drive has ACK/NAK balance, BREAK or BREAK_REPLY is transmitted, and a new connection may be opened if the drive still has frames to transmit. The firmware is not notified. If BREAK is received while the drive does *not* have ACK/NAK balance, BREAK or BREAK_REPLY is transmitted. The current command is aborted and returns a Check Condition status, with sense data indicating an ACK/NAK timeout.
NAK and ACK/NAK Timeout	If a NAK is received on a RESPONSE frame, the RESPONSE frame is retransmitted with the RETRANSMIT bit set to 0. If an ACK or NAK is not received for a RESPONSE frame within 1ms, the RESPONSE frame will be retransmitted with the RETRANSMIT bit set to one. The drive will retry sending a RESPONSE frame once.
Bad Frame CRC	If a frame fails the CRC check, the frame is NAKed by the drive and discarded. This is a link layer function. The command associated with a NAKed DATA or XFER_RDY frame is aborted with a Check Condition status, and sense data corresponding to DATA_PHASE_ERROR is returned. COMMAND frames that fail the CRC check are NAKed and discarded.
OPEN_REJECT	OPEN_REJECT – Retrievable Variations
	OPEN_REJECT (RETRY) - Will be retried indefinitely by the drive. This case is considered to occur when the initiator is temporarily not available to accept connections.
	OPEN_REJECT (RATE_NOT_SUPPORTED) - If this occurs, it must mean that a link between the drive and initiator negotiated to a lower link rate after the command was received. The drive will retry the connection at a lower rate, and if a connection eventually fails for this reason at 1.5 Gbps, the command is internally aborted.
	OPEN REJECT (PATHWAY_BLOCKED)- Handled the same as OPEN_REJECT(RETRY)
	OPEN_REJECT (NO DESTINATION) - Handled the same as OPEN_REJECT(RETRY)
	OPEN_REJECT – Non-Retryable Variations - If these are received, the command is internally aborted by the drive.
	OPEN_REJECT (BAD_DESTINATION).
	OPEN_REJECT (WRONG_DESTINATION)
	OPEN REJECT (PROTOCOL_NOT_SUPPORTED)
Credit Timeout	If credit is not received before the credit timer expires, DONE (CREDIT_TIMEOUT) is sent to the initiator.
DONE Timeout	If credit is extended and the DONE timer expires, BREAK is sent by hardware to tear down the connection.
CREDIT_BLOCKED	If CREDIT BLOCKED is received and the drive has frames to send in the current connection, DONE (CREDIT_TIMEOUT) is returned. Otherwise, DONE (NORMAL) is returned.
OPEN Frame Checking	Reserved fields in the OPEN frame are not checked.
	The Dest Address field is checked, and if it doesn't match OPEN_REJECT (WRONG_DESTINATION) is returned.
	The Protocol field is checked and if it isn't set to SSP OPEN_REJECT (PROTOCOL_NOT_SUPPORTED) is returned.

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Error	Error Handling Procedure
	If the Link Rate exceeds the physical link rate on that port, OPEN_REJECT (LINK_RATE_NOT_SUPPORTED) is returned.
	The initiator bit is not checked.
OPEN Response Timeout	If AIP or OPEN_ACCEPT is not received before the OPEN Response timer expires, the hardware transmits BREAK.
CLOSE Timeout	If CLOSE is not received before the CLOSE timer expires, the hardware transmits BREAK.
PHY Not Ready	If Link Reset occurs outside of a connection, commands can execute normally across the link reset. If a link reset occurs inside of a connection, the behavior is like BREAK: it is treated as an abruptly closed connection. If the command cannot be continued normally (e.g., a frame is corrupted by OOB signals, or there is no ACK/NAK balance), the command is terminated with a Check Condition status, with sense data corresponding to ACK/NAK TIMEOUT.

15.5 Transport Layer

The Transport layer is the interface between the application layer and port layer. It defines frame formats and constructs and parses frame contents. For SSP, the transport layer receives only frames from the port layer that are going to be ACKed by the link layer.

This section describes Transport Layer behaviors of the Drive. For a complete description of SAS Transport Layer, see the ANSI specification SPL-4 at Ansi.org.

The transport layer defines the frame format as follows.

Table 15 - 14: SAS Frame Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Frame Type							
1-3	Hashed Destination Address							
4	Reserved							
5-7	Hashed Source Address							
8-9	Reserved							
10	Reserved			TLR Control = 00b		Retry Data Frames =0b	Retransmit	RSVD
11	Reserved						Number of Fill Bytes	
12-15	Reserved							
16-17	Tag							
18-19	Target Port Transfer Tag							
20-23	Data Offset							
24-m	Information Unit							
	Fill Bytes (if needed)							
(n-3)-n	CRC							

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The Frame Type field defines the format of the INFORMATION UNIT field as follows:

Table 15 - 15: Information Unit Fields

Code	Name of Frame	Information Unit	Originator	IU Size (bytes)
01h	DATA	Data	initiator or Target	1-1024
05h	XFER_RDY	Data Transfer Ready	Target	12
06h	COMMAND	Command	initiator	28-284
07h	RESPONSE	Response	Target	24-1024
16h	TASK	Task Management Function	initiator	28
f0-ffh	Vendor-specific			
All others	Reserved			

- Hashed Destination SAS Address contains the hashed value of the destination SAS address.
- Hashed Source SAS Address contains the hashed value of the source SAS address.
- TLR Control is not supported.
- Retry Data Frames is not supported.
- Changing Data Pointer is not supported.
- Number of Fill Bytes indicates the number of fill bytes between the INFORMATION UNIT field and the CRC field. The Retransmit bit is set to 1 for RESPONSE frames when attempting to retransmit this frame due to receiving an error during the initial transmission. It is set to 0 for all other frame types. The Number of Fill Bytes field is set to 0 for all frame types except DATA frames.
- Tag contains a value that allows the SSP port to establish a context for commands and task management functions.
- Target Port Transfer Tag is set and used by the drive. The initiator should echo this field in the outbound data IU.
- Information Unit (IU) contains the information unit, the format of which is defined by the FRAME TYPE field.
- Fill bytes are included after the INFORMATION UNIT field, so the CRC field is aligned on a four-byte boundary.

15.5.1 Command Information Unit

The COMMAND frame is sent by an SSP initiator port to request that a command be processed by the drive.

Table 15 - 16: COMMAND Information Unit

	Bit							
Byte	7	6	5	4	3	2	1	0
0-7	Logical Unit Number							
8	Reserved							
9	Disable First Burst=0	Reserved				Task Attribute		
10	Reserved							
11	Additional CDB Length (DWords)							Reserved

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12-27	CDB
28-n	Additional CDB Bytes

The Logical Unit Number contains the address of the logical unit. The drive supports only a LUN of 0's. Disable First Burst is not supported by the drive.

The Task Attributes are defined as follows:

Table 15 - 17: Task Attributes

Value	Attribute
000b	Simple_Q
001b	Head_of_Q
010b	Ordered_Q
100b	ACA_Q (not supported)
101b	Reserved

Additional CDB Length contains the length in DWords (four bytes) of the ADDITIONAL CDB field. CDB and Additional CDB Bytes together contain the CDB.

15.5.2 TASK Information Units

Table 15 - 18: TASK Information Unit

	Bit							
Byte	7	6	5	4	3	2	1	0
0-7	Logical Unit Number							
8-9	Reserved							
10	Task Management Function							
11	Reserved							
12-13	Tag of Task to be Managed							
14-27	Reserved							

- Logical Unit Number contains the address of the logical unit. The drive supports only a LUN of 0's.

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Task Management Function is defined as follows:

Table 15 - 19: Task Management Function

Value	Function
01h	ABORT TASK: The drive performs the ABORT TASK associated with the value of the TAG OF TASK TO BE MANAGED field.
02h	ABORT TASK SET: The drive performs the ABORT TASK SET by aborting all outstanding tasks for the initiator that sent the TMF.
04h	CLEAR TASK SET: This TMF causes the drive to abort all tasks in the task set. The action is equivalent to receiving a series of Abort Task requests from all initiators. A Unit Attention condition is generated for all other initiators with tasks in the task set. The Additional Sense Code consists of Commands cleared by another initiator.
08h	LUN RESET: The LUN RESET causes the target to execute a hard reset. This means: • Abort all tasks for all initiators on either both ports. • Release any device reservation on either port.
10h	I_T NEXUS RESET: The I_T NEXUS RESET causes the drive to abort all outstanding tasks for the initiator that sent the TMF. In addition, a Unit Attention is set for the initiator that sent the TMF, indicating I_T NEXUS LOSS. This TMF does not affect task sets for other initiators.
40h	CLEAR ACA (not supported)
80h	QUERY TASK: The drive returns a response of FUNCTION SUCCEEDED if the specified task exists, or FUNCTION COMPLETE if the specified task does not exist.
81h	QUERY TASK SET: The drive returns a response of FUNCTION SUCCEEDED if there is any task exist, or FUNCTION COMPLETE if there is no task exist.
82h	QUERY ASYNCHRONOUS EVENT (formerly QUERY UNIT ATTENTION): The drive returns a response of FUNCTION SUCCEEDED if there is a Unit Attention or a deferred error pending, or FUNCTION COMPLETE if there is no Unit Attention or no deferred error pending.
Others	RESERVED: The drive returns a RESPONSE frame with the DATAPRES field set to RESPONSE_DATA and its RESPONSE CODE field set to TASK MANAGEMENT FUNCTION NOT SUPPORTED.

- If TMF is set to ABORT TASK or QUERY TASK, Tag of Task to Be Managed specifies the Tag value from the COMMAND frame that contained the task to be aborted or checked. For all other TMF's, this field is ignored.
- If TMF is set to QUERY ASYNCHRONOUS EVENT, the Additional Response Information argument is set to 000000h for the response of FUNCTION COMPLETE. If the response is FUNCTION SUCCEED, the Additional Response Information argument is set as defined in the following table.

Table 15 - 20: Additional Response Information Argument for Query Async Event

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Reserved		UADE Depth		Sense Key			
1	Additional Sense Code							
2	Additional Sense Code Qualifier							

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- UADE Depth is the number of pending Unit Attention conditions or deferred errors.
- Sense Key is the value of the SENSE KEY field in the highest-priority pending Unit Attention condition or deferred error.
- Additional Sense Code is the value of the ADDITIONAL SENSE CODE field in the highest-priority pending Unit Attention condition or deferred error.
- Additional Sense Code Qualifier is the value of the ADDITIONAL SENSE CODE QUALIFIER field in the highest-priority pending Unit Attention condition or deferred error.

Table 15 - 21: **UADE DEPTH Field**

Code	Description
00b	The combined number of Unit Attention conditions and deferred errors is unknown.
01b	The combined number of Unit Attention conditions and deferred errors is one.
10b	The combined number of Unit Attention conditions and deferred errors is greater than one.
11b	Reserved

15.5.3 XFER_RDY Information Units

The XFER_RDY frame is sent by the drive to request write data (outbound data) from the initiator.

Table 15 - 22: **XFER_RDY Information Unit**

	Bit							
Byte	7	6	5	4	3	2	1	0
0-3	Requested Offset							
4-7	Write Data Length							
8-11	Reserved							

- Requested Offset contains the buffer offset of the segment of write data that the initiator may transmit to the drive (using DATA frames). The requested offset is a multiple of four.
- Write Data Length contains the number of bytes of write data the initiator may transmit to the drive (using DATA frames) from the requested offset.

15.5.4 DATA Information Units

The DATA frame is sent by the drive to the initiator (in bound data) or by the initiator to the drive (out bound data).

Table 15 - 23: **Data Information Unit**

	Bit							
Byte	7	6	5	4	3	2	1	0
0-(n-1)	Data							

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15.5.5 RESPONSE Information Units

The RESPONSE frame is sent by the drive to the initiator (in bound data) or by the initiator to the drive (out bound data).

Table 15 - 24: Response Information Unit

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-7	Reserved							
8-9	Retry Delay Timer							
10	Reserved							DataPres
11	Status							
12-15	Reserved							
16-19	Sense Data Length (n bytes)							
20-23	Response Data Length (m bytes)							
24-(24+m)	Response Data							
(24+m) - (23+m+n)	Sense Data							

Retry Delay Timer contains the retry delay timer code which is defined as follows:

Table 15 - 25: Try Delay Timer Code

Status Code	Retry Delay Timer Code	Description
BUSY	0000h	Same as normal busy
	0001h-FFEFh	The number of 100 millisecond increments the initiator should wait before sending another command to the drive
	FFF0h-FFFDh	Reserved
	FFEFh	The initiator should stop sending commands to the drive.
	FFFFh	The drive is not able to accept the command.
QUEUE FULL	0001h-FFEFh	The initiator should wait before sending another command to the drive until: • At least the number of 100 millisecond increments indicated in the Retry Delay Timer Code field have elapsed; or • A command addressed to the drive completes.
	FFF0h-FFFFh	Reserved
GOOD	0000h-FFFFh	Reserved
CHECK CONDITION	0000h-FFFFh	Reserved
CONDITION MET	0000h-FFFFh	Reserved
RESERVATION CONFLICT	0000h-FFFFh	Reserved

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ACA ACTIVE	0000h-FFFFh	Reserved
TASK ABORT	0000h-FFFFh	Reserved

DataPres indicates the format and content of the STATUS field, SENSE DATA LENGTH field, RESPONSE DATA LENGTH field, RESPONSE DATA field, and SENSE DATAfield:

Table 15 - 26: DataPres

Value	DataPres Description
00b	NO DATA: no data present.
01b	RESPONSE_DATA: response data present.
10b	SENSE_DATA: sense data present.
11b	Reserved

Table 15 - 27: RESPONSE DATA

	Bit							
Byte	7	6	5	4	3	2	1	0
0-2	Reserved							
3	Response Code							

Response Codes are defined as follows:

Table 15 - 28: Response Codes

Value	Response Code Description
00b	Task Management Function complete.
02b	Invalid Frame
04b	Task Management Function not supported.
05b	Task Management Function failed.
08b	Task Management Function succeeded.
09b	Invalid LUN
Others	Reserved

15.5.6 Sequences of SSP Information Units

SSP Information Unit sequences are used to execute SCSI commands. This section provides a brief overview of SAS SSP Information Unit sequences that would be required to complete a SCSI command.

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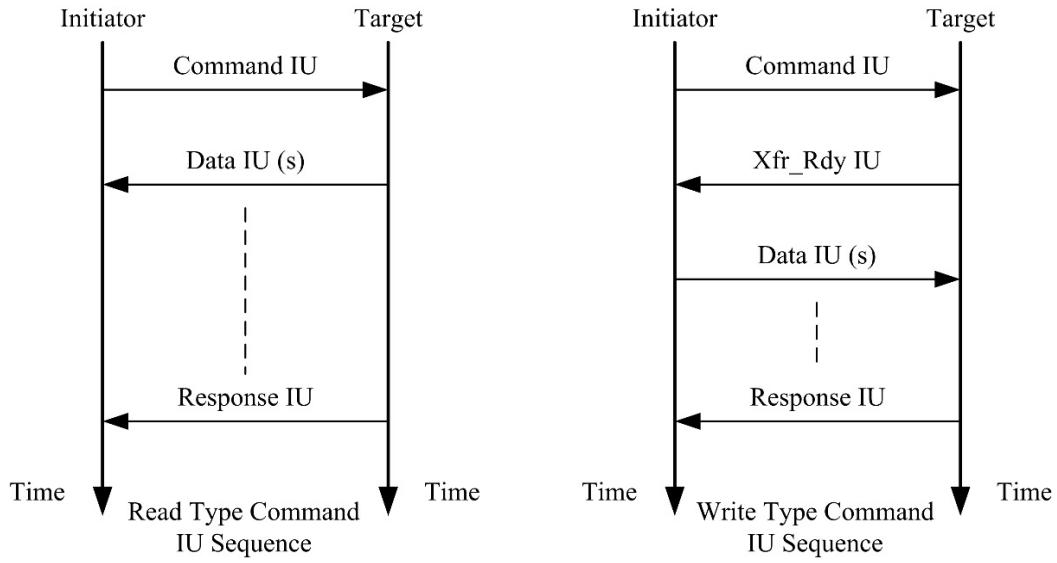
Figure 15 - 2: **SSP Information Unit Sequences**



15.5.7 Transport Layer Error Handling

This section defines the Transport layer error handling by the drive.

Table 15 - 29: **Transport Layer Error Handling**

Error	Error Handling Procedure
SSP Header Field Checking	Reserved fields in SSP frames are not checked.
Data Offset Error	If a DATA frame with an invalid Data Offset is received, the command associated with the DATA frame is aborted with a Check Condition status and sense data corresponding to a DATA OFFSET ERROR is returned.
I_T NEXUS Loss Timeout	If a connection cannot be established to an initiator before the I_T NEXUS LOSS timer expires (Mode Page 0x19), all commands from the initiator are internally aborted. The first new command received from the affected initiator results in a CHECK CONDITION with sense data corresponding to I_T NEXUS LOSS OCCURRED.
initiator Response Timeout	If DATA frames corresponding to an outstanding XFER_RDY frame are not received before the initiator Response timer expires (Mode Page 0x19), the command is aborted with a Check Condition status and sense data corresponding to INITIATOR RESPONSE TIMEOUT is returned for the affected command.
Data Overflow	If more data is received than requested via an XFER_RDY frame, the affected command is aborted with a Check Condition status, and sense data corresponding to TOO MUCH WRITE DATA is returned.
Invalid Target Port Transfer Tag	If a DATA frame is received and the TPTT is not set to the value used in the corresponding XFER_RDY frame, the frame is discarded. If a COMMAND or TASK frame is received with the TPTT set to a value other than 0xFFFF, a RESPONSE frame with RESPONSE_DATA set to INVALID FRAME is returned.
Invalid Frame Length	If a DATA frame is received with zero bytes of payload data, the frame is discarded. This is not considered an error. If a COMMAND/TASK frame that is too short is received, RESPONSE data corresponding to INVALID FRAME is returned. The additional CDB length field of a COMMAND frame is not checked for correctness. If a DATA frame is received with a payload greater than 1024 bytes, the frame is discarded. The command is aborted with a Check Condition status, and sense data corresponding to DATA_PHASE_ERROR is returned.

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16.0 SCSI Command Set

A summary of the SCSI commands supported by the drives are listed below. O = Optional, M = Mandatory

Table 16 - 1: SCSI Commands Supported

Type	Code	Description	Page Number
M	04h	FORMAT UNIT	123
M	12h	INQUIRY	127
O	4Ch	LOG SELECT	152
O	4Dh	LOG SENSE	155
O	15h	MODE SELECT (6) (15)	185
O	55h	MODE SELECT (10) (55)	186
O	1Ah	MODE SENSE (6) (1A)	187
O	5Ah	MODE SENSE (10) (5A)	221
O	5Eh	PERSISTENT RESERVE IN	222
O	5Fh	PERSISTENT RESERVE OUT	225
O	90h	PRE-FETCH (16)	229
O	34h	PRE-FETCH (10)	229
M	08h	READ (6)	230
M	28h	READ (10)	231
O	A8h	READ (12)	233
O	88h	READ (16)	234
O	7Fh/09h	READ (32)	236
O	3Ch	READ BUFFER	236
M	25h	READ CAPACITY (10)	242
O	9Eh/10h	READ CAPACITY (16)	243
O	37h	READ DEFECT DATA(10)	245
O	B7h	READ DEFECT DATA (12)	247
O	3Eh	READ LONG (10) (3E)	249
O	9Eh/11h	READ LONG (16)	250
O	07h	REASSIGN BLOCKS	251
O	1Ch	RECEIVE DIAGNOSTICS RESULTS	252
M	17h	RELEASE (6) (17)	253
O	57h	RELEASE (10) (57)	254

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Type	Code	Description	Page Number
O	A3h/05h	REPORT DEVICE IDENTIFIER	255
O	A0h	REPORT LUNS	256
O	A3h/0Ch	REPORT SUPPORTED OPERATION CODES	257
O	A3h/0Dh	REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS	261
M	03h	REQUEST SENSE	263
O	A3h/05h	REPORT DEVICE IDENTIFIER	255
O	A0h	REPORT LUNS	256
O	A3h/0Ch	REPORT SUPPORTED OPERATION CODES	257
O	A3h/0Dh	REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS	261
M	03h	REQUEST SENSE	263
M	16h	RESERVE (16)	264
O	56h	RESERVE (56)	265
O	01h	REZERO UNIT	266
O	48h	SANITIZE	267
O	A2h	SECURITY PROTCOL IN	268
O	B5h	SECURITY PROTCOL OUT	270
O	0Bh	SEEK (6)	272
O	2Bh	SEEK (10)	272
M	1Dh	SEND DIAGNOSTIC	273
O	A4h/06h	SET DEVICE IDENTIFIER	277
O	1Bh	START STOP UNIT	278
O	35h	SYNCHRONIZE CACHE (10)	279
O	91h	SYNCHRONIZE CACHE (16)	280
M	00h	TEST UNIT READY	281
O	42h	UNMAP	282
O	2Fh	VERIFY (10)	284
O	AFh	VERIFY (12)	286
O	8Fh	VERIFY (16)	286
O	7Fh/0Ah	VERIFY (32)	287
M	0Ah	WRITE (6)	288
M	2Ah	WRITE (10)	289

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Type	Code	Description	Page Number
O	AAh	WRITE (12)	291
O	8Ah	WRITE (16)	291
O	7Fh/0Bh	WRITE (32)	292
O	2Eh	WRITE AND VERIFY (10)	293
O	AEh	WRITE AND VERIFY (12)	286
O	8Eh	WRITE AND VERIFY (16)	294
O	7Fh/0Ch	WRITE AND VERIFY (32)	295
O	3Bh	WRITE BUFFER	296
O	3Fh	WRITE LONG (10)	300
O	9Fh/11h	WRITE LONG (16)	291
O	41h	WRITE SAME (10)	305
O	93h	WRITE SAME (16)	306
O	7Fh/0Dh	WRITE SAME (32)	307
O	9Ch	WRITE ATOMIC (16)	308
O	7Fh/0Fh	WRITE ATOMIC (32)	309

16.1 SCSI Control Byte

The Control Byte is the last byte of every CDB, with the exception of 32-byte CDBs, where it is located at Byte 1. The format of this byte is shown below.

Table 16 - 2: SCSI Control Byte

BIT							
7	6	5	4	3	2	1	0
VU = 0		Reserved			NACA	FLAG	LINK

Field	Description
VU	Vendor Unique
NACA	The NACA (Normal ACA) bit specifies whether an ACA condition is established if the command terminates with a Check Condition status. A NACA bit set to 1 specifies that an ACA is established. A NACA bit set to 0 specifies that an ACA is not established. If the ACA is enabled (Mode Page 0 Sub Page D3), the NACA bit is ignored.
FLAG	If LINK is 0, FLAG must also be 0. If LINK is 1, FLAG may also be 1. Typically, this bit is used to cause an interrupt in the initiator between linked commands. Note: The drive ignores the LINK bit and FLAG bit in the CDB.
LINK	

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16.2 Abbreviations

The following abbreviations are used throughout this section:

Table 16 - 3: Abbreviations

Abbreviation	Description
LUN	Logical Unit Number. An encoded three bit identifier for the logical unit.
VU	Vendor-unique
LBA	Logical Block Address
RSVD	Reserved
MSB	Most Significant Byte
LSB	Least Significant Byte

16.3 FORMAT UNIT (04)

FORMAT UNIT (04) requests that the device server format the medium into logical blocks accessible by the application client. This is specified in the number of blocks and block length values received in the last Mode Parameter Block Descriptor in a MODE SELECT command. The device server may certify the medium and create control structures for medium management and defects. The degree to which the medium is altered is vendor-specific.

Table 16 - 4: FORMAT UNIT (04)

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Command code = 04h							
1	FMTPINFO		LONG LIST	FMTDATA	CMPLIST	Defect List Format		
2	VU = 0							
3	Reserved							
4	Reserved							FFMT
5	Control Byte - Refer to SCSI Control Byte							

- FMTPINFO is Format Protection Information. In combination with the Protection Field Usage field in the Parameter List Header, it specifies whether the drive enables or disables the use of protection information (see the table in the Parameter List Header section).
- LONGLIST is set to 1 to specify that the long parameter list header is to be used, or set to 0 to specify that the short parameter list header is to be used.
- FMTDATA is set to 1 to specify that a Data Out phase follows the Command phase. The Data Out phase consists of a Parameter List header, optionally followed by an Initialization Pattern Descriptor, optionally followed by a Defect List. If FmtData=0, the following defaults are assumed: DPRY=0, DCRT=1, STPF=1, IP=0, DSP=0, Immed=0.
- CMPLIST is ignored.
- Defect List Format is ignored.
- FFMT specifies whether a fast format should be performed. Regardless of the FFMT setting, the format makes all LBAs immediately available for writing. Refer to section 18.12.1 for format times.

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Notes:

1. It is recommended that the MODE SELECT command be issued prior to the FORMAT UNIT command to specify parameters that affect the formatting process.
2. The Block Length parameter of the Mode Select Parameter List's Block Descriptor is used during formatting and is saved following a successful format operation. If a MODE SELECT command has not been issued since the last reset or startup (bring-up) sequence, then the Block Length from the previous format operation is used.
3. After receiving a FORMAT UNIT command, the target responds to commands as follows:
   - All commands except REQUEST SENSE and INQUIRY return the Check Condition status, while the format operation is an active I/O process.
   - When tagged queuing is enabled (DQue = 0), all commands except REQUEST SENSE and INQUIRY return Queue Full status, while the FORMAT UNIT command is a queued I/O process.
   - When tagged queuing is disabled (DQue = 1), all commands except REQUEST SENSE and INQUIRY return Busy status, while the FORMAT UNIT command is a queued I/O process.
   - If a REQUEST SENSE command is received while a format operation is an active I/O process, the target returns Good status. The Sense Key is set to Not Ready and the Additional Sense Code and qualifier is set to Format in Progress.
   - If an INQUIRY command is received while a format operation is an active I/O process, the target returns Good status and Inquiry data as requested.
   - The format operation must complete successfully for the drive to be usable. If the command is interrupted by a reset, power down, or an unrecoverable error, the drive enters a degraded mode of operation, with reading and writing prohibited. To exit the degraded mode, another FORMAT UNIT command must be sent by the initiator and completed successfully by the target.
   - The FORMAT UNIT command sets the Unit Attention Condition for all initiators except the one that issued the FORMAT UNIT command.

16.3.1 Parameter List Header

Following is the format of the Parameter List Header sent during the data out phase when FmtData is set to 1.

Table 16 - 5: Short Parameter List Header

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved					Protection Field Usage		
1	FOV	DPRY	DCRT	STPF = 1	IP	Obsolete	Immed	VS
2-3	Defect List Length = 0							

Table 16 - 6: Long Parameter List Header

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved					Protection Field Usage		
1	FOV	DPRY	DCRT	STPF = 1	IP	Obsolete	Immed	VS
2	Reserved							
3	P_I_Information				Protection Interval Exponent			
4-7	Defect List Length = 0							

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Protection Field Usage, in combination with the format protection information (FMTPINFO) field in the CDB, specifies whether the drive enables or disables the use of protection information:

Table 16 - 7: **Protection Field Usage**

FMTPINFO	Protection Field Usage	Description
00h	000h	The drive is formatted to Type 0 Protection.
01h	xxxh	Check Condition status is returned with the Sense Key set to Illegal Request and the Additional Sense Code set to Invalid Field in the CDB.
10h	000h	The drive is formatted to Type 1 Protection.
11h	000h	The drive is formatted to Type 2 Protection.
11h	001h	Type 3 protection is not supported. Check Condition status is returned with the Sense Key set to Illegal Request, and the Additional Sense Code set to Invalid Field in the Parameter List.

All other combinations of FMTPINFO and Protection Field Usage return a Check Condition status, with the Sense Key set to Illegal Request and the Additional Sense Code set to Invalid Field in the Parameter List.

Type 0 protection specifies that the drive disables the use of protection information and formats to the block size specified. Following a successful format, the PROT_EN bit in the READ CAPACITY (16) parameter data indicates that protection information is disabled.

Type 1 and Type 2 protection specify that the drive enables the use of protection information and formats to the block size specified + 8 (e.g., if the block length is 512, then the formatted block length is 520). See format of data below. When protection information is written during a FORMAT UNIT command, protection information is written with a default value of all 0xFF's. Following a successful format, the PROT_EN bit in the READ CAPACITY (16) parameter data indicates that protection information is enabled, and the P_TYPE field in the READ CAPACITY (16) parameter data indicates the protection type.

Table 16 - 8: **Logical Block Fields**

	Bit							
Byte	7	6	5	4	3	2	1	0
0 ... n	User Data							
n ... n+1	Logical Block Guard							
n+2 ... n+3	Logical Block Application Tag							
n+4 ... n+7	Logical Block Reference Tag							

- Logical Block Guard contains a CRC that covers the preceding user data. This field is generated and checked per the SBC standard.
- Logical Block Application Tag may be modified by the initiator if the ATO bit is set to 0 in Mode Page 0x0A. If the ATO bit is set to 1, the initiator does not modify the Logical Block Application Tag field. This field is generated and checked per the SBC standard. The Logical Block Guard field contains a CRC that covers the preceding user data. This field is generated and checked per the SBC standard.

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- Logical Block Reference Tag is generated and checked depending on protection types. With Type 1 protection, the Logical Block Reference Tag in the first logical block of the data transfer contains the least significant four bytes of the LBA in the Logical Block Address field of the command. Subsequent blocks contain the previous logical block reference tag, plus one. With Type 2 protection, the Logical Block Reference Tag in the first logical block of the data transfer contains the value in the Expected Initial Logical Block Reference Tag field of the command. Subsequent blocks contain the previous logical block reference tag, plus one.
- FOV (Format Options Valid) bit, when set to zero, indicates that the target should use its default settings for the DPRY (0), DCRT (1), STPF (1), IP (0), and DSP (1) bits. These bits must all be set to 0 in the Parameter List Header when FOV=0, or the command will be terminated with a Check Condition status, Sense Key of Illegal Request, and an Additional Sense Code of Invalid Field in Parameter List. FOV=1 indicates that the values set in DPRY, DCRT, STPF, IP, and DSP are defined as shown below.
- DPRY (Disable Primary) bit, if set to 0, disables error injection mode. A DPRY bit set to 1 enables error injection mode.
- DCRT (Disable Certification) is ignored; certification is not supported.
- STPF (Stop Format) is ignored.
- IP (Initialization Pattern) bit, if set to 0, specifies that an initialization pattern descriptor is not included, and all customer data will be initialized to zeroes. An IP bit of 1 specifies that an Initialization Pattern Descriptor is included in the FORMAT UNIT parameter list following the parameter list header. The Initialization Pattern Descriptor provides a means of enabling the Security Initialize option, which is not enabled by default. If anything in the Initialization Pattern Descriptor is not set as specified below, the command will be immediately terminated with a Check Condition status, Sense Key of Illegal Request, and an Additional Sense Code of Invalid Field in Parameter List.

Table 16 - 9: Initialization Pattern Descriptor

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		SI	Reserved				
1	IP Type							
2 -3	Initialization Pattern Length							
4-n	Initialization Pattern							

- SI (Security Initialize) bit specifies that the drive attempts to erase all locations that may contain customer data, including known defects.
- Initialization Pattern Type must be either 0 or 1. A value of 0 indicates the drive will use the default initialization pattern; all customer data will be initialized to zeros. A value of 1 indicates all customer data will be initialized to the specified initialization pattern.
- Initialization Pattern Length indicates the length of the initialization pattern being sent by the host in bytes. This value must be one of 512, 520, 528, 4096, 4160, or 4224.
- Initialization Pattern specifies the initialization pattern. If the pattern is for a logical block size of 4096, 4160, or 4224, then the data must be a logical block of data at 512, 520, or 528, repeated 8 times.
- DSP (Disable Saving Parameters) bit, when 0, indicates the target is to save all the current MODE SELECT saveable parameters during the format operation. When the bit is 1, the target is not to save the current MODE SELECT saveable parameters.
- Immed (Immediate) bit, if set to 0, requests that status be returned at the end of the format operation. An immediate bit set to 1 requests that status be returned immediately following CDB validation and transfer of data in the Data Out phase. If the format operation has the immediate bit set to one and terminates in error, DEFERRED ERROR SENSE data is generated.
- P_I_Information must be 0.
- Protection Interval Exponent is the number of protection intervals per logical block size, expressed as a power of 2. This value must be 0 (one protection interval per logical block) for logical block sizes 512 and 520. This value may be 0 or 3 (one or eight protection intervals per logical block) for logical block sizes 4096 and 4160. This value is assumed to be 0 if the long parameter list header format is not used. See SBC-3 for more details regarding protection intervals.
- Defect List Length must be 0. A user-supplied defect list is not supported. Otherwise, the command is terminated with a Check Condition status. The Sense Key is set to Illegal Request and the Additional Sense Code is set to Invalid Field in Parameter List.

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16.4 Inquiry (12)

The INQUIRY (12) command requests the target parameters to be sent to the initiator.

Table 16 - 10: INQUIRY (12)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Operation Code = 12h							
1	Reserved						CmdDT=0	EVPD
2	Page Code							
3-4	Allocation Length							
5	Control Byte - Refer to Refer to SCSI Control Byte.							

- EVPD bit of 1 specifies that the target return the vital product data page identified by the Page Code field in the CDB. The available VPD pages are defined in the addendum provided for each different drive model in the section entitled Inquiry Data Format.
- Page Code specifies which page of vital product data information the drive shall return.

Table 16 - 11: Page Code Descriptions

EVPD	Page Code	Description
0	0	The target returns the standard INQUIRY data.
0	Non-zero	The drive returns a Check Condition status with the Sense Key of Illegal Request and the Additional Sense Code of Invalid Field in the CDB.
1	Non-zero	The drive returns the vital product data of page code requested.

- Allocation Length specifies the number of bytes the initiator has allocated for INQUIRY data to be returned. An allocation length of zero implies that no data is to be returned. The target terminates the DATA IN phase when all available INQUIRY data has been transferred or when allocation length bytes have been transferred, whichever is less.
- If an INQUIRY command is received from an initiator with a pending Unit Attention condition (before the target reports Check Condition status), the target processes the INQUIRY command. The Unit Attention condition is not cleared by this action.
- The INQUIRY command is a Priority command and is not queued.
- The inquiry data is set at the time of manufacture and will not change (without a FRU change), with the following exceptions:
- Product Revision Level (EVPD=0) can be changed when microcode is downloaded with the Write Buffer command.
- The information returned for EVPD=1, Page Code = 3 is not fixed.

Notes:

1. The inquiry data returned when media is not available will not be complete.
2. Byte 0 of the returned data on an INQUIRY command is the same no matter which pages are returned. This description is used for all the following page definitions.
3. The Peripheral Qualifier field of zero (0) indicates that the peripheral device is currently connected to this logical unit. A Peripheral Device Type field of zero (0) indicates that this device is a Direct Access Storage Device (DASD).

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16.4.1 Inquiry Data - General

Fields with a value shown inside quotes (e.g., value ='xyz') are character fields. A value not in quotes is a numeric value. Character fields are alphanumeric and represented in ASCII.

16.4.2 Inquiry Data - EVPD = 0, Page Code = 00h - Standard Inquiry Data Page

Table 16 - 12: Inquiry Data Format - EVPD = 0 (Page Code = 00h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	RMB = 0	Reserved						
2	Version = 6							
3	Obsolete		Norm ACA=0	HiSup = 1	Response Data Format = 2			
4	Additional Length = 159 (9Fh)							
5	SCCS=0	ACC=0	TPGS=0		3PC=0	Reserved		Protect=1
6	Obsolete	EncSer = 1	Port	MultiP=1	Obsolete			RSVD
7	Obsolete		RSVD	RSVD	Obsolete		CmdQue= 1	RSVD
8-15	Vendor ID = "HGST " (ASCII)							
16-31	Product ID (ASCII)							
32-35	Product Revision Level (ASCII)							
36-43	Unit Serial Number (ASCII)							
44-95	Reserved							
96-145	Copyright Notice (ASCII)							
146-149	Date of Manufacture							
150-151	Week of Manufacture							
152-163	Reserved							

- Qualifier: 0 indicates that the LUN specified is currently supported. Qualifier is set to 011b when the specified LUN is not present.
- Peripheral Device Type: 0 indicates that the device is a Direct-Access Peripheral Device.
- RMB Removable Medium Bit: This is always set to 0 to indicate no removable media exists.
- Version indicates the level of the ANSI standard that the product supports. The drive supports ANSI SCSI Primary Commands – 4 (SPC-4).
- NormACA (Normal ACA): 0 indicates the device server does not support setting the NACA bit to 1 in the Control Byte of the CDB, as defined in the SAM.
- HiSup bit: 1 indicates that the drive uses the hierarchical addressing model to assign LUNs to logical units.
- Response Data Format: 2 indicates that the INQUIRY Data Format as specified in the ANSI SCSI version 2 is supported by the target.
- Additional Length indicates the following number of bytes of INQUIRY information.

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- SCCS bit: 0 indicates that the device does not contain an embedded storage array controller component.
- ACC bit: 0 indicates that no access controls coordinator may be addressed through this logical unit.
- TPGS field: 0 indicates that the device does not support asymmetric logical unit access.

- 3PC bit: 0 indicates that the device does not support third-party copy commands.
- Protect bit: 1 indicates that the drive supports protection information.
- EncSer Enclosure Services bit: 0 indicates that the target does not contain an embedded enclosure services component.
- Port bit: 0 indicates that the drive received the Inquiry command on port A; 1 indicates that the drive received the Inquiry command on port B.
- MultiP MultiPort bit: 1 indicates that the target has multiple ports and implements multi-port requirements.
- CmdQue is set to one to indicate that the drive supports command queuing.
- Vendor ID is “HGST” padded with ASCII blanks.
- Product ID is specified in Section 4.3.1
- Product Revision Level indicates the level of microcode.
- Unit Serial Number contains the drive serial number.

16.4.3 Inquiry Data - EVPD = 1 - Page Code = 00h - Supported VPD Pages

Table 16 - 13: Inquiry Data Format - EVPD = 1 (Page Code = 00h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 00h							
2	Reserved							
3	Page Length = 0Fh							
4	Supported Page Code = 00h							
5	Supported Page Code = 03h							
6	Supported Page Code = 80h							
7	Supported Page Code = 83h							
8	Supported Page Code = 86h							
9	Supported Page Code = 87h							
10	Supported Page Code = 88h							
11	Supported Page Code = 8Ah							
12	Supported Page Code = 8Dh							
13	Supported Page Code = 90h							
14	Supported Page Code = 91h							
15	Supported Page Code =B0h							
16	Supported Page Code =B1h							

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17	Supported Page Code =B2h
18	Supported Page Code = D2h

- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to , and contains the same value as in the page code field of the INQUIRY command descriptor block.
- Page Length specifies the length of the following page data.
- Supported Page Code contains the Page Codes supported by the target. The list is in ascending order.

16.4.4 Inquiry Data - EVPD = 1, Page Code = 03h - ASCII Information Page

Table 16 - 14: Inquiry Data Format - EVPD = 1 (Page Code = 03h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 03h							
2	Reserved							
3	Page Length = 204 (CCh)							
4	ASCII Fields Length = 00h							
5-7	Reserved							
8-23	Reserved							
24-35	ASCII uCode Identifier							
36-39	Reserved							
40-41	Major Version							
42-43	Minor Version							
44-47	User Count							
48-51	Build Number							
52-79	Build Date String							
80-81	Code ID							
82-83	Compatibility ID							
84-91	Product ID							
92-99	Interface ID							
100-107	Code Type							
108-119	User Name							
120-135	Machine Name							
136-167	Directory Name							
168-171	Operating State							

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172-175	Functional Mode							
176-179	Degraded Reason							
	Bit							
Byte	7	6	5	4	3	2	1	0
180-183	Broken Reason							
184-187	Code Mode							
188-195	ASCII uCode Revision							
196-199	Context Failure Reason							
200-203	South Assert Address							
204-205	North Assert Code							
206	PwrCtlUpd	PwrCtlHw	Power Controller Firmware Level					
207	Power Controller Firmware Level							

- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length specifies the length (in bytes) of the vendor-unique VPD information (bytes 4 - 163). If the allocation length of the CDB is too small to transfer all the data, the Page Length field is not adjusted to reflect the truncation.
- ASCII uCode Identifier contains the drive's microcode identifier. The field is alphanumeric (ASCII), left-aligned, and the unused bytes are ASCII spaces (20h).
- Major Version and Minor Version contain version numbers of the code loaded on the drive.
- User Count contains the number of times the code has been built since the master build.
- Build Number contains the master build version number.
- Build Date String contains the date the code on the drive was built, in an extended string format.
- Code ID contains a binary value for firmware development tracking.
- Compatibility ID contains a binary value for firmware development tracking.
- Product ID contains the name of the product represented by this code.
- Interface ID contains the interface type and serial interface speed (e.g., SCSI or FCAL 4Gb) of the code.
- Code Type contains the intended use of the code. (e.g., local, released, test).
- User Name contains the username of the person who built this version of the code.
- Machine Name contains the workstation on which this version of the code was built.
- Directory Name contains the last 32 characters of the directory from where this code was built.
- Operating State is the drive operating state. The least significant bit contains the following:

0 = OM_BROKEN	A hardware failure was detected, or there was an error loading the context.
1 = OM_DEGRADED	A soft failure occurred (incomplete format).
2 = OM_INACCESSIBLE	The drive is good.
3 = OM_STARTING	The context is loading.
4 = OM_NORMAL	The context is loaded and ready to read/write.

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5 = OM_STOPPED	The drive reached a ready state but now has been stopped.
6 = OM_NOTIFY	The drive is good, but NOTIFY has not arrived (SAS).
7 = OM_WAKEUP	The context is loading but will not report LUN_BECOMING_READY.

- Functional Mode is the drive functional mode. The least significant byte (0x0000000n) contains the following:

0 = OM_NORMAL_MODE	Not in special or recovery mode
1 = OM_SPECIAL_CMD	Special command mode on
The second byte (0x000n0000) contains the following: 0 = Idle functions are not enabled. 1 = Idle functions are enabled.	

- Degraded Reason (UECType) is why the drive is in a degraded mode; i.e., how to exit this mode.
- Broken Reason (UECType) is why the drive is in a broken mode; i.e., how to exit this mode
- Code Mode is the type of code the drive is running. The least significant bit contains the following:
- 0 = Drive is running code that has been loaded from NAND.
- ASCII uCode Revision is the revision level of the media access firmware. This field is alphanumeric.
- Context Failure Reason is the qualifier when the broken reason indicates a damaged context.
- South Assert Address is for debug of firmware asserts.
- North Assert Code is for debug of firmware asserts.
- PwrCtlUpd indicates the power controller firmware has been updated since the last drive POR. A drive POR is required to activate the new power controller firmware.
- PwrCtlHw indicates the power controller hardware revision. Zero indicates the power controller is an ADM1168. One indicates the power controller is not an ADM1168.
- Power Controller Firmware Level is the level of firmware currently in the power controller EEPROM.

16.4.5 Inquiry Data - EVPD = 1, Page Code = 80h - Unit Serial Number Page

Table 16 - 15: Inquiry Data Format - EVPD = 1 (Page Code = 80h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 80h							
2	Reserved							
3	Page Length = 16 (10h)							
4-19	Serial Number (ASCII)							

- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length is set to 16. This field specifies the length of the following page data.
- Serial Number indicates the drive serial number, right-aligned.

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16.4.6 Inquiry Data - EVPD = 1, Page Code = 83h - Device Identification Page

Table 16 - 16: Inquiry Data Format - EVPD = 1 (Page Code = 83h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 83h							
2	Reserved							
3	Page Length = 72 (48h)							
4	Protocol Identifier = 0h				Code Set = 1			
5	PIV=0	RSVD	Association=0		Identifier Type = 3			
6	Reserved							
7	Designator Length = 8							
8-15	LUN (World Wide ID)							
16	Protocol Identifier = 6h				Code Set = 1			
17	PIV=1	RSVD	Association = 1		Identifier Type = 3			
18	Reserved							
19	Designator Length = 8							
20-27	Target Port Identifier (World Wide ID)							
28	Protocol Identifier = 6h				Code Set = 1			
29	PIV=1	RSVD	Association = 1		Identifier Type = 4			
30	Reserved							
31	Designator Length = 4							
32-35	Relative Port Identifier							
36	Protocol Identifier = 6h				Code Set = 1			
37	PIV=1	RSVD	Association = 2		Identifier Type = 3			
38	Reserved							
39	Designator Length = 8							
40-47	Target Device Name Identifier (Worldwide ID)							
48	Protocol Identifier = 0h				Code Set = 3			
49	PIV=1	RSVD	Association = 2		Identifier Type = 3			
50	Reserved							
51	Designator Length = 24							
52-75	Target Device Identifier (World Wide ID)							

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- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length is set to 80. This field specifies the length of the following page data.
- Protocol Identifier is valid only when PIV (Protocol Identifier Value) =1. A value of 6 for Protocol Identifier specifies SAS devices.
- Code Set specifies the data type for the identifier field: 1 indicates binary data; 3 indicates ASCII.
- PIV (Protocol Identifier Valid): 0 indicates that the Protocol Identifier field should be ignored; 1 indicates that the Protocol Identifier field contains a valid value.
- Association specifies the entity associated with the Identifier field: 0h for LUN, 1h for Target or Relative Port, or 2h for Target Device.
- Designator Type specifies the format and assignment authority for the identifier: 3h indicates NAA format of the WWID for LUN, Target Port and Target Device; 4h indicates Relative Port; 8h indicates SCSI name string.
- Designator Length specifies the length in bytes of the designator data.
- Designator is the actual data described by the prior 4 bytes (Protocol Identifier through Designator Length) for each Designator in the page.
  - The LUN, Target Port, and Target Device Name Identifiers are defined in the NAA IEEE WWID format, where Worldwide ID is a 64-bit unique identification for each drive. The format is 5000CCAh xxxh yyb n, where:
    - xxx is the 12-bit block assignment defined for each model and manufacturing site.
    - yy is the 2-bit port/node ID select.
    - n is the 22-bit drive unique serial number.
- Relative Port Identifier indicates the port that received the Inquiry command: 0000 0001h for the Primary Port, or 0000 0002h for the Secondary Port.
- The SCSI name string Designator data is defined in the NAA IEEE WWID format (above), ending with 4 bytes of 00h to provide a multiple of 4 in length and null termination.

16.4.7 Inquiry Data - EVPD = 1, Page Code = 86h - Extended INQUIRY Data Page

Table 16 - 17: Inquiry Data Format - EVPD = 1 (Page Code = 86h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Peripheral Qualifier			Peripheral Device Type = 0				
1	Page Code = 86h							
2-3	Page Length = 003Ch							
4	Activate Microcode		SPT			GRD_CHK	APP_CHK	REF_CHK
5	Reserved		UASK_SUP	GROUP_SUP	PRIOR_SUP	HEADSUP	ORDSUP	SIMPSUP
6	Reserved				WU_SUP	CRD_SUP	NV_SUP	V_SUP
7	Reserved			P_I_I_SUP	Reserved			LUICLR
8	Reserved			R_SUP	Reserved			CBCS
9	Reserved				Multi I_T Nexus Microcode Download			

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10-11	Extended Self-Test Completion Minutes			
12	POA_SUP	HRA_SUP	VSA_SUP	Reserved
13	Maximum Supported Sense Data Length			
14-63	Reserved			

- Activate Microcode is set to 01b to indicate that the device server:
  - Activates the microcode before completion of the final command in the WRITE BUFFER sequence, and;
  - Establishes a Unit Attention condition for the initiator port associated with every I_T nexus, except the I_T nexus on which the WRITE BUFFER command was received, with the Additional Sense Code set to MICROCODE HAS BEEN CHANGED.
- SPT (Supported Protection Type) is set to 001b to indicate that the drive supports type 1 and type 2 protection.
- GRD_CHK (Guard Check bit) is set to 1 to indicate that the drive checks the Logical Block Guard Tag field in the protection information, if any.
- APP_CHK (Application Tag Check bit) is set to 1 to indicate that the drive checks the Logical Block Application Tag field in the protection information, if any.
- REF_CHK (Reference Tag Check bit) is set to 1 to indicate that the drive checks the Logical Block Reference Tag field in the protection information, if any.
- UASK_SUP (Unit Attention Condition Sense Key Specific Data Supported bit) is set to 0 to indicate that the device server does not return sense key-specific data for the UNIT ATTENTION Sense Key.
- GROUP_SUP (Group Supported bit) is set to 0 to indicate that the grouping function is not supported.
- PRIOR_SUP (Priority Supported bit) is set to 0 to indicate that task priority is not supported.
- HEADSUP (Head of Queue Supported) bit is set to 0 to indicate that Head of Queue is not supported.
- ORDSUP (Ordered Supported bit) is set to 0 to indicate that ordered tasks are not supported.
- SIMPSUP (Simple Supported bit) is set to 1 to indicate support for Simple task attributes.
- WU_SUP (Write Uncorrectable Supported bit) is set to 1 to indicate support for WR_UNCOR in the WRITE LONG command.
- CRD_SUP (Correction Disable Supported bit) is set to 1 to indicate support for COR_DIS in the WRITE LONG command.
- NV_SUP (Non-volatile Supported bit) is set to 0 to indicate that non-volatile cache features are not supported.
- V_SUP (Volatile Supported) is set to 1 to indicate support of a volatile cache.
- P_I_I_SUP (Protection Information Interval Supported bit) is set to 0 to indicate that the logical unit does not support protection information intervals.
- R_SUP (Referrals Supported bit) is set to 0 to indicate that the device server does not support referrals.
- POA_SUP (Power On Activation Supported bit) is set to 1 to indicate that the device server supports a WRITE BUFFER command with the MODE field set to 0Dh and the PO_ACT bit set to 1.
- HRA_SUP (Hard Reset Activation Supported bit) is set to 1 to indicate that the device server supports a WRITE BUFFER command with the MODE field set to 0Dh and the HR_ACT bit set to 1.
- VRA_SUP (Vendor Specific Activation Supported bit) is set to 1 to indicate that the device server supports a WRITE BUFFER command with the MODE field set to 0Dh and the VSE_ACT bit set to 1.
- Maximum Supported Sense Data Length indicates the maximum length in bytes of sense data that the device server can return in the same I_T_L_Q nexus transaction as the status.

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16.4.8 Inquiry Data - EVPD = 1, Page Code = 87h - Mode Page Policy Page

Table 16 - 18: **Inquiry Data Format - EVPD = 1 (Page Code = 87h)**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 87h							
2-3	Page Length = 0004h							
4	Reserved		Policy Page Code = 3Fh					
5	Policy Subpage Code = FFh							
6	MLUS=1	Reserved					Mode Page Policy = 0	
7	Reserved							

- Policy Page Code is set to 3Fh, and Policy Subpage Code is set to FFh, to indicate that the descriptor applies to all mode pages and subpages
- MLUS Multiple Logical Units Share is set to 1 to indicate the policy is shared by multiple logical units.
- Mode Page Policy is set to 00b to indicate that all mode pages and subpages are shared.

16.4.9 Inquiry Data - EVPD = 1, Page Code = 88h - SCSI Ports Page

Table 16 - 19: **Inquiry Data Format - EVPD = 1 (Page Code = 88h)**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 88h							
2-3	Page Length = 48 (0030h)							
4-5	Reserved							
6-7	Primary Relative Port = 0001h							
8-9	Reserved							
10-11	initiator Port Transport ID Length = 0							
12-13	Reserved							
14-15	Primary Target Port Descriptors Length = 0Ch							
16	Protocol Identifier				Code Set = 1			
17	PIV=1	RSVD	Association = 1		Identifier Type = 3			
18	Reserved							
19	Identifier Length = 8							

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	Bit							
Byte	7	6	5	4	3	2	1	0
20-27	Primary Target Port Identifier (World Wide ID)							
28-29	Reserved							
30-31	Secondary Relative Port = 0002h							
32-33	Reserved							
34-35	initiator Port Transport ID Length = 0							
36-37	Reserved							
38-39	Secondary Target Port Descriptors Length = 0Ch							
40	Protocol Identifier				Code Set = 1			
41	PIV=1	RSVD	Association = 1			Identifier Type = 3		
42	Reserved							
43	Identifier Length = 8							
44-51	Secondary Target Port Identifier (Worldwide ID)							

- Protocol Identifier is valid only when PIV=1. A Protocol Identifier value of 6 specifies SAS devices.
- Code Set specifies the data type for the identifier field; 1 indicates binary data.
- PIV Protocol Identifier Valid is set to 1, to indicate that the Protocol Identifier field contains a valid value.
- Association specifies the entity associated with the Identifier field : 1h for Target or Relative Port.
- Identifier Type specifies the format and assignment authority for the identifier: 3h indicates NAA format of the WWID for the Target Port.
- Identifier contains the actual Identifier Descriptor.
- The Target Port Identifiers are defined in the NAA IEEE WWID format where:
- Worldwide ID is a 64-bit unique identification for each drive.
- The format is 5000CCAh xxxh yyb n, where xxx is the 12-bit block assignment defined for each model and manufacturing site, yy is the 2-bit port/node ID selection, and n is the 22-bit drive unique serial number.

16.4.10 Inquiry Data - EVPD = 1, Page Code = 8Ah - Power Condition Page

Table 16 - 20: Inquiry Data Format - EVPD = 1 (Page Code = 8Ah)

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 8Ah							
2-3	Page Length = 14 (000Eh)							
4	Reserved						STANDBY_Y = 0	STANDBY_Z = 1
5	Reserved					IDLE_C=0	IDLE_B=0	IDLE_A=1
6-7	Stopped Condition Recovery Time = 0							

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8-9	Standby_Z Condition Recovery Time = 10 (0Ah)
10-11	Standby_Y Condition Recovery Time = 0
12-13	Idle_A Condition Recovery Time = 10 (0Ah)
14-15	Idle_B Condition Recovery Time - 0
16-17	Idle_C Condition Recovery Time = 0

- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length is set to 14. This field specifies the length of the following page data.
- STANDBY_Y, STANDBY_Z, IDLE_C, IDLE_B, IDLE_A are set to 0 to indicate these Power Conditions are not supported.
- Recovery Time indicates the time, in one-millisecond increments, that the logical unit takes to transition from the associated power condition to the active power condition. These Recovery Times are set to 0 to indicate the associated power conditions are not supported.

16.4.11 Inquiry Data - EVPD = 1, Page Code = 8Dh - Power Consumption Page

Table 16 - 21: Inquiry Data Format - EVPD = 1 (Page Code = 8Dh)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 8Dh							
2-3	Page Length = 8 (0008h)							
4	Power Consumption Identifier = 00h							
5	Reserved					Power Consumption Units = 3		
6-7	Power Consumption Value = 0009h							
8	Power Consumption Identifier = 01h							
9	Reserved					Power Consumption Units = 3		
10-11	Power Consumption Value = 000Bh							
8	Power Consumption Identifier = 02h							
9	Reserved					Power Consumption Units = 3		
10-11	Power Consumption Value = 000Eh							

- Power Consumption Identifier is a reference handle to specify which descriptor is selected by the Power Consumption mode page.
- Power Consumption Units is set to 3 to indicate the value is in watts.
- Power Consumption Value is the maximum power consumption associated with the identifier in the Power Consumption Identifier field, using the units specified by the Power Consumption Units.

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16.4.12Inquiry Data - EVPD = 1, Page Code = 90h - Protocol Specific Logical Unit Information Page

Table 16 - 22: Inquiry Data Format - EVPD = 1 (Page Code = 90h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 90h							
2-3	Page Length = 24 (0018h)							
4-15	Protocol-specific logical unit information descriptor 0							
16-27	Protocol-specific logical unit information descriptor 1							

- Qualifier is set to 0, to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0, to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length is set to 24. It specifies the length of the following page data.
- Protocol-specific logical unit information descriptor 0 is defined in following table.
- Protocol-specific logical unit information descriptor 1 is defined in following table.

Table 16 - 23: Protocol-specific Logical Unit Information Descriptor

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Relative Port Identifier							
2	Reserved				Protocol Identifier = 6h			
3-5	Reserved							
6-7	Descriptor Length (0004h)							
8	Reserved						Power Disable Supported = 1h	TLR Control Supported = 0h
9-11	Reserved							

- Relative Port Identifier is set to 1 for Port A (Primary Port) or 2 for Port B (Secondary Port).
- Protocol Identifier is set to 6 to specify that this is a SAS SSP Descriptor.
- TLR Control Supported specifies support of the TLR CONTROL field in the SAS SSP frame header. This field is set to 0 to indicate that the drive does not support Transport Layer Retries.

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16.4.13Inquiry Data - EVPD = 1, Page Code = 91h

Table 16 - 24: Protocol-specific Port Information VPD Page to SAS SSP

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 91h							
2-3	Page Length = 24 (0018h)							
4-15	Port Information Descriptor 0							
16-27	Port Information Descriptor 1							

- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length is set to 24. This field specifies the length of the following page data.
- Port Information Descriptor 0 and Descriptor 1 are defined in the followingtable.

Table 16 - 25: Port Information Descriptor for SAS SSP

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Relative Port Identifier							
2	Reserved				Protocol Identifier (6h)			
3	Reserved							PWR_D_S
4-5	Reserved							
6-7	Descriptor Length (0004h)							
8-11	SAS PHY Information Descriptor 0							

- Relative Port Identifier is set to 1 for Port A (Primary Port) or 2 for Port B (Secondary Port).
- Protocol Identifier is set to 6 to specify that this is a SAS SSP Descriptor.
- PWR_D_S, Power Disable Supported, is set to 1 to specify that the POWER DISABLE signal is supported.
- SAS PHY Information Descriptor 0 is defined in following table.

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Table 16 - 26: **SAS PHY Information Descriptor for SAS SSP**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved							
1	PHY Identifier							
2	Reserved							SSP Persistent Capable
3	Reserved							

- PHY Identifier is set to 0 for Port A (Primary Port) or 1 for Port B (Secondary Port).
- SSP Persistent Capable is set to 0 to indicate that the PHY does not support persistent connections.

16.4.14 Inquiry Data - EVPD = 1, Page Code = B0h - Block Limits VPD Page

Table 16 - 27: **Inquiry Data Format - EVPD = 1 (Page Code = B0h)**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = B0h							
2-3	Page Length = 60 (003Ch)							
4	Reserved							WSNZ=0
5	Maximum Compare and Write Length = 0							
6-7	Optimal Transfer Length Granularity							
8-11	Maximum Transfer Length = 0							
12-15	Optimal Transfer Length = 0							
16-19	Maximum Prefetch XDRead XDWrite Transfer Length = 0							
20-23	Maximum Unmap LBA Count = FFFFFFFFh							
24-27	Maximum Unmap Block Descriptor Count = FFFFFFFFh							
28-31	Optimal Unmap Granularity							
32-35	UGAVALID=1	Unmap Granularity Alignment = 0						
36-43	Maximum Write Same Length = 0							
44-47	Maximum Atomic Transfer Length = 00000080h							
48-51	Atomic Alignment = 00000080h							
52-55	Atomic Transfer Length Granularity = 00000008h							
56-59	Maximum Atomic Transfer Length with Atomic Bound = 0							

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60-63	Maximum Atomic Boundary Size = 0

- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length is set to 60 (3Ch). It specifies the length of the following page data.
- WSNZ Write Same No Zero is set to 0 to indicate the device server supports a value of 0 in the NUMBER OF LOGICAL BLOCKS field, in the WRITE SAME command CDB.
- Maximum Compare and Write Length is set to 0 to indicate the device server does not support the COMPARE AND WRITE command.
- Optimal Transfer Length Granularity indicates the optimal transfer length granularity size in logical blocks for any of the following supported media access commands: PREFETCH, READ, VERIFY, WRITE, WRITE AND VERIFY. It will be either 8 or 1, depending on the block size (512.../4k...) the drive is formatted with.
- Maximum Transfer Length is set to 0 to indicate that there is no reported limit on the maximum transfer length in logical blocks that the device server accepts for a single request, using any of the following supported media access commands: PREFETCH, READ, VERIFY, WRITE, WRITE AND VERIFY.
- Optimal Transfer Length is set to 0 to indicate there is no reported value for the optimal transfer length in logical blocks for any of the following supported media access commands: PREFETCH, READ, VERIFY, WRITE, and WRITE AND VERIFY.
- Maximum Prefetch XDRead XDWrite Transfer Length indicates the maximum transfer length in logical blocks that the device server accepts for a single PRE-FETCH command. It is set to 0 to be less than or equal to the Maximum Transfer Length (described above).
- Maximum Unmap LBA Count is set to FFFFFFFFh. It indicates the maximum number of LBAs that may be unmapped by an UNMAP command.
- Maximum Unmap Block Descriptor Count is set to FFFFFFFFh. It indicates the maximum number of UNMAP block descriptors contained in the parameter data transferred to the device server for an UNMAP command.
- Optimal Unmap Granularity indicates the optimal granularity in logical blocks for unmap requests. It will be either 8 or 1, depending on the block size (512.../4KB...) the drive is formatted with.
- UGAVALID Unmap Granularity Alignment VALID is set to 1 to indicate that the UNMAP GRANULARITY ALIGNMENT field is valid.
- Unmap Granularity Alignment is set to 0 to indicate the LBA of the first logical block to which the OPTIMAL UNMAP GRANULARITY field applies.
- Maximum Write Same Length is set to 0 to indicate that there is no reported limit on the number of logical blocks that may be requested for a single WRITE SAME command.
- Maximum Atomic Transfer Length for the WRITE ATOMIC command is 64KB (80h 5xx sectors or 10h 4K sectors).
- Atomic Alignment is 64KB. It indicates that the starting LBA for a WRITE ATOMIC command must be aligned to an 80h sector boundary for 5xx formatted block size, or to a 10h sector boundary for 4K formatted block size.
- Atomic Transfer Length Granularity is 4K (8h 5xx sectors or 1h 4KB sector). Transfer length specified in the WRITE ATOMIC CDB must be a multiple of this value.
- Maximum Atomic Transfer Length with Atomic Boundary is 0, indicating that no maximum is specified.
- Maximum Atomic Boundary Size of 0 indicates that non-zero values for the atomic boundary field in the WRITE ATOMIC CDB are not supported.

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16.4.15 Inquiry Data - EVPD = 1, Page Code = B1h - Block Device Characteristics VPD Page

Table 16 - 28: Inquiry Data Format - EVPD = 1 (Page Code = B1h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = B1h							
2-3	Page Length = 60 (003Ch)							
4-5	Medium Rotation Rate = 1 (1h)							
6	Reserved							
7	WABEREQ		WACEREQ		Nominal Form Factor = 3h			
8-63	Reserved							

- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length is set to 60. This field specifies the length of the following page data.
- Medium Rotation Rate is set to 1 to indicate the drive is an SSD.
- WABEREQ is set to 1 to indicate that following a Sanitize Block Erase, the drive will respond to a read command to in-range LBAs with Good status, prior to a write command being issued to those LBAs. The data pattern for the read commands will consist of all zeros.
- WACEREQ is set to 1 for models with encryption enabled to indicate that following a Sanitize Cryptographic Erase, the drive will respond to a read command to in-range LBAs with Good status, prior to a write command being issued to those LBAs. The data pattern for the read command will consist of all zeroes. WACEREQ is set to 0 for models with encryption disabled to indicate that Sanitize Cryptographic Erase is not supported, and therefore the drive behavior following this unsupported function is not specified.
- Nominal Form Factor is set to 3h.

16.4.16 Inquiry Data - EVPD = 1, Page Code = B2h - Logical Block Provisioning VPD Page

Table 16 - 29: Inquiry Data Format - EVPD = 1 (Page Code = B2h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = B2h							
2-3	Page Length = 4 (0004h)							
4	Threshold Exponent = 0							
5	LBPU= 1	LBPWS= 1	LBPWS10 =1	Reserved		LBPRZ=1	ANC_SUP=1	DP=0
6	Reserved					Provisioning Type = 1		
7	Reserved							

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- Threshold Exponent is set to 0 to indicate that the logical unit does not support logical block provisioning thresholds.
- LBPU is set to 1 to indicate that the device supports the UNMAP command.
- LBPWS is set to 1 to indicate that the device supports the WRITE SAME(16) command to unmap LBAs.
- LBPWS10 is set to 1 to indicate that the device supports the WRITE SAME(10) command to unmap LBAs.
- LBPRZ is set to 1 to indicate that for an unmapped LBA specified by a read operation, the device returns user data with all bits set to 0 to the Data-In Buffer.
- ANC_SUP is set to 1 to indicate that the device supports anchored LBAs.
- DP is set to 0 to indicate no Provisioning Group Descriptor is present.
- Provisioning Type is set to 1 to indicate the logical unit is resource-provisioned.

16.4.17 Inquiry Data - EVPD = 1, Page Code = D2h - Component and Assembly Information Page

Table 16 - 30: Inquiry Data Format - EVPD = 1 (Page Code = D2h)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = D2h							
2	Reserved = 0							
3	Page Length = 120 (78h)							
4	HDC Version Length = 19 (13h)							
5-23	ASCII HDC Version							
24	Card Serial Number Length = 19 (13h)							
25-43	ASCII Card Serial Number							
44	NAND FLASH Version Length = 19 (13h)							
45-63	ASCII NAND FLASH Version							
64	Card Assembly Part Number Length = 19 (13h)							
65-83	ASCII Card Assembly Part Number							
84	Second Card Serial Number Length = 19 (13h)							
85-103	ASCII Second Card Serial Number							
104	Second Card Assembly Part Number Length= 19 (13h)							
105-123	ASCII Second Card Assembly Part Number							

- Qualifier is set to 0 to indicate that the LUN specified in the Command Block is currently supported.
- Peripheral Device Type is set to 0 to indicate that the device is Direct Access.
- Page Code is set to the value of the page code field in the CDB.
- Page Length is set to 120. This field specifies the length of the following page data.

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Notes:

1. If the media is not available, bytes 0 through 3 are valid. All the other fields are ASCII blanks (20h) with a null terminator (00h).
2. All ASCII fields are alphanumeric, left aligned, and padded on the right with ASCII blanks (20h) with a null terminator (00h).

16.5 Log Select (4C)

The LOG SELECT (4C) command provides a means for the initiator to clear statistical information maintained by the drive and reported via the LOG SENSE command.

Table 16 - 31: Log Select (4C)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 4Ch							
1	Reserved						PCR	SP
2	PC		Page Code					
3	Subpage Code = 0							
4-6	Reserved							
7-8	Parameter List Length = 0							
9	Control Byte – Refer to SCSI Control Byte							

- PCR (Parameter Code Reset) determines whether the Log Sense parameters will be cleared and Unit Attention posted for all other initiators. A value of 1 indicates that the parameters will be cleared, while a value of zero (except when PC = 11b) indicates that the parameters will not be cleared. Parameter List Length must be zero when PCR is 1. The PC field is ignored for list parameters, i.e. when the Format and Linking (F&L) field contains 01b or 11b.
- SP (Save Parameters bit): 0 indicates that the page parameters will not be saved. A value of 1 indicates that the page parameters that are savable will be saved after they have been changed. The SP bit *must* be 1 if Parameter List Length is greater than 0; otherwise, a Check Condition status is returned. The Sense Key is then set to Illegal Request, with an Additional Sense Code of Invalid Field in the CDB.
- PC (Page Control) defines the type of parameters to be selected. A value of 11b (and PCR unused) indicates that the Default Cumulative values are set to their default values of 0. If the PC field is set to 01b, and PCR is set to 1, the Current Cumulative values are also set to their default values of 0.
- Parameter List Length *must* be zero when PC = 11b. Otherwise, the command is terminated and a Check Condition status is returned. The Sense Key is then set to Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- Page Code identifies the page being selected. This field *must* be set to the values indicated in Page 0. If the Page Code value is invalid, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- If page code field is set to 0, the selection applies to all log parameters in all valid log pages.
- If page code field is set to a non-zero value, the selection applies to all log parameters specified by this field.
- Subpage Code specifies the subpage to select. This field is not supported and must be set to 0.
- Parameter List Length specifies the length in bytes of the parameter list located in the DATA OUT buffer. A parameter list length of zero indicates that no pages will be transferred.
- If the PARAMETER LIST LENGTH field is set to 0, the PCR bit, the SP bit, and the PC fields apply to the page(s) addressed by the page code field.
- If the PARAMETER LIST LENGTH field is set to a non-zero value, and PAGE CODE or SUBPAGE CODE is a non-zero value, the command is terminated with a Check Condition status. The Sense Key is then set to ILLEGAL REQUEST, and the Additional Sense Code is set to INVALID FIELD IN THE CDB.

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1. A specified length greater than 0x00FF will generate a Check Condition status. A length that results in log data being truncated will also generate a Check Condition status.
2. For page 0Fh, the maximum parameter list length supported is 4004h (4 bytes for the header and 100h bytes for each of the 40h parameters that are supported). The Parameter List Length must be an integral of the number of parameters plus the 4-byte header. (Example: Parameter length =104h for one parameter, 204h for 2 parameters, 4004h for all 40h parameters.)

The drive allows updates only to the current cumulative values. A value of 0 is acceptable and is not considered an error.

The drive updates only pages 0Eh (the Start/Stop Cycle page) and 0Fh (the Application Client page). For other pages, the parameters are ignored. If the Data Out buffer contains multiple pages, the application client should send the pages in ascending order. If the Data Out buffer contains multiple log parameters within a page, all log parameters within the page should be sent in ascending order by parameter code value.

The drive returns a Check Condition status if the application client sends pages out of order, or if a parameter code is out of order or missing. The Sense Key is then set to Illegal Request and an Additional Sense Code set to Invalid Field in Parameter List. If one or more CDB fields are not set correctly, the command will be terminated with a Check Condition status. The Sense Key will then be set to Illegal Request, with an Additional Sense Code of Invalid Field in the CDB. To indicate that parameters have changed, the target generates a Unit Attention condition for all initiators except the one that issued the LOG SELECT command (when PCR=1).

The following list contains all individual page parameters (counters) that are set to their default value of 0 by the LOG SELECT command:

Page 02h parameters (counters for write errors):

- Write errors recovered without delay
- Write errors recovered with possible delays
- LBAs with write fault errors
- Total errors recovered
- Number of times recovery invoked
- Total write byte count
- LBAs with hard errors

Page 03h parameters (counters for read errors)

- Read errors recovered without delay
- Read errors recovered with possible delays
- LBAs with ECC detected errors
- Total errors recovered
- Number of times recovery invoked
- Total read byte count
- LBAs with hard errors

Page 05h parameters (Counters for Verify Errors):

- Errors recovered without delay
- Errors recovered with possible delays
- LBAs with ECC detected errors
- Total errors recovered
- Number of times recovery invoked
- Total bytes verified
- LBAs with hard errors

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Page 06h parameters (Counters for non-medium errors and other hardware type failures):

- Non-Medium Error Counter

Page 15h parameters (Background Medium Scan Information):

- BMS Status parameter
- All Medium Scan parameters

Page 18h parameters (SAS PHY Error counts - only cleared for the port which receives the Log Select)

- Invalid DWORD Count
- Running Disparity Error Count
- Loss of DWORD Synchronization Count
- PHY Reset Problem Count

Page 37h parameters:

- Media Exception
- Hardware Exception
- Total Read Commands
- Total Write Commands

16.6 Log Sense (4D)

The LOG SENSE (4D) command allows the initiator to retrieve the drive's statistical data.

Table 16 - 32: Log Sense (4D)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 4Dh							
1	Reserved						PPC = 0	SP
2	PC		Page Code					
3	Subpage Code = 0							
4	Reserved							
5-6	Parameter Pointer = 0							
7-8	Allocation Length							
9	Control Byte - Refer to SCSI Control Byte							

- PPC (Parameter Pointer Control bit) must be set to 0. This specifies that the drive transfers data, starting from the field specified in the parameter pointer field, for the number of bytes specified by the allocation length. If the PPC bit is set to 1, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- SP (Save Parameters bit): 0 specifies that the drive does not save any log parameters; 1 indicates that all saveable page parameters (denoted by a DS = 0 in the parameter header control byte) will be saved.
- PC (Page Control) defines the type of parameters to be selected. This field must be set to 01b to specify the current cumulative values. Any other value in this field causes the command to end with a Check Condition status, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.

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- Page Code identifies which page is being requested. This field must be set to the values indicated in Page 0. If the Page Code value is invalid, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- Subpage Code specifies the subpage to select. This field is not supported and must be set to 0.
- Parameter Pointer specifies the beginning field for the transfer. This field must be set to 0000h. If the Parameter Pointer Field is not 0, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- Allocation Length specifies the maximum number of bytes the initiator has allocated for returned Log Sense data. No bytes are transferred if the length is 0 (this condition is not considered an error). The target terminates the Data-In phase when all available Log Sense data has been transferred, or when the number of bytes equals the Allocation Length, whichever occurs first.

16.6.1 Log Page Parameters

Each log page begins with a 4-byte page header, optionally followed by variable-length log parameters. In the page header, the Page Code field identifies which log page is being transferred. The Page Length field specifies the length in bytes of the subsequent log parameters.

Each log parameter begins with a 4-byte parameter header followed by one or more bytes of parameter value data.

- The Parameter Code field identifies which log parameter is being transferred for that log page.
- The Parameter Control field, the 3rd byte of each parameter header, contains several fields:
- DU (Disable Update bit) is set to 0 to indicate that the drive updates the log parameter value to reflect events that should be noted by that parameter.
- TSD (Target Save Disable bit) is set to 0 to indicate the drive provides a target-defined method for saving log parameters.
- ETC (he Enable Threshold Comparison bit is set to 0 to indicate the drive does not perform comparisons between cumulative and threshold values.
- TMC (Threshold Met Criteria field) is not valid, because this drive does not perform threshold comparisons. This field is set to 0.
- Format and Linking indicates the type of log parameter and how parameters that reach their maximum value are handled.
- 00b -Data counter: If any other parameter in this log page reaches its maximum value, then this parameter stops incrementing until reinitialized by a Log Select command.
- 01b - List format ASCII data: There are no maximum values to handle.
- 10b - Data counter: If another parameter reported in this log page reaches its maximum value, then this parameter does not stop incrementing. This parameter may be reinitialized by a Log Select command.
- 11b - List format binary data: There are no maximum values to handle.

16.6.2 Log Sense Page 0h - Supported Log Sense Pages

This page is used to determine which additional pages the initiator can request.

Table 16 - 33: Log Sense Page 0h - Supported Log Sense Pages

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 0					
1	Reserved							
2-3	Page Length = 0012h (Number of Pages Supported)							
4	First supported page 00h							
5	Second supported page 02h							
6	Third supported page 03h							

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7	Fourth supported page 05h
8	Fifth supported page 06h
9	Sixth supported page 0Dh
10	Seventh supported page 0Eh
11	Eighth supported page 0Fh
12	Ninth supported page 10h
13	Tenth supported page 11h
14	Eleventh supported page 15h
15	Twelfth supported page 17h
16	Thirteenth supported page 18h
17	Fourteenth supported page 19h
18	Fifteenth supported page 1Ah
19	Sixteenth supported Page Code =2Fh
20	Seventeenth supported Page Code = 30h
21	Eighteenth supported Page Code = 37h

16.6.3 Log Sense Page 2h - Counters for Write Errors

Table 16 - 34: Log Sense Page 2h - Counters for Write Errors

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 02h					
1	Reserved							
2-3	Page Length = 54h							
4-5	Parameter Code = 0000h							
6	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
7	Parameter Length = 08h							
8-15	Errors Recovered without Delay							
16-17	Parameter Code = 0001h							
18	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
19	Parameter Length = 08h							
20-27	Errors Recovered with Possible Delays							
28-29	Parameter Code = 0002h							
30	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	

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31	Parameter Length = 08h					
32-39	Reserved					
40-41	Parameter Code = 0003h					
42	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0	F&L = 00b
43	Parameter Length = 08h					
44-51	Total errors recovered					
52-53	Parameter Code = 0004h					
54	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0	F&L = 00b
55	Parameter Length = 08h					
56-63	Times Recovery Invoked					
64-65	Parameter Code = 0005h					
66	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0	F&L = 00b
67	Parameter Length = 08h					
68-75	Total Bytes Written					
76-77	Parameter Code = 0006h					
78	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0	F&L = 00b
79	Parameter Length = 08h					
80-87	Count of Hard Errors					

Notes:

1. All parameter counts indicate the number of sectors with the specified types of errors, except Times Recovery Invoked, which is a cumulative count of all recovery steps attempted on all sectors written.

16.6.4 Log Sense Page 3h - Counters for Read Errors

Table 16 - 35: **Log Sense Page 3h - Counters for Read Errors**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 03h					
1	Reserved							
2-3	Page Length = 54h							
4-5	Parameter Code = 0000h							
6	DU = 0	DS = 0	TSD=0	ETC = 0	TMC = 0		F&L = 00b	
	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**

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7	Parameter Length = 08h					
8-15	Errors recovered without delay					
16-17	Parameter Code = 0001h					
18	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0	F&L = 00b
19	Parameter Length = 08h					
20-27	Errors recovered with possible delays					
28-29	Parameter Code = 0002h					
30	DU = 0	DS = 0	TSD=0	ETC = 0	TMC = 0	F&L = 00b
31	Parameter Length = 08h					
32-39	Reserved					
40-41	Parameter Code = 0003h					
42	DU = 0	DS = 0	TSD=0	ETC = 0	TMC = 0	F&L = 00b
43	Parameter Length = 08h					
44-51	Total errors recovered					
52-53	Parameter Code = 0004h					
54	DU = 0	DS = 0	TSD=0	ETC = 0	TMC = 0	F&L = 00b
55	Parameter Length = 08h					
56-63	Times recovery invoked					
64-65	Parameter Code = 0005h					
66	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0	F&L = 00b
67	Parameter Length = 08h					
68-75	Total bytes read					
76-77	Parameter Code = 0006h					
78	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0	F&L = 00b
79	Parameter Length = 08h					
80-87	Count of hard errors					

Note:

1. All parameter counts indicate the number of sectors with the specified types of errors, except Times Recovery Invoked, which is a cumulative count of all recovery steps attempted on all sectors read. ECC-on-the-fly correction is not included in any counters.

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16.6.5 Log Sense Page 5h - Counters for Verify Errors

Table 16 - 36: **Log Sense Page 5h - Counters for Verify Errors**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 05h					
1	Reserved							
2-3	Page Length = 54h							
4-5	Parameter Code = 0000h							
6	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
7	Parameter Length = 08h							
8-15	Errors recovered without delay							
16-17	Parameter Code = 0001h							
18	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
19	Parameter Length = 08h							
20-27	Errors recovered with possible delays							
28-29	Parameter Code = 0002h							
30	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
31	Parameter Length = 08h							
32-39	Reserved							
40-41	Parameter Code = 0003h							
42	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
43	Parameter Length = 08h							
44-51	Total errors recovered							
52-53	Parameter Code = 0004h							
54	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
55	Parameter Length = 08h							
56-63	Times recovery invoked							
64-65	Parameter Code = 0005h							
66	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
67	Parameter Length = 08h							
68-75	Total Bytes Verified							
76-77	Parameter Code = 0006h							
78	DU = 0	DS = 0		TSD = 0	TMC = 0		F&L = 00b	

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79	Parameter Length = 08h
80-87	Count of hard errors

Note:

1. All parameter counts indicate the number of sectors with the specified types of errors, except Times Recovery Invoked, which is a cumulative count of all recovery steps attempted on all sectors verified. ECC-on-the-fly correction is not included in any counters.

16.6.6 Log Sense Page 6h - Counters for Non-medium Errors

This page counters for non-medium errors.

Table 16 - 37: Log Sense Page 6h - Counters for Non-medium Errors

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 06h					
1	Reserved							
2-3	Page Length = 0Ch							
4-5	Parameter Code = 00h							
6	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
7	Parameter Length = 08h							
8-15	Error count							

16.6.7 Log Sense Page Dh - Temperature Information

Table 16 - 38: Log Sense Page Dh - Temperature Information

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 0Dh					
1	Reserved							
2-3	Page Length = 0Ch							
4-5	Parameter Code = 0000h							
6	DU = 0	DS = 1	TSD = 0	ETC = 0	TMC = 0		F&L = 11b	
7	Parameter Length = 02h							
8	Reserved							
9	Temperature (Celsius)							
	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**

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10-11	Parameter Code 0001h					
12	DU = 0	DS = 1	TSD = 0	ETC = 0	TMC = 0	F&L = 11b
13	Parameter Length = 02h					
14	Reserved					
15	Reference Temperature (Celsius)					

Notes:

1. Reference Temperature is the threshold, in degrees Celsius, for case temperature warnings.

16.6.8 Log Sense Page Eh - Manufacturing Date Information

Table 16 - 39: Log Sense Page Eh - Manufacturing Date Information

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 0Eh					
1	Reserved							
2-3	Page Length = 34h							
4-5	Parameter Code = 0001h							
6	DU=0	DS=1	TSD=0	ETC=0	TMC = 0		F&L = 01b	
7	Parameter Length = 06h							
8-11	Year of Manufacture (4 ASCII characters)							
12-13	Week of Manufacture (2 ASCII characters)							
14-15	Parameter Code 0002h							
16	DU=0	DS=0	TSD=0	ETC=0	TMC = 0		F&L = 01b	
17	Parameter Length = 06h							
18-21	Accounting Date Year (4 ASCII characters)							
22-23	Accounting Date Week (2 ASCII characters)							
24-25	Parameter Code 0003h							
26	DU=0	DS=1	TSD=0	ETC=0	TMC = 0		F&L = 11b	
27	Parameter Length = 04h							
28-31	Reserved							
32-33	Parameter Code 0004h							
34	DU=0	DS=1	TSD=0	ETC=0	TMC = 0		F&L = 11b	
35	Parameter Length = 04h							
36-39	Reserved							
40-41	Parameter Code 0005h							

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42	DU=0	DS=1	TSD=0	ETC=0	TMC = 0	F&L = 11b
43	Parameter Length = 04h					
44-47	Reserved					
48-49	Parameter Code 0006h					
50	DU=0	DS=1	TSD=0	ETC=0	TMC = 0	F&L = 11b
51	Parameter Length = 04h					
52-55	Reserved					

Notes:

1. The week and year that the device was manufactured is set in the parameter field defined by parameter code 0001h. The date of manufacture cannot be saved using the LOG SELECT command. The data is expected in numeric ASCII characters (30-39h) in the form YYYYWW. The accounting date specified by parameter code 0002h is a parameter that can be saved using the LOG SELECT command.

16.6.9 Log Sense Page Fh - Application Client Log

Table 16 - 40: Log Sense Page Fh - Application Client Log

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page Code = 0Fh					
1	Reserved							
2-3	Page Length = 4000h							
	Application Client Log Parameter							
4-259	First (1st) Application Client Log Parameter							
...								
16132-16387	Sixty-Fourth (64th) Application Client Log Parameter							

Table 16 - 41: Log Sense Page Fh, Application Client Log Parameter Structure

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Parameter Code							
2	DU = 1	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 11b	
3	Parameter Length = FCh							
4-255	First Parameter Byte Last Parameter Byte							

Notes:

1. Parameter Codes 0000h through 003Fh are supported.
2. The values stored in the parameter bytes represent data sent to the device in a previous LOG SELECT command.

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16.6.10 Log Sense Page 10h - Self-test Results

The results of the 20 most recent self-tests are stored in this Log page.

Table 16 - 42: Log Sense Page 10h - Self-test Results

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 10h					
1	Reserved							
2-3	Page Length = 190h							
4-23	1st self-test results log parameter							
...								
384- 403	20th self-test results log parameter							

Table 16 - 43: Log Sense Page 10h - Self-test Results Log Parameter Structure

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Parameter code							
2	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 11b	
3	Parameter Length = 10h							
4	Function Code			RSVD	Self-Test Results Value			
5	Extended Segment Number = 0							
6-7	Timestamp							
8-15	LBA of First Failure							
16	Reserved				Sense Key			
17	Additional Sense Code							
18	Additional Sense Code Qualifier							
19	Vendor-specific							

- Parameter Code identifies the log parameter for the log page. The parameter code field for the results of the most recent test is 0001h. The parameter for the next most recent is 0002h.
- Function Code contains the content of the Function Code field in the SEND DIAGNOSTIC command that initiated this self-test.
- Extended Segment Number identifies the number of the segment that failed during self-test. If no segment failed, this field is 00h.
- Self-test Results Value is described in the following table.

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Table 16 - 44: **Log Sense Page 10h - Self-test Results Value**

Value	Description
0h	The self-test routine completed without error.
1h	The background self-test routine was aborted by the initiator using a SEND DIAGNOSTIC command, with the Abort Background self-test function.
2h	The self-test routine was aborted by the application client by a Task Management function or a reset.
3h	An unknown error occurred while the target was executing the self-test routine and the target was unable to complete the self-test routine.
4h	The self-test completed with a test element that failed. It is not known which test element failed.
5h	The first segment of the self-test failed.
6h	The second segment of the self-test failed.
7h	The third or greater segment of the self-test failed (see the Extended segment number field).
8h-Eh	Reserved.
Fh	The self-test is in progress.

Table 16 - 45: **Log Sense Page 10h - Extended Segment Number**

Extended Segment Number	Short Self-test	Extended Self-test
1h	Drive Ready Test	
2h	Drive Diagnostics	
3h	SMART	
4h	Low-Level Format Check	
5h	PLI Capacitor Self-Test	
6h	Random Verify	
7h	Verify First 300MB Verify Last 100MB	Verify all LBAs
8h	Recheck SMART	

- Timestamp contains the total accumulated power-on hours of the target at the time the self-test completed.
- LBA of First Failure contains the LBA of the first logical block address where a self-test error occurred. If no errors occurred during the self-test or the error is not related to a LBA then the field is FFFFFFFFFFFFFFFFh.
- Sense Key, Additional Sense Code, and an Additional Sense Code Qualifier will contain the additional information relating to the error or exception conditions during self-test.
- See SEND DIAGNOSTIC (1D) for detailed listing of operations carried out by SEND DIAGNOSTIC command and Power on Diagnostics.

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16.6.11 Log Sense Page 11h - Solid State Media Log Page

The Solid State Media log page indicates parameters specific to SCSI target devices that contain solid state media. A device server that implements the Solid State Media log page implements one or more of the defined parameters.

Table 16 - 46: Log Sense Page 11h - Solid State Media Log Page

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	DS	SPF (0)	Page Code = 11h					
1	Reserved							
2-3	Page Length = (n -3)							
	Solid State Media Log Parameters							
4	Solid State Media Parameter (First). *See Table Below.*							
...	First Medium Scan Parameter							
...								
n	Solid State Media Parameter (Last). *See Table Below.*							

Note: The DS Disable Save bit, SPF subpage format bit, Page Code, Subpage Code and Page Length are described in SCSI Primary Commands – 4 (SPC-4).

Table 16 - 47: Log Sense Page 11h - Solid State Media Log Page Parameter Codes

Parameter Code	Description
0001h	Percentage Used Endurance Indicator
All other values	Reserved

Table 16 - 48: Log Sense Page 11h - Percentage Used Endurance Indicator Parameter Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Parameter Code (0001h)							
2	DU	Obsolete	TSD	ETC	TMC		Format and Linking (11b)	
3	Parameter Length (04h)							
4-6	Reserved							
7	Percentage Used Endurance Indicator							

- Format and Linking is set to 11b, indicating that this parameter is a binary format list parameter. The values for the other bits and fields in the parameter control byte for a binary format list parameter are defined in SCSI Primary Commands – 4 (SPC-4).
- Parameter Length indicates the number of bytes to follow in the log parameter.

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- Percentage Used Endurance Indicator indicates an estimate of the percentage of device life that has been used. The field value is set to 0 at the time of manufacture. A value of 100 indicates that the estimated endurance of the device has been consumed, but may not indicate a device failure (e.g., minimum power-off data retention capability reached for devices using flash technology). The value may exceed 100. Values greater than 254 is reported as 255. The device server shall update the value at least once per power-on hour.

16.6.12 Log Sense Page 15h - Background Medium Scan Operations

Table 16 - 49: Log Sense Page 15h - Background Medium Scan Operations

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 15h					
1	Reserved							
2-3	Page Length = (19 + 24N -3)							
	Background Medium Scan Parameters							
4-19	BMS Status Parameter							
20-43	First Medium Scan Parameter							
...								
19+24N	Last Medium Scan Parameter							

The following table describes the BMS Status Parameter structure.

Table 16 - 50: BMS Status Parameter Structure

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Parameter Code = 0000h							
2	DU=0	DS=0	TSD=0	ETC=0	TMC=0		F&L = 11b	
3	Page Length = 0Ch							
4-7	Power On Minutes							
8	Reserved							
9	BMS Status							
10-11	Number of Scans Performed							
12-13	Medium Scan Progress							
14-15	Reserved							

- Power On Minutes indicates the total power on minutes at the time the log page is requested.

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Table 16 - 51: **BMS Status**

BMS Status	Description
00h	No scans active.
01h	Background medium scan is active.
02h	Background pre-scan is active.
03h-04h	Not supported.
05h	Background scan halted due to medium formatted without P-List.
06h	Background scan halted due to a vendor-specific cause.
07h	Background scan halted due to temperature out of range.
08h	Scan suspended until BMS Interval Timer expires.
09h - FFh	Reserved

- Number of Scans Performed indicates the number of background scans that have been performed over the life of the drive.
- Medium Scan Progress is a percent complete indication of the medium scan. The returned value is a numerator that has 65,536 (1 00 00h) as its denominator.

The following table describes the Medium Scan Parameter structure.

Table 16 - 52: **Medium Scan Parameter Structure**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Parameter Code = 0001h - 0800h							
2	DU=0	DS=0	TSD=0	ETC=0	TMC=0		F&L = 11b	
3	Page Length = 14h							
4-7	Power On Minutes							
8	Reassign Status				Sense Key			
9	Additional Sense Code							
10	Additional Sense Code Qualifier							
11-15	Reserved							
16-23	LBA							

- Power On Minutes indicates the total power-on minutes at the time the error was detected.
- Reassign Status is set to 0h. Auto-reallocation is automatic; no action needs to be taken by the initiator.

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16.6.13 Log Sense Page 17h - Non-Volatile Cache Log Parameters

Table 16 - 53: Log Sense Page 17h - Non-Volatile Cache Log Parameters

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	DS = 0	SPF = 0	Page Code = 17h					
1	Subpage Code = 00h							
2-3	Page Length = 0010h							
4-5	Parameter Code = 0000h							
6	DU = 0	Obsolete	TSD = 0	ETC = 0	TMC = 0		Format and Linking = 11b	
7	Parameter Length = 04h							
8	Obsolete							
9-11	Remaining Non-Volatile Time							
12-13	Parameter Code = 0001h							
14	DU = 0	Obsolete	TSD = 0	ETC = 0	TMC = 0		Format and Linking = 11b	
15	Parameter Length = 04h							
16	Obsolete							
17-19	Maximum Non-volatile Time							

- Remaining Non-Volatile Time is set to 00_0000h to indicate that the nonvolatile cache is permanently volatile.
- Maximum Non-Volatile Time is set to 00_0000h to indicate that the nonvolatile cache is volatile.

16.6.14 Log Sense Page 18h - Protocol-Specific Log Parameters

Table 16 - 54: Log Sense Page 18h - Protocol-Specific Log Parameters

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Page code = 18h							
1	Subpage Code = 00h							
2-3	Page Length = D8h							
Protocol-Specific Log Parameters								
4-111	First Protocol-Specific Log Parameter - Primary Port							
112-219	Last Protocol-Specific Log Parameter - Secondary Port							

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Table 16 - 55: **Log Sense Page 18h - SAS Log Descriptor**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Parameter Code (0001h for Primary Port; 0002h for Secondary Port)							
2	DU=0	Obsolete	TSD =0	ETC =0	TMC (00b)		Format and Linking	
3	Parameter Length (68h)							
4	Reserved				Protocol Identifier (6h)			
5	Reserved							
6	Generation Code							
7	Number of Phys (01h)							
8	Reserved							
9	Phy Identifier (00h)							
10	Reserved							
11	SAS PHY Log Descriptor Length (60h)							
12	Reserved	Attached Device Type			Attached Reason			
13	Reason				Negotiated Physical Link Rate			
14	Reserved				Attached SSP initiator Port	Attached STP initiator Port	Attached SMP initiator Port	Reserved
15	Reserved				Attached SSP Target Port	Attached STP Target Port	Attached SMP Target Port	Reserved
16-23	SAS Address (the address of the target port)							
24-31	Attached SAS Address (the address received in the incoming IDENTIFY)							
32	Attached PHY Identifier (the PHY Identifier received in the incoming Identifier)							
33-39	Reserved							
40-43	Invalid DWord Count							
44-47	Running Disparity Error Count							
48-51	Loss of DWord Synchronization							
52-55	PHY Reset Problem							
56-57	Reserved							
58	PHY Event Descriptor Length (0Ch)							
59	Number of Event Descriptors (04h)							
60-62	Reserved							
63	PHY Event Source (01h) (Invalid DWORD Count)							

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64-67	PHY Event
68-71	Peak Value Detector Threshold (00h)
72-74	Reserved
75	PHY Event Source (02h) (Running Disparity Error Count)
76-79	PHY Event
80-83	Peak Value Detector Threshold (00h)
84-86	Reserved
87	PHY Event Source (03h) (Loss of DWORD Sync)
88-91	PHY Event
92-95	Peak Value Detector Threshold (00h)
96-98	Reserved
99	PHY Event Source (04h) (PHY Reset problem)
100-103	PHY Event
104-107	Peak Value Detector Threshold (00h)

- Attached Device Type is set to the value received by this PHY during an Identify Sequence.
- Attached Reason indicates the value of the REASON field in the last received IDENTIFY address frame (see Table 4 - 12). This occurs during the identification sequence, if the Phy is a physical Phy and a SAS Phy or expander Phy is attached. If the Phy is a physical Phy, and a SATA Phy is attached, then the ATTACHED REASON field is set to 0h after the initial Register - Device to Host FIS has been received. If the Phy is a virtual Phy, then the ATTACHED REASON field is set to 0h.
- Reason indicates the reason for the last link reset sequence as reported in the last transmitted IDENTIFY address frame (see Table 15 - 8). If the Phy is a physical Phy, and a SATA Phy is attached, then the REASON field indicates the reason for the link reset sequence.
- Negotiated PHY Link Rate is set to the link rate negotiated during last Link Reset Sequence. This link rate is:
- 8h when the PHY is enabled, and the negotiated speed is 1.5G
- 9h when the PHY is enabled, and the negotiated speed is 3G
- Ah when the PHY is enabled, and the negotiated speed is 6G
- Bh when the PHY is enabled, and the negotiated speed is 12G
- Generation Code is a one-byte counter, incremented by 1 by the device server each time the values in this mode page or the SAS-2 Phy mode page are incremented (see SAS PHY Mode Page - Subpage 3). Generation Code is a one-byte counter incremented by 1 by the device server each time the values in this mode page or the SAS-2 Phy mode page are changed. A GENERATION CODE field set to 00h indicates the generation code is unknown. The device server wraps this field to 01h as the next increment after reaching its maximum value (i.e., FFh). The GENERATION CODE field is also contained in the Protocol-Specific Port log page and may be used to correlate Phy settings across mode page and log page accesses when field values are changed. A GENERATION CODE field set to 00h indicates the generation code is unknown. The device server shall wrap this field to 01h as the next increment after reaching its maximum value (i.e., FFh). The GENERATION CODE field is also contained in the Protocol-Specific Port log page and may be used to correlate Phy settings across mode page and log page accesses.
- Attached Reason indicates the value of the REASON field received in the IDENTIFY address frame.
- Attached initiator Port bits is set to the value received by this PHY during an Identify Sequence.
- Attached Target Port is set to the value received by this PHY during an Identify Sequence.
- SAS Address contains the SAS address transmitted by this PHY during an Identify Sequence.
- Attached SAS Address contains the SAS address received by this PHY during an Identify Sequence.
- Attached PHY Identifier contains the SAS PHY Identifier received by this PHY during an Identify Sequence.

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- Invalid DWord Count indicates the number of invalid DWords that have been received outside of Phy reset sequences. The count wraps at the maximum value.
- Running Disparity Error Count will increment by 1 when the port has acquired DWord synchronization and detects a transmission word containing a running disparity error at the receiver. When the port has lost DWord synchronization, the Running Disparity Error Count is not incremented. The count stops at the maximum value.
- Loss of DWord Synchronization indicates the number of times the Phy has lost DWord synchronization and restarted the link reset sequence of Phy reset sequences. The count wraps at the maximum value.
- Phy Reset Problem indicates the number of times the Phy reset sequence has failed due to a failure to gain DWord sync in the retry speed match speed negotiation. The count wraps at the maximum value.

16.6.15 Log Sense Page 19h - General Statistics and Performance

Table 16 - 56: Log Sense Page 19h - General Statistics and Performance

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	DS = 0	SPF = 0	Page Code = 19h					
1	Subpage Code = 00h							
2-3	Page Length = 005Ch							
4-5	Parameter Code = 0001h							
6	DU = 0	Obsolete	TSD = 0	ETC = 0	TMC = 0		Format and Linking = 10b	
7	Parameter Length = 40h							
8-15	Number of Read Commands							
16-23	Number of Write Commands							
24-31	Number of Logical Blocks Received							
32-39	Number of Logical Blocks Transmitted							
40-47	Read Command Processing Intervals							
48-55	Write Command Processing Intervals							
56-63	Weighted Number of Read Commands plus Write Commands							
64-71	Weighted Read Command Processing plus Write Command Processing							
72-73	Parameter Code = 0002h							
74	DU = 0	Obsolete	TSD = 0	ETC = 0	TMC = 0		Format and Linking = 10b	
75	Parameter Length = 08h							
76-83	Idle Time Intervals							
84-85	Parameter Code = 0003h							
86	DU = 0	Obsolete	TSD = 0	ETC = 0	TMC = 0		Format and Linking = 11b	
87	Parameter Length = 08h							
88-95	Time Interval Descriptor							

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- Number of Read Commands indicates the number of read commands received by the logical unit.
- Number of Write Commands indicates the number of write commands received by the logical unit.
- Number of Logical Blocks Received indicates the number of logical blocks received by any SCSI target port for the logical unit, as a result of write commands.
- Number of Logical Blocks Transmitted indicates the number of logical blocks transmitted by any SCSI target port for the logical unit as a result of read commands.
- Read Command Processing Interval is not supported and is set to 0.
- Write Command Processing Interval is not supported and is set to 0.
- Weighted Number of Read Commands Plus Write Commands is not supported and is set to 0.
- Weighted Read Command Processing Plus Write Command Processing is not supported and is set to 0.
- Idle Time Intervals indicates the cumulative number of idle times spent while there are no commands in the task set, and there are no commands being processed by the logical unit.
- Idle Time is calculated using the Time Interval in Parameter 0003h:

  Idle Time = (Time Increments not Processing Commands x Time Interval) The Time Interval Descriptor contains the time interval in seconds.

Table 16 - 57: Time Interval Descriptor

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-3	Exponent							
4-7	Integer							

- Exponent contains the negative power of 10 to multiply with the Integer field.
- Integer, when multiplied by the Exponent, contains the value that represents one time interval. The Exponent and Integer are set to the equivalent of 50ms (5x10-2 seconds).

16.6.16 Log Sense Page 1Ah - Accumulated Transitions

Table 16 - 58: Log Sense Page 1Ah - Accumulated Transitions

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page code = 1Ah					
1	Subpage Code (00h)							
2-3	Page Length (30h)							
4-5	Parameter Code 0001h							
6	DU	Obsolete	TSD	ETC	TMC		FMT & Linking	
7	Parameter Length = 4							
8-11	Accumulated Transitions to Active State							
12-13	Parameter Code 0002h							
14	DU	Obsolete	TSD	ETC	TMC		FMT & Linking	

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15	Parameter Length = 4					
16-19	Accumulated Transitions to Idle_A					
20-21	Parameter Code 0003h					
22	DU	Obsolete	TSD	ETC	TMC	FMT & Linking
23	Parameter Length = 4					
24-27	Accumulated Transitions to Idle_B					
28-29	Parameter Code 0004h					
30	DU	Obsolete	TSD	ETC	TMC	FMT & Linking
31	Parameter Length = 4					
32-35	Accumulated Transitions to Idle_C					
36-37	Parameter Code 0008h					
38	DU	Obsolete	TSD	ETC	TMC	FMT & Linking
39	Parameter Length = 4					
40-43	Accumulated Transitions to Standby_Z					
44-45	Parameter Code 0009h					
46	DU	Obsolete	TSD	ETC	TMC	FMT & Linking
47	Parameter Length = 4					
48-51	Accumulated Transitions to Standby_Y					

16.6.17 Log Sense Page 2Fh - SMART Status and Temperature Reading

Table 16 - 59: **Log Sense Page 2Fh - SMART Status and Temperature Reading**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page Code = 2Fh					
1	Reserved							
2-3	Page Length = 4Ch							
4-5	Parameter Code = 0000h							
6	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		Format & Linking = 11b	
7	Parameter Length = 8							
8	SMART Sense Code Byte							
9	SMART Sense Qualifier							
10	Most Recent Temperature Reading							
11	Vendor Temperature Trip Point							

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12	Vendor-Unique Maximum Temperature
13	Vendor-Unique - Reserved
14	Vendor-Unique – Most Recent Raw Temperature Reading
15	Vendor-Unique - Reserved
16-79	Vendor-Unique Parameters (See Note:)

Notes:

1. All temperature values are adjusted for the specified temperature offset value specified in Mode Page 00h.

Table 16 - 60: Log Sense Page 2Fh - Vendor-unique Parameter Format for Parameters >0000h

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Parameter Code							
2	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 11b	
3	Page Length = 4							
4	SMART Parameter Sense Code Byte							
5	SMART Parameter Sense Qualifier							
6	SMART Attribute Percentage of Threshold							
7	SMART Attribute Trip							

- Smart Parameter Sense Code is the one-byte value indicating the severity of this particular parameter when host notification for SMART trip is made. For example, 0x5D indicates pre-fail attribute and 0x0B indicates warning attribute.
- Smart Parameter Sense Qualifier is the one-byte value that uniquely identifies each particular parameter when host notification for SMART trip is made.
- Smart Attribute Percentage of Threshold indicates an estimate of the percentage of threshold reached for the vendor-unique SMART attributes. The value in the field is set to 0 at the time of manufacture. A value of 100 indicates that the threshold has been reached and SMART trip is reported to the host if enabled. See Mode Page 0x1C (Information Exceptions Control). The value is allowed to exceed 100. Values greater than 254 are reported as 255. The device server shall update the value at least once per power-on hour. Note that the Volatile memory backup attribute is a pass/fail indicator so it will always read 0 unless the capacitor self-test fails, and in that case it would report 100.
- Smart Attribute Trip is set to 1b if the threshold for that SMART attribute has ever been exceeded. It is set to 0b if the threshold has *never* been exceeded.

Table 16 - 61: Vendor-unique Parameter Codes >0000h

Parameter Code	Description
0001h	Remaining Reserve 1
0002h	Remaining Reserve XOR
0003h	XOR Depletion
0004h	Volatile Memory Backup Failure
0005h	Wear Indicator

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0006h	System Area Wear Indicator
0007h	Channel Hangs
0008h	Flash Scan Failure
>0008h	Reserved

16.6.18 Log Sense Page 30h - Reserved Content

Table 16 - 62: **Log Sense Page 30h - Reserved Content**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page Code = 30h					
1	Reserved							
2-3	Page Length = 0030h							
4-5	Parameter Code = 0000h							
6	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 00b	
7	Parameter Length = 2Ch							
8-51	Reserved							

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16.6.20 Log Sense Page 30h - Miscellaneous Data Counters

Table 16 - 63: **Log Sense Page 37h - Miscellaneous Data Counters**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved		Page Code = 37h					
1	Reserved							
2-3	Page Length = 0030h (48)							
4-5	Parameter Code = 0000h							
6	DU=0	DS=0	TSD=0	ETC=0	TMC = 0		F&L = 00b	
7	Parameter Length = 2Ch							
8-11	Power-On Hours (Hours Only)							
12-19	Total Bytes Read							
20-27	Total Bytes Written							
28	Maximum Drive Temp (Degrees Celsius)							
29-30	G-List Count							
31	Number of Information Exceptions							
32	MED EXC	HDW EXC	Reserved					
33-40	Total Read Commands							
41-48	Total Write Commands							
49-51	Reserved							

- Power-On Hours specifies the total time the drive has been powered on, in hours.
- Maximum Drive Temperature specifies the maximum temperature, in degrees Celsius, the drive has ever reached.
- G-List Count returns the total number of defects that are currently reported when the G-List bit is selected during READ DEFECT DATA (37h) <XREF> and READ DEFECT DATA (B7h) <XREF> commands. This count does not include the number of defects included in the drive P-List (defects that were discovered during the manufacturing tests).
- Number of Information Exceptions gives the number of Information Exceptions during the life of the drive and not the number of Information Exceptions that have been reported. The number of reported Information Exceptions may be less due to the settings of Mode Page 0x1C. Note: This field does not include occurrences of any Information Exception Warnings.
- Media Exception and Hardware Exception, if set, indicate that an Information Exception has occurred during the life of the drive. These flags are set during an Information Exception that may or may not coincide with the reporting of an Information Exceptions as mentioned above.
- Total Read Commands is a counter incremented for each Read (6) and Read (10) command received.
- Total Write Commands is a counter incremented for each Write (6), Write (10), Write Verify and Write Verify (16) command received.

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16.7 Mode Select (6) (15)

The MODE SELECT (6) (15) command provides a means for the initiator to specify LUN or device parameters to the target. It also allows an initiator to specify options the target uses in error recovery, caching, and formatting.

Table 16 - 64: MODE SELECT (6) (15)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 15h							
1	Reserved			PF = 1	Reserved			SP
2-3	Reserved							
4	Parameter List Length							
5	Control Byte - Refer to SCSI Control Byte							

There is a single set of Mode Page parameters shared by all initiators.

- PF Page Format bit: 1 indicates that the data sent by the initiator after the Mode Select Header and the Block Descriptor, if any, complies with the Page Format. The target ignores this field, as it accepts mode parameters only in the Page Format.
- SP Save Pages bit: 0 = The drive does not save the pages sent during the Data-out phase. Instead, it uses them for all subsequent commands until the power is removed, a reset is received, or a new MODE SELECT command is received. A value of 1 = The drive saves the data in the reserved area of the media. It will be used for all the following commands until another MODE SELECT command is issued. This information is maintained over a power cycle or reset of the drive.
- Parameter List Length specifies the number of bytes to be sent from the initiator. A parameter list length of 0 suppresses data transfer and is not considered an error.

The MODE SELECT parameter list contains a 4-byte header followed by 0, or a block descriptor optionally followed by one or more pages. The pages that are valid with this command are defined in the addendum under the heading Mode Select Data, as they vary with the drive model.

Application Note

The initiator should issue a MODE SENSE command requesting all Changeable Values (see PCF field in byte two of the CDB) prior to issuing a MODE SELECT command. This is necessary to determine which pages are implemented by the drive, and the length of those pages. In the pages of the MODE SENSE command, the drive returns the number of bytes supported for each page. The Page Length set by the initiator in the MODE SELECT command must be the same value as returned by the drive in MODE SENSE Page Length. If not, the drive returns a Check Condition status, with a Sense Key of Illegal Request.

Notes:

1. An initiator might send a MODE SELECT command that changes any parameters that apply to other initiators. In that case, the drive generates a Unit Attention condition for all initiators except for the one that issued the MODE SELECT command. The drive then sets the Additional Sense Code to Parameters Changed (2Ah).

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16.8 MODE SELECT (10) (55)

The MODE SELECT (10) (55) command provides a means for the initiator to specify LUN or device parameters to the target. See the MODE SELECT (10) (15) command for a description of the fields in this command.

Table 16 - 65: MODE SELECT (10) (55)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 55h							
1	Reserved			PF=1	Reserved			SP
2-6	Reserved							
7-8	Parameter List Length							
9	Control Byte - Refer to SCSI Control Byte.							

Table 16 - 66: MODE SENSE (10) (55)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 1Ah							
1	Reserved				DBD	Reserved		
2	PCF		Page Code					
3	Subpage Code							
4	Allocation Length							
5	Control Byte - Refer to SCSI Control Byte							

16.9 MODE SENSE (6) (1A)

The MODE SENSE (6) (1A) command provides a means for the drive to report various device parameters to the initiator. It is the complement to the MODE SELECT command.

Table 16 - 69: MODE SENSE (6) (1A)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 1Ah							
1	Reserved				DBD	Reserved		
2	PCF		Page Code					
3	Subpage Code							
4	Allocation Length							

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5	Control Byte - Refer to SCSI Control Byte

- DBD (Disable Block Descriptor): 0 indicates the target returns the Block Descriptor; 1 indicates the target will not return the Block Descriptor.
- Allocation Length indicates the maximum number of bytes that the initiator has set aside for the DATA IN phase. A value of 0 is not considered an error. If the allocation length is smaller than the amount available, that portion of the data up to the allocation length will be sent. This may result in only a portion of a multi-byte field being sent.
- PCF Page Control Field defines the type of Page Parameter values to be returned.

Table 16 - 68: PCF Description

PCF	Description
0 0	Report Current Values. The drive returns the current values under which the logical unit is presently configured, for the specified page code. • Initially following power-up but before the media is accessed, the default return values become current. Once the media can be accessed, the saved values are read from the Reserved Area and become current. • The parameters set in the last successful MODE SELECT command are returned. • The saved values are returned, if a MODE SELECT command has not been executed since the last power-on, hard RESET condition, or TARGET RESET message. Following the completion of startup, execution of the MODE SELECT command can modify the current values. **Note**: 1. Those parameters associated with format are not considered current and are not saved until the successful completion of a FORMAT UNIT command. 2. In addition, the current values take on the saved values after a reset if the parameters were saved. If the Page Code is 3Fh, then all pages implemented by the target are returned to the initiator with fields and bit values set to current values. 3. If the Page Code is not 3Fh, the page defined by the Page Code, if supported by the target, is returned with fields and bits set to current values. 4. The drive will not process the MODE SELECT command until the completion of spin-up; the initiator cannot modify the current values prior to the saved values being read in.
0 1	Report Changeable Value. The drive returns the changeable values for the page code specified. The requested page is returned with information that indicates which fields are changeable. All bits of parameters that are changeable are set to 1. Parameters defined by the drive are set to 0. If any part of a field is changeable, all bits in that field are set to one. **Note:** 1. For a value field such as the buffer ratios of page 2 the bit field will not indicate the range of supported values but rather that the field is supported.
1 0	Report Default Value. The drive returns the default values for the page code specified. The parameters not supported by the drive are set to 0.
1 1	Report Saved Value. The drive returns the saved value for the page code specified. Report Saved Values are one of the following: • The values saved as a result of a MODE SELECT command, or • Identical to the default values. • Zero when the parameters are not supported.

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1. The Page Length byte value of each page returned by the drive indicates up to which fields are supported on that page.
2. Page Code specifies which page or pages to return. Page code usage is defined in the following table.

Table 16 - 69: Page Code Usage

Page Code	Description
00h-1Ch	Return specific page, if supported.
3Fh	Return all supported pages.

If a Page Code of 3Fh is used, MODE SENSE returns the pages in ascending order, with one exception: Page 0 is always returned last in response to a MODE SENSE command.

If an unsupported page is selected, the command is terminated with a Check Condition status and an available sense of ILLEGAL REQUEST/INVALID FIELD IN THE CDB.

- Subpage Code specifies the subpage to return and may be set to a specific page, or to FFh for all supported subpages.

16.9.1 Mode Parameter List

The mode parameter list contains a header that may be followed by block descriptors, which may be followed by variable-length pages.

16.9.1.1 Header

The header used for the 6-byte CDB is defined below.

Table 16 - 70: Mode Parameter Header (6)

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Mode Data Length							
1	Medium Type = 0							
2	WP=0	Reserved		DPOFUA=1	Reserved			
3	Block Descriptor Length (= 0, 8, or 16)							

The header used for the 10-byte CDB is defined below.

Table 16 - 71: Mode Parameter Header (10)

	Bit							
Byte	7	6	5	4	3	2	1	0
0-1	Mode Data Length							
2	Medium Type = 0							
3	WP=0	Reserved		DPOFUA =1	Reserved			
4				Reserved				LONGLBA=0
5	Reserved							

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6-7	Block Descriptor Length (= 0, 8, or 16)

- Mode Data Length specifies the length in bytes of the following data that is available to be transferred when using the MODE SENSE command. The mode data length does not include the length byte itself. When using the MODE SELECT command, this field is reserved.
- Medium Type is always set to 0 in the drive (Default Medium Type).
- WP (Write Protect) is reserved when used with the MODE SELECT command. When used with the MODE SENSE command, 0 indicates that the medium is write-enabled.
- DPOFUA bit: 1 = the target supports the FUA and DPO bits in the Read and Write Commands.
- LONGLBA bit: 0 = the 8-byte Block Descriptor follows the header; 1 = the 16-byte Block Descriptor follows the header.
- Block Descriptor Length specifies the length in bytes of the block descriptors. When used with the MODE SELECT command, 0, 8, or 16 is supported by the drive. When used with the MODE SENSE command, the drive returns 8 to indicate that only a single block descriptor is available.

Notes:
1. DPOFUA is ignored during MODE SELECT command processing, although the SCSI Standard states that it is reserved during MODE SELECT. Ignoring it allows the Mode Sense Parameter List for the byte containing this bit to be re-used as a Mode Select Parameter List.

16.9.1.1 Block Descriptor

The Block Descriptor provides formatting information about the Number of Blocks (user addressable) to format at the specified Block Length. Two Block Descriptor formats are defined below based on the LBA size.

Table 16 - 72: Block Descriptor (4-byte LBA)

Byte	Description
0-3	Number of Blocks
4	Density Code = 0
5-7	Block Length

Table 16 - 73: Block Descriptor (8-byte LBA)

Byte	Description
0-7	Number of Blocks
8	Density Code = 0
9-11	Reserved
12-15	Block Length

- Number of Blocks: When used with the MODE SELECT command, the Number of Blocks field must be:
  - Zero to indicate that the available blocks are dependent on the supplied Block Length:
    - If the Block Length specified in the MODE SELECT block descriptor is not changed, the available blocks do not change.
    - If the Block Length specified in the MODE SELECT block descriptor is changed, the available blocks are reset to the default capacity for the newly specified block length.
  - 0xFFFFFFFF for the 8-byte LBA format or 0xFFFFFFFFFFFFFFFF for the 16-byte LBA format to indicate all available blocks - default capacity. If a soft capacity is desired, use that value. Refer to section 4.1 for a table showing default and soft capacity limits.
  - The exact number of blocks in the data area of the drive, which can be obtained with the MODE SENSE.
  - The number of blocks less than exact one, in order to CLIP the number of blocks.

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- Any other value is invalid and causes the command to fail with a Check Condition status.
- When used with the MODE SENSE command, the field contains the exact number of blocks.

- Density Code is always 0 for direct access devices.
- Block Length: The Block Length field reflects the number of bytes of user data per sector (not including any protection information). When used with the MODE SELECT command, the Block Length field must contain one of the following values: 512, 520, 528, 4096, 4160, and 4224 (8-byte step) or zero; otherwise, the drive will terminate the command with a Check Condition status.
  - If the block length parameter is different from the current block length, a FORMAT UNIT command is required to force the parameter to become current.
  - When used with the MODE SENSE command, the field is dependent on how the media is currently formatted.

16.9.1.2 Page Descriptor

Table 16 - 74: Mode Parameter Page Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	PS	SPF	Page Code					
1	Page Length							
2-n	Mode Parameters							

Each mode page contains a page code, a page length, and a set of mode parameters.

- PS (Parameter Saveable): 1 = When using the MODE SENSE command, the mode page can be saved by the drive in the reserved area of the drive; 0 = the supported parameters cannot be saved. When using the MODE SELECT command, the PS bit is reserved (0).
- SPF (Sub-Page Format) bit: 0 = the short page format is used; 1 = the long format is used, supporting sub-pages. The drive supports the following mode page codes:

Table 16 - 75: Mode Parameter Page Format

Page	Description	PS
00	Vendor-unique Parameters	1
01	Read-Write Error Recovery Parameters	1
02	Disconnect/Reconnect Control Parameters	1
03	Format Device Parameters	0
04	Rigid Disk Geometry Parameters	0
07	Verify Error Recovery Parameters	1
08	Caching Parameters	1
0A	Control Mode Page	1
0C	Notch Parameters	1
19	Port Control Page	1
1A	Power Control Parameters	1
1C	Informational Exceptions Control	1

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- Page Length specifies the length in bytes of the mode parameters that follow. If the initiator does not set this value to what is returned for the page by the MODE SENSE command, the drive terminates the command with a Check Condition status.

16.9.2 Mode Page 00h - Vendor-unique Parameters

Table 16 - 76: Mode Page 00h - Vendor-unique Parameters

	Bit								Default
Byte	7	6	5	4	3	2	1	0	
0	PS	0	Page Code = 00h						80h
1	Page Length = 13h								13h
2	Ignored					EMTE	EM		00h
3	Ignored								00h
4	Ignored								00h
5	Ignored			FDD	Ignored				00h
6	Ignored				OCT (High Nibble)				00h
7	Overall Command Timer (Low Byte)								00h
8	Ignored								00h
9	Temperature Threshold								00h
10	Temperature Offset								00h
11	Ignored								00h
12	Error Injection	Read Reporting Threshold							43h
13	Ignored								00h
14	Ignored				FFMT	Ignored			08h
15	Ignored					SPI Flash Test	Reserved	Reserved	04h
16-19	Active Ports								01h 01h 00h 00h
20	Speedbump								00h

Note:
Fields marked in the table as 'Ignored' are not used or checked by the drive. They will be initialized to zero but can be set as desired for compatibility with older drives.

1. EMTE forces Endurance Manager throttling when set to 1. Regardless of write data rate, the Endurance Manager will continuously limit the write data rate at the most aggressive setting. This feature is intended for engineering evaluation only, and not for normal drive operation.
2. EM enables the Endurance Manager when set to 1. The Endurance Manager monitors bytes written to the drive over time and limits the rate to ensure drive life.
3. FDD (Format Degraded Disable) controls the reporting of Format Degraded sense data for Test Unit Ready commands, when the drive is in a format-degraded state. When the FDD bit is 1, Format Degraded sense data is not reported for a Test Unit

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Ready command; 0 means it is reported for the aforementioned condition. This bit does not affect the reporting of Format Degraded conditions for any media access commands.

- OCT (Overall Command Timer) controls the maximum command execution time, from receipt by the drive until status is returned. If the command is unable to complete in the specified amount of time, it will be aborted with a Check Condition status and a Aborted Command Sense Key. The Overall Command Timer does not alter the behavior of the Command Aging Limit or Recovery Time Limit. Each unit of this timer is 50 milliseconds. Setting the value to 0 disables the feature.

4. Temperature Threshold specifies the threshold value in degrees Celsius for the thermal sensor Information Exception Warning. The reporting is controlled by Mode Page 0x1C. A value of 0 selects the default value (70 degrees Celsius).
5. Temperature Offset specifies a signed, 1-byte value to apply to the raw temperature reading. This offset is applied to all temperature readings provided by the drive except the Most Recent Raw Temperature Reading value in Log Page 2Fh.
6. Error Injection indicates whether internal error injection is currently enabled or disabled. This bit is read-only. A value of 1 indicates that error injection mode is currently enabled. A value of 0 indicates that error injection mode is currently disabled. Error injection mode is a drive feature that randomly injects pseudo errors during read commands. It is controlled by the DPRY bit of the Format command. This mode should be used only in test mode, to validate drive and system error reporting and handling functionality.
7. Read Reporting Threshold specifies the bits-in-error threshold at which recovered errors is reported when PER in Mode Page 0x01 is set to 1. The bit error on the media needs to exceed this threshold before reporting occurs. Valid values for this field range from 6 to 58 bits in error.
8. FFMT (Fast Format) specifies whether a fast format should be performed. Regardless of the FFMT setting, the format makes all LBAs immediately available for writing. Refer to section 18.12.1 for format times.
9. SPI Flash Test enables the periodic SPI flash background test. The test ensures the SPI flash storing the drive's boot code is healthy. When enabled, this test runs once every 24 hours of device power-on time. If it fails, a SMART Flash Scan trip occurs. The test is enabled if this bit is set to 1 and disabled if this bit is set to 0.
10. Active Port displays how many ports are active. There are 4 bytes that correspond to each of the four ports. A value of one would mean that the port is active. The last two ports (2 & 3) cannot be enabled.
11. Speedbump adds a delay to command processing in a value of microseconds.

16.9.3 Mode Page 01h - Read/Write Error Recovery Parameters

Table 16 - 77: Mode Page 01h - Read/Write Error Recovery Parameters

Byte	Bit 7	6	5	4	3	2	1	0	Default
0	PS	0	Page Code = 01h						81h
1	Page Length = 0Ah								0Ah
2	AWRE	ARRE	TB	RC	EER = 0	PER	DTE	DCR	C0A
3	Read Retry Count								01h
4	Correction Span								00h
5	Head Offset Count								00h
6	Data Strobe Offset Count								00h
7	Reserved								00h
8	Write Retry Count								00h
9	Reserved								00h
10-11	Recovery Time Limit								00h

The Read-Write recovery parameters used during any command that performs a read or write operation to the medium are as follows:

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- AWRE (Automatic Write Reallocation Enabled bit) is ignored. Automatic Write Reallocation is always performed.
- ARRE (Automatic Read Reallocation Enabled bit) is ignored. Automatic Read Reallocation is always performed.
- TB specifies whether LBAs are to be transferred to the host, even if they are in error. The device returns a block of zeroed data for any LBAs in error. This feature is enabled when set to 1.
- RC (Read Continuous bit) is ignored.
- EER (Enable Early Recovery bit) is ignored.
- PER (Post Error bit) specifies whether recovered errors are reported. It is used in conjunction with the Read Reporting Threshold in Mode Page 0x00. Setting this bit to 1 enables recovered error reporting of media bit errors that exceed the Read Reporting Threshold in Page 0x00. Setting this bit to 0 disables recovered error reporting of media errors.
- DTE (Data Terminate on Error bit) is ignored.
- DCR (Disable Correction bit) is ignored.
- Read Retry Count is ignored. Read recovery is always performed.
- Correction Span is ignored.
- Head Offset Count is ignored.
- Data Strobe Offset Count is ignored.
- Write Retry Count is ignored.
- Recovery Time Limit is ignored.

16.9.4 Mode Page 02h - Disconnect/Reconnect Parameters

The Disconnect/Reconnect page enables the initiator to tune the performance of the SAS Link. The drive uses the parameters to control when it attempts to regain control of the link during READ (operation code 08h and 28h) and WRITE (0Ah, 2Ah and 2E).

Table 16 - 78: Mode Page 02h - Disconnect/Reconnect Parameters

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	0	Page Code = 02h						82h
1	Page Length = 0Eh								0Eh
2	Read Buffer Full Ratio								00h
3	Write Buffer Empty Ratio								00h
4-5	Bus Inactivity Time Limit								00h
6-7	Disconnect Time Limit = 0								00h
8-9	Maximum Connect Time Limit								00h
10-11	Maximum Burst Size								00h
12	DTDC								00h
13-15	Reserved								00h

- Read Buffer Full Ratio is ignored.
- Bus Inactivity Time Limit specifies the maximum time that the SAS target port is permitted to maintain a connection without transferring a frame to the initiator port, specified in 100-microsecond increments. When this value is exceeded, the target port prepares to close the connection by transmitting DONE. A value of zero indicates that there is no bus inactivity time limit.
- Disconnect Time Limit is not supported.
- Write Buffer Empty Ratio is ignored.

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- Maximum Connect Time Limit specifies the maximum amount of time the drive will keep a SAS connection open. The time is specified in 100-microsecond increments. The default value of zero indicates no time limit. A maximum value of FFFFh specifies a connection time limit of 6.55 seconds. When this time expires, the drive will prepare to close the connection.
- DTDC is ignored.

16.9.5 Mode Page 03h - Format Device Parameters

The Format Device page contains parameters that specify the medium format. This page contains no changeable parameters.

Table 16 - 79: Mode Page 03h - Format Device Parameters

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	0	Page Code = 03h						03h
1	Page Length = 16h								16h
2-3	Tracks per Zone								00h
									00h
4-5	Alternate Sectors per Zone = 0								00h
									00h
6-7	Alternate Tracks per Zone = 0								00h
									00h
8-9	Alternate Tracks per Logical Unit = 0								00h
									00h
10-11	Sectors Per Track								00h
									00h
12-13	Data Bytes per Block								00h
									00h
14-15	Interleave = 0001h or 0000h								00h
									01h
16-17	Track Skew Factor								00h
									00h
18-19	Cylinder Skew Factor								00h
									00h
20	SSEC	HSEC	RMB	SURF	Reserved				40h
21-23	Reserved								00h

- Tracks per Zone is obsolete for SSDs.
- Sectors per Track is obsolete for SSDs.
- Data Bytes per Block specifies the number of user data bytes per block. The value depends upon the current formatted Block Length.
- Interleave value of 1 or 0 is valid, but this field is ignored.

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- Track Skew Factor is obsolete for SSDs.
- Cylinder Skew Factor is obsolete for SSDs.
- SSEC: 0 indicates that the drive does not support soft sector formatting.

- HSEC: 1 indicates that the drive supports hard sector formatting.
- RMB: 1 indicates that the media does not support removable Fixed Disk.
- SURF is obsolete for SSDs.

16.9.6 Mode Page 04h - Rigid Disk Drive Geometry Parameters

The Rigid Disk Drive Geometry page specifies various parameters for the drive.

Table 16 - 80: Mode Page 04h - Rigid Disk Drive Geometry Parameters

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	0	Page Code = 04h						04h
1	Page Length = 16h								16h
2-4	Number of Cylinders								00h
									00h
5	Number of heads								00h
6-8	Starting Cylinder - Write Pre-compensation = 0								00h
									00h
9-11	Starting Cylinder - Reduced Write Current = 0								00h
									00h
12-13	Drive Step Rate = 0 (Not used)								00h
									00h
14-16	Landing Zone Cylinder = 0 (Not used)								00h
									00h
17	Reserved								00h
18	Rotational Offset = 0 (Not used)								00h
19	Reserved								00h
20-21	Medium Rotation Rate								00h
									01h
22-23	Reserved								00h

- Medium Rotation Rate is set to 1 to indicate that the drive is an SSD.

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16.9.7 Mode Page 07h - Verify Error Recovery Parameters

Table 16 - 81: **Mode Page 07h - Verify Error Recovery Parameters**

	Bit								Default
Byte	7	6	5	4	3	2	1	0	
0	PS	0	Page Code = 07h						87h
1	Page Length = 0Ah								0Ah
2	Reserved				EER=0	PER	DTE	DCR	00h
3	Verify Retry Count								01h
4	Correction Span								00h
5-9	Reserved								00h
10-11	Verify Recovery Time Limit								00h

The Verify recovery parameters are used by the target when recovering from and reporting errors. These errors are associated with verifying initiator data for the following commands:

- VERIFY
- WRITE AND VERIFY (only the verify portion of the command only)
- EER (ignored)
- PER (ignored). The PER setting in Mode Page 01h is used for VERIFY commands.
- DTE (ignored)
- DCR (ignored)
- Correction Span (ignored)
- Verify Recovery Time Limit (ignored)

16.9.8 Mode Page 08h - Caching Parameters

The Caching Parameters page defines parameters that affect the use of the cache.

Table 16 - 82: **Mode Page 08h - Caching Parameters**

	Bit								Default
Byte	7	6	5	4	3	2	1	0	
0	PS	0	Page Code = 08h						88h
1	Page Length = 12h								12h
2	IC	ABPF	CAP	DISC	SIZE	WCE	MF	RCD	04h
3	Demand Read Retention Priority				Write Retention Priority				00h
4-5	Disable Pre-fetch Transfer Length								FFh
6-7	Minimum Pre-fetch								00h
8-9	Maximum Pre-fetch								FFh
10-11	Maximum Pre-fetch Ceiling								FFh

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12	FSW	LBCSS	DRA	Reserved	00h
13	Number of Cache Segments				00h
14-15	Cache Segment Size				00h
16	Reserved				00h
17-19	Non-Cache Segment Size				00h

- IC (initiator Control bit) is ignored.
- ABPF (Abort Pre-fetch bit) is ignored.
- CAP (Caching Analysis Permitted) is not supported and is ignored.
- DISC (Discontinuity) is not supported and is ignored.
- SIZE Enable bit is ignored.
- WCE (Write Cache Enable bit) is ignored. Fail-safe write caching is always enabled.
- MF (Multiplication Factor bit) is ignored.
- RCD (Read Cache Disable bit) is ignored.
- Demand Read Retention Priority is not supported.
- Write Retention Priority is not supported.
- Disable Pre-fetch Transfer Length is ignored.
- Minimum Pre-fetch is ignored.
- Maximum Pre-fetch is ignored.
- Maximum Pre-fetch Ceiling is ignored.
- FSW Force Sequential write is not supported and is ignored. All logical blocks are written in sequential order.
- LBCSS Logical Block Cache Segment Size bit is ignored
- DRA (Disable Read Ahead) is ignored.
- Number of Cache Segments is ignored.
- Cache Segment Size is ignored.
- Non-Cache Segment Size is not supported and is ignored.

16.9.9 Mode Page 0Ah - Control Mode Page Parameters

Table 16 - 83: Mode Page 0Ah - Control Mode Page Parameters

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	0	Page Code = 0Ah						8Ah
1	Page Length = 0Ah								0Ah
2	TST=0			TMFonly=0	DPICZ	D_Sense=0	GLTSD=0	RLEC=0	00h
3	Queue Algorithm Modifier				RSVD	QErr		DQue	00h
4	RSVD	RAC=0	UA_INTLCK_CTRL=0		SWP=0	Obsolete			00h
5	ATO	TAS=0	ATMPE	RWWP	Reserved				00h
6-7	Obsolete								00h

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8-9	Busy Timeout Period	00h
10-11	Extended Self-test Routine Completion Time	XXh

The following are parameter options for Page 0A:

- DPICZ Disable Protection Information Check Zero bit set to 0 indicates that checking of protection information bytes is enabled. A DPICZ bit set to one indicates that checking of protection information is disabled on commands with:
- RDPROTECT field (see SCSI Block Commands - 3 (SBC-3)) set to 0;
- VRPROTECT field (see SCSI Block Commands - 3 (SBC-3)) set to 0; or
- ORPROTECT field (see SCSI Block Commands - 3 (SBC-3)) set to 0.
- Queue Algorithm Modifier specifies restrictions on the algorithm used for reordering commands that are tagged with the SIMPLE message.

Table 16 - 84: Queue Algorithm Modifier

Bit	Description
0h	Restricted Reordering. The target reorders the actual execution sequence of the queued commands from each initiator to maintain data integrity for that initiator.
1h	Unrestricted Reordering Allowed. The target may reorder the actual execution sequence of the queued commands in any manner it selects. Any data integrity exposures related to command sequence order are explicitly handled by the initiator, through the selection of appropriate commands and queue tag messages.
2h-7h	Reserved
8h	Command reordering is disabled.
9h-Fh	Reserved

- QErr (Queue Error Management) specifies how the device server shall handle blocked tasks when another task receives a Check Condition status.

Table 16 - 85: Queue Error Management

QERR Value	Description
00b	Specifies that all tasks from all initiators are blocked from execution when a Contingent Allegiance (CA condition) is pending. Those blocked tasks may resume normal execution after the CAcondition is cleared.
01b	Specifies that all tasks from all initiators are aborted when the target returns a Check Condition status. A Unit Attention condition is generated for each initiator that had commands in the queue, except for the initiator that received the Check Condition status. The Sense Key is set to Unit Attention, and an Additional Sense Code will be set to Commands Cleared by Another initiator.
10b	Reserved
11b	When a Check Condition status is sent to an initiator, the blocked tasks for the initiator are aborted when the status is sent.

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- DQue (Disable Queuing bit): 0 specifies that tagged queuing is enabled if the target supports tagged queuing; 1 specifies that tagged queuing is disabled. Command queuing is always enabled on the drive, so this bit is ignored.
- ATO (Application Tag Owner bit): 1 specifies that the contents of the Logical Block Application Tag field in the protection information, if any, may not be modified by the drive. When set to 0, the bit specifies that the contents of the Logical Block Application Tag field in the protection information, if any, may be modified by the drive. If the ATO bit is set to 0, the drive will ignore the contents of the Logical Block Application Tag field in the protection information.
- ATMPE (Application Tag Mode Page Enabled bit): 0 specifies that the Application Tag mode page (see SBC-3) is disabled, and the contents of logical block application tags are not defined. A setting of 1 enables the Application Tag mode page.

If the ATMPE is set to one, *and* the ATO bit is set to one, *and* the value in the DPICZ bit allows protection information checking for the specified command, *and* the APP_CHK bit is set to one in the Extended INQUIRY VPD page; *then* knowledge of the value of the

Application Tag comes from the values in the Application Tag Mode page as specified by the DPICZ bit.

- RWWP (Reject Write Without Protection bit): 0 specifies that the device server processes write commands that include user data without protection information, such as a WRITE (10) command with the WRPROTECT field set to 000b (see SBC-3). A RWWP bit set to 1 specifies that the device server in a logical unit that has been formatted with protection information terminates with a Check Condition status. The Sense Key is set to ILLEGAL REQUEST, and the Additional Sense Code is set to INVALID FIELD IN CDB any write command that is specified to include user data without protection information.
- Busy Timeout Period is not supported and is ignored.
- Extended Self-test Routine Completion Time is an advisory parameter that an initiator may use. It determines the time in seconds that the target requires to complete self-test routine, when the target is not interrupted by an initiator, and no errors occur during the execution.

16.9.9.1 Control Extension Subpage

Table 16 - 86: **Control Extension Subpage**

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	SPF = 1	Page Code = 0Ah						CAh
1	Subpage Code = 01h								01h
2-3	Page Length = 001Ch								001Ch
4	Reserved					TCMOS	SCSIP	IALUAE	00h
5	Reserved				Initial Priority				00h
6	Maximum Sense Data Length								00h
7-31	Reserved								00h

- TCMOS (Timestamp Changeable by Methods Outside this Standard) is set to 0 to specify that the timestamp shall not be changed by any method except those defined by this standard.
- SCSIP (SCSI Precedence) is set to 0 to specify that methods outside this standard may change the timestamp and that the SET TIMESTAMP command is illegal.
- IALUAE (Implicit Asymmetric Logical Unit Access Enabled) is set to 0 to specify that implicitly managed transitions between primary target port asymmetric access states are disallowed or not supported.
- Initial Command Priority is set to 0 to indicate that the device server does not support priorities with the SET PRIORITY command.
- Maximum Sense Data Length specifies the maximum number of bytes of sense data the device server returns in the same I_T_L_Q nexus transaction as the status. A setting of 0 specifies that there is no limit. The device server returns sense data bytes, in the same I_T_L_Q nexus transaction as the status. The length of this amount cannot exceed the smaller of

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- The Maximum Sense Data Length field or
- The Maximum Supported Sense Data Length field in the Extended INQUIRY VPD page (Page 86h).

16.9.9.2 Application Tag Subpage

The Application Tag mode page specifies the Application Tag that a device server configured for protection information shall use for each LBA range if the ATO bit in the Control Mode page (see SCSI Primary Commands – 4 (SPC-4)) is set to 1 (one). The mode page policy for this page is shared.

Parameter data is returned by the device server, in the Application Tag mode page. If a method not defined by this standard changes the data, the device server establishs a Unit Attention condition for the SCSI initiator port associated with every I_T nexus. The Additional Sense Code is set to MODE PARAMETERS CHANGED.

Table 16 - 87: Application Tag Mode Page

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	PS	SPF = 1	Page Code = 0Ah					
1	Subpage Code = 02h							
2-3	Page Length = n-3							
4-15	Reserved							
Application Tag Descriptors								
16-39	Application Tag descriptor [First]							
(n-24)-n	Application Tag descriptor [Last]							

- The Parameters Savable (PS) bit, the subpage format (SPF) bit, the Page Code field, the Subpage Code field, and the Page Length field are defined in SCSI Primary Commands – 4 (SPC-4).
- The SPF bit, the Page Code field, the Subpage Code field, and the Page Length field is set to the values shown in the previous table.

The Application Tag Descriptors are defined in the following table.

Table 16 - 88: Application Tag Descriptor Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Last	Reserved						
1-5	Reserved							
6-7	Logical Block Application Tag							
8-15	Logical Block Address							
16-23	Logical Block Count							

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- Last bit: 1 specifies that this Application Tag descriptor is the last valid Application Tag descriptor in the Application Tag mode page; 0 specifies that the Application Tag descriptor is *not* the last one of them.
- The Logical Block Application Tag field specifies the value to be compared with the Logical Block Application Tag field associated with data read or written to the LBA.
- The Logical Block Address field contains the starting LBA for this Application Tag descriptor. The Logical Block Address field in the first Application Tag descriptor is set to 0000_0000_0000_0000h. For subsequent Application Tag descriptors, the Logical Block Address field is the sum of the values in:
- The Logical Block Address field in the previous Application Tag Descriptor and
- The Logical Block Count field in the previous Application Tag Descriptor.
- The sum of these:
- Logical Block Address field in the Application Tag descriptor, with the Last bit set to 1
- Logical Block Count field in the Application Tag descriptor with the Last bit set to 1 equals the Returned Logical Block Address field in the Read Capacity (16) parameter data.
- If an invalid combination of the Last bit, Logical Block Application Tag field, and Logical Block Address field are sent by the application client, then the device server terminates the Mode Select command (see SCSI Primary Commands – 4 (SPC- 4)). A Check Condition status is returned, with the Sense Key set to Illegal Request and the Additional Sense Code set to Invalid Field In Parameter List.
- The Logical Block Count field specifies the number of logical blocks to which this Application Tag descriptor applies.
- A Logical Block Count field set to 0000_0000_0000_0000h specifies that this Application Tag descriptor is ignored.
- The drive supports a maximum of 16 ApplicationTag Descriptors.

16.9.10 Mode Page 0Ch - Notch Parameters

The Notch Parameters page is obsolete for SSDs and is presented here for informational purposes only.

Table 16 - 89: Mode Page 0Ch - Notch Parameters

	Bit								
Byte	7	6	5	4	3	2	1	0	Default
0	PS	0	Page Code = 0Ch						8Ch
1	Page Length = 16h								16h
2	ND = 1	LPN = 0	Reserved						80h
3	Reserved								00h
4-5	Maximum Number of Notches								00h
									00h
6-7	Active Notch								00h
									00h
8-11	Starting Boundary								00h
									00h
12-15	Ending Boundary								00h
									00h

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16-23	Pages Notched	0000h 0000h 0000h 0000h

16.9.11 Mode Page 18h (Protocol-Specific Logical Unit)

This page defines the protocol-specific parameters that affect the logical unit.

Table 16 - 90: **Mode Page 18h (Protocol-Specific Logical Unit)**

	Bit								
Byte	7	6	5	4	3	2	1	0	Default
0	PS=0	SPF=0	Page Code = 18h						18h
1	Page Length = 6h								6h
2	Reserved		Transport Layer Retries=0			Protocol Identifier = 6h			6h
3	Reserved								00h
4-7	Reserved								00h

- Transport Layer Retries is unchangeable and set to 0. The drive does not support Transport Layer Retries as defined in SAS 1.1.

16.9.12 Mode Page 19h - Port Control Parameters

The Protocol-Specific Port mode page contains parameters that affect SSP target port operation. One copy of the mode page is shared by all SSP initiator ports.

16.9.12.1 Short Format of Port Control Page

Table 16 - 91: **Short (Port Control Parameters) Short Format**

	Bit								
Byte	7	6	5	4	3	2	1	0	Default
0	PS	SPF = 0	Page Code = 19h						99h
1	Page Length = 0Eh								0Eh
2	RSVD	Continue AWT	Broadcast Asynchronous Event	Ready LED Meaning	Protocol Identifier = 6h				06h
3	Reserved								00h
4-5	I_T Nexus Loss Timer								07h-D0h
6-7	initiator Response Timeout								07h-D0h
8-9	Reject to Open Limit								0000h

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10-15	Reserved	00h

- PS Parameters Savable is set to 1 to indicate the parameters are savable
- SPF is set to 0 for access to the short format mode page.
- Protocol Identifier has a value of 6h to indicate this is a SAS SSP-specific mode page.
- Continue AWT bit: 1 = the SAS port does *not* stop the Arbitration Wait Time timer or set it to zero when the SAS port receives an OPEN_REJECT (RETRY); 0 = the SAS port *does* stop the Arbitration Wait Time timer and sets it to zero when it receives an OPEN_REJECT (RETRY).
- Broadcast Asynchronous Event bit: 1 = the device server enables origination of Broadcast (Asynchronous Event); 0 = the device server disables origination of Broadcast (Asynchronous Event).
- Ready LED Meaning specifies the READY LED signal behavior. In general, when the bit is 0, and the drive is in a ready state, the LED is usually on, but it flashes on and off when commands are processed. When the bit is 1, the LED is usually off, but it flashes on and off when commands are processed. For additional implementation specifics, see the SAS standards.
- I_T Nexus Loss Time contains the time (in milliseconds) that the SSP target port retries connection requests to an SSP initiator port. These requests have been rejected with responses indicating the SSP initiator port may no longer be present before recognizing an I_T nexus loss. A value of 0 indicates a vendor-specific amount of time and defaults to a 2-second (7D0h) time period. A value of FFFFh indicates an unlimited period.
- initiator Response Timeout contains the time in milliseconds that the SSP target port waits for the receipt of a Data frame after sending the XFER_RDY frame requesting data. When this time expires, the associated command is be aborted. A value of 0 indicates that the SSP target port will disable the timer. This value is enforced by the transport layer. The default value of 7D0h specifies a 2-second time period.
- Reject to Open Limit contains the minimum time in 10 µs increments that the target port waits to establish a connection request with an initiator port on an I_T nexus. This is after receiving an OPEN_REJECT (RETRY), OPEN_REJECT (CONTINUE 0), or OPEN_REJECT (CONTINUE 1). This value may be rounded as defined in SCSI Primary Commands – 4 (SPC-4). When this value is set to 0000h, the minimum time is vendor-specific. This minimum time is enforced by the transport layer.

16.9.12.2 Long Format of Port Control Page

The drive maintains an independent set of port control mode page parameters for each SAS initiator port.

Table 16 - 92: Long Format of Port Control Page

	Bit								
Byte	7	6	5	4	3	2	1	0	Default
0	PS	SPF=1	Page Code = 19h						D9h
1	Subpage Code								...
2-3	Page Length (n-3)								0000h
4	Reserved								00h
5	Reserved				Protocol Identifier = 6h				06h
6	Protocol Specific Mode Parameters								...
n									...

- SPF is set to one for access to the long format mode page.
- Subpage Code indicates which subpage is being accessed. The drive supports the subpage codes shown below. If the Subpage Code is not supported, the drive returns a Check Condition status, with the Sense Key set to ILLEGAL REQUEST and the Additional Sense Code set to ILLEGAL FIELD IN PARAMETER LIST:

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01h	PHY Control and Discover Subpage
02h	Shared Port Control Subpage
FFh	All supported Subpages

- Page Length specifies the length in bytes of the subpage parameters after the Page Length.
- Protocol Identifier has a value of 6h, indicating this is a SAS SSP-specific mode page.

16.9.12.3 PHY Control and Discover - Subpage 1

The PHY Control and Discover subpage contains PHY-specific parameters. The MODE SENSE command returns the current settings for the initiator.

Table 16 - 93: PHY Control and Discover - Subpage 1

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	SPF=1	Page Code = 19h						D9h
1	Subpage Code = 1								01h
2-3	Page Length = 0064h								0064h
4	Reserved								00h
5	Reserved				Protocol Identifier = 6h				06h
6	Generation Code								00h
7	Number of PHYS = 2								02h
8-55	SAS PHY Mode Descriptor 0								...
56-103	SAS PHY Mode Descriptor 1								...

- Protocol Identifier has a value of 6h, indicating this is a SAS SSP-specific mode page.
- Generation Code is a one-byte counter incremented by 1 by the device server. This happens every time the values in this mode page change, or the field values in the SAS Phy mode page (see SAS PHY Mode Page - Subpage 3) change. A value of 00h indicates the generation code is unknown. The device server wraps this field to 01h as the next increment after reaching its maximum value (FFh). This field is also contained in the Protocol- Specific Port log page and may be used to correlate Phy settings across mode page and log page accesses.
- Number of PHYS is set to 2, to represent the dual-ported drive (one PHY per port).
- SAS PHY Mode Descriptor is defined in Table 116 on page 152. There are two SAS PHY Mode Descriptor fields, one per port.

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Table 16 - 94: **SAS PHY Mode Descriptor**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved							
1	PHY Identifier							
2-3	Reserved							
4	RSVD	Attached Device Type			Attached Reason			
5	Reason				Negotiated Logical Link Rate			
6	Reserved				Attached SSP initiator Port	Attached STP initiator Port	Attached SMP initiator Port	Reserved
7	Reserved				Attached SSP Target Port	Attached STP Target Port	Attached STP Target Port	Reserved
8-15	SAS Address							
16-23	Attached SAS Address							
24	Attached PHY Identifier							
25-31	Reserved							
32	Programmed Minimum Physical Link Rate				Hardware Minimum Physical Link Rate			
33	Programmed Maximum Physical Link Rate				Hardware Maximum Physical Link Rate			
34-41	Reserved							
42-43	Vendor Specific							
44-47	Reserved							

- PHY Identifier identifies the PHY associated with the other data in this SAS PHY Mode Descriptor Page.
- Attached Reason indicates the value of the REASON field in the last received IDENTIFY address frame. This frame is associated with the PHY Identifier list in this SAS PHY Mode Descriptor. See “Identify Address Frame”.
- Attached Device Type indicates the value of the DEVICE TYPE field in the last received IDENTIFY address frame described above.
- Attached SAS Address indicates the value of the attached SAS address in the last received IDENTIFY address frame described above.
- Attached PHY Identifier indicated the value of the attached PHY Identifier field in the last received IDENTIFY address frame described above.
- SAS Address contains the Unique Port Identifier for the port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.
- Hardware Minimum Physical Link Rate is the minimum link rate supported by the port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.
- Hardware Maximum Physical Link Rate is the maximum link rate supported by the port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.
- Programmed Minimum Physical Link Rate is the current minimum link rate used during speed negotiation by the port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.

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- Programmed Maximum Physical Link Rate is the current maximum link rate used during speed negotiation by the port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.

16.9.12.4 Shared Port Control - Subpage 2

Table 16 - 95: **Shared Port Control - Subpage 2**

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	SPF=1	Page Code = 19h						D9h
1	Subpage Code = 2								02h
2-3	Page Length = 000Ch								000Ch
4	Reserved								00h
5	Reserved				Protocol Identifier = 6				06h
6-7	Power Loss Timeout								0000h
8-15	Reserved								00h

- Power Loss Timeout is the maximum time, in one-millisecond increments, that the drive port responds to connection requests with OPEN_REJECT (RETRY) after receiving NOTIFY (POWER LOSS EXPECTED).
- Power Loss Timeout is restarted after each NOTIFY (POWER LOSS EXPECTED) received.
- A value of 0000h specifies that the maximum time is vendor-specific and automatically defaults to 2 seconds.

16.9.12.5 SAS PHY Mode Page - Subpage 3

Table 16 - 96: **SAS PHY Mode Page - Subpage 3**

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	SPF=1	Page Code 19h						D9h
1	Subpage Code = 3								03h
2-3	Page Length = 002Ch								002Ch
4	Reserved								00h
5	Reserved				Protocol Identifier = 6				06h
6	Generation Code								00h
7	Number of Phys = 02h								02h
8-27	SAS PHY Mode Descriptor 0								-
28-47	SAS PHY Mode Descriptor 1								-

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- Generation Code is a one-byte counter incremented by 1 by the device server, every time the values in this mode page or the SAS PHY mode page (see SAS PHY Mode Page - Subpage 3) field values are changed.
- A value of 00h indicates the generation code is unknown. The device server wraps this field to 01h as the next increment after reaching its maximum value (FFh).
- The Generation Code field is also contained in the Protocol-Specific Port log page and may be used to correlate Phy settings across mode page and log page accesses.

Table 16 - 97: PHY Mode Descriptor (0 and 1)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved							
1	PHY Identifier							
2-3	Descriptor Length (0010h)							
4-7	Programmed PHY Capabilities							
8-11	Current PHY Capabilities							
12-15	Attached PHY Capabilities							
16-17	Reserved							
18	Reserved			Negotiated SSC	Negotiated Physical Link Rate			
19	Reserved					Enable Slumber	Enable Partial	Hardware Muxing Supported='0'

- Phy Capabilities are defined in SAS Speed Negotiation.
- Enable Partial enables the drive to support Partial Slumber Power Down.
- Enable Slumber enables the drive to support Slumber Power Down.
- See Section 15.4.6 for more information on Power Management.

16.9.13 Mode Page 1Ah - Power Control

Table 16 - 98: Mode Page 1Ah - Power Control

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	0	Page Code = 1Ah						9Ah
1	Page Length = 26h								26h
2	Reserved							Standby_Y	00h
3	Reserved				Idle_C	Idle_B	Idle_A	Standby_Z	00h
4-7	Idle_A Condition Timer								00h

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8-11	Standby_Z Condition Timer	00h
12-15	Idle_B Condition Timer	00h
16-19	Idle_C Condition Timer	00h
20-23	Standby_Y Condition Timer	00h
24-39	Reserved	00h

- Standby_Y bit: 1 = the standby_y condition timer is enabled; 0 = the device ignores the standby_y condition timer.
- Idle_C bit: 1 = the idle_c condition timer is enabled; 0 = the device ignores the idle_c condition timer.
- Idle_B bit: 1 = the idle_b condition timer is enabled; 0 = the device ignores the idle_b condition timer.
- Idle_A bit: 1 = the idle_a condition timer is enabled; 0 = the device ignores the idle_c condition timer.
- Standby_Z bit: 1 = the standby_z condition timer is enabled; 0 = the device ignores the standby_z condition timer.
- Idle_A Condition Timer field specifies the initial value, in 100-millisecond increments, for the idle_a power condition timer. The minimum allowable inactivity time for idle_a is 1 second. Any value less than this is accepted but automatically defaults to 1 second.
- Standby_Z Condition Timer specifies the initial value, in 100-millisecond increments, for the standby_z power condition timer. The minimum allowable inactivity time for standby_z is 2 minutes. Any value less than this is accepted but automatically defaults to two minutes.
- Idle_B Condition Timer specifies the initial value, in 100-millisecond increments, for the idle_b power condition timer. The minimum allowable inactivity time for idle_b is 2 minutes. Any value less than this is accepted but automatically defaults to 2 minutes.
- Idle_C Condition Timer specifies the initial value, in 100-millisecond increments, for the idle_c power condition timer. The minimum allowable inactivity time for idle_c is 2 minutes. Any value less than this is accepted but automatically defaults to 2 minutes.
- Standby_Y Condition Timer specifies the initial value, in 100-millisecond increments, for the standby_y power condition timer. The minimum allowable inactivity time for standby_y is 2 minutes. Any value less than this is accepted but automatically defaults to 2 minutes.

16.9.13.1 Power Consumption - Subpage 1

Power Consumption ID specifies the current power consumption mode enabled on the drive.

Table 16 - 99: **Power Consumption - Subpage 1**

	BIT								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	SPF=1	Page Code = 1Ah						DAh
1	Subpage Code = 01h								01h
2-3	Page Length = 000Ch								000Ch
4-6	Reserved								0000h
7	Power Consumption ID								02h
8-15	Reserved								0000h

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The valid values are:

Value	Power Consumption Mode
0x00	9 Watt
0x01	11 Watt
0x02	14 Watt

16.9.14 Mode Page 1Ch - Informational Exceptions Control

Table 16 - 100: Mode Page 1Ch - Informational Exceptions Control

	Bit								
Byte	7	6	5	4	3	2	1	0	Default
0	PS	0	Page Code = 1Ch						9Ch
1	Page Length = 0Ah								0Ah
2	PERF	RSVD	EBF	EWASC	DEXCPT	TEST	EBACKERR	LOGERR	10h
3	Reserved				Method of Reporting				03h
4-7	Interval Time								00h
									00h
									00h
									00h
8-11	Report Count								00h

- The PERF Performance bit is not supported and is ignored. Informational Exception operations will not cause performance delays.
- The EBF Enable Background Function bit is not supported and is ignored. Background functions are always enabled.
- EWASC Enable Warning ASC bit: 0 = warnings are not reported; 1 = warnings are reported. The Method of Reporting field controls the reporting method. EWASC is independent of DEXCPT.
- DEXCPT Disable Exception Control bit: 0 = exception operations are enabled. The reporting of information exception conditions when the DEXCPT bit is set to 0 is determined from the Method of Reporting field. 1 = the target disables all information exception operations.
- TEST bit: 1 = the drive will generate false drive notifications at the next interval time (as determined by the INTERVAL TIMER field), if the DEXCPT is zero. The Method of Reporting and Report Count apply. The false drive failure is reported as sense qualifier 5DFFh. 0 = the drive will stop generating any false drive notifications.
- EBACKERR Enable Background Error bit: 0 = reporting is disabled for background self-test errors and background scan errors via Information Exceptions Control; 1 = reporting is enabled for these background errors as Information Exception Warnings. The method of reporting these errors is determined from the MRIE field.
- LOGERR Log Errors is not used and ignored internally by the target.

Method of Reporting Informational Exceptions indicates the methods used by the target to report informational exception conditions.

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Table 16 - 101: **Reporting Informational Exceptions**

Code	Description
0h	No Reporting of Informational Exception Condition. This method instructs the target to not report informational exception condition.
1h	Asynchronous Event Reporting. Not supported.
2h	Generate Unit Attention. This method instructs the target to report informational exception conditions by returning a Check Condition status on any command. The Sense Key is set to Unit Attention, and the Additional Sense Code indicates the cause of the informational exception condition. The command that has the Check Condition is not executed before the informational exception condition is reported.
3h	Conditionally Generate Recovered Error. This method instructs the target to report informational exception conditions, dependent on the value of the PER bit of the error recovery parameters mode page. The target does so by returning a Check Condition status on any command. The Sense Key is set to Recovered Error, and the Additional Sense Code indicates the cause of the informational exception condition. The command that has the Check Condition completes without error before any informational exception condition is reported.
4h	Unconditionally Generate Recovered Error. This method instructs the target to report informational exception conditions, regardless of the value of the PER bit of the error recovery parameters mode page. The target does this by returning a Check Condition status on any command. The Sense Key is set to Recovered Error, and the Additional Sense Code indicates the cause of the informational exception condition. The command that has the Check Condition completes without error before any informational exception condition is reported.
5h	Generate No Sense. This method instructs the target to report informational exception conditions by returning a Check Condition status on any command. The Sense Key is set to No Sense, and the Additional Sense Code indicates the cause of the informational exception condition. The command that has the Check Condition completes without error before any informational exception condition is reported.
6h	Only Report Informational Exception Condition on Request. This method instructs the target to preserve the informational exception(s) information. To find out about information exception conditions, the Application Client polls the target by issuing an unsolicited Request Sense command. The Sense Key is set to No Sense, and the Additional Sense Code indicates the cause of the informational exception condition.
7h-Fh	Reserved.

- Interval Timer indicates the period, in 100-millisecond increments, to report that an informational exception condition has occurred. The target does not report informational exception conditions more frequently than the time specified by the Interval Timer field; it reports as soon as possible after the time interval has elapsed. After the informational exception condition has been reported, the interval timer is restarted. A value of zero for Interval Timer indicates that the target reports the informational exception condition only once and will override the value set in the Report Count field.
- Report Count indicates the number of times the target reports an informational exception condition. A value of 0 indicates no limits on the number of times the target reports an informational exception condition.

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16.9.14.1 Background Control - Subpage 01h

Table 16 - 102: **Background Control - Subpage 01h**

	Bit								
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**Default**
0	PS	SPF=1	Page Code = 1Ch						DCh
1	Subpage Code = 01h								01h
2-3	Page Length = 0Ch								000Ch
4	Reserved					S_L_Full	LOWIR	EN_BMS	00h
5	Reserved							EN_PS	00h
6-7	Background Medium Scan Interval Time								00A8h
8-9	Background Pre-Scan Time Limit								0000h
10-11	Minimum Idle Time Before Background Scan								0000h
12-13	Maximum Time To Suspend Background Scan (Ignored)								0000h
14-15	Reserved								0000h

- S_L_FULL (Suspend on Log Full bit): 0 = background scans may continue if the results log (Log Sense Page 15h) is full; 1 = background scans are suspended when the log is full.
- LOWIR (Log Only When Intervention Required bit): 0 = all medium errors are logged in the results log (Log Sense Page 15h); 1 = only unrecovered medium errors are logged.
- EN_BMS (Enable Background Medium Scan bit): 0 = background medium scans are disabled; 1 = background medium scans are enabled. If a background medium scan is in progress when the EN_BMS bit is changed from 1 to 0, the medium scan is suspended until the EN_BMS bit is set to 1. Then the medium scan resumes from the suspended location.
- EN_PS (Enable Pre-Scan bit): 0 = the pre-scan is disabled. If a pre-scan operation is in progress when EN_PS is changed from 1 to 0, the pre-scan is halted. A value of 1 specifies that a pre-scan operation will start after the next power-on cycle. Once this pre-scan has completed, another pre-scan does not occur unless the EN_PS bit is set to 0, then set to 1, and another power-on cycle occurs.
- Background Medium Scan Interval Time specifies the minimum time, in hours, between the start of one background medium scan operation and the start of the next background medium scan operation.
- Background Pre-Scan Time Limit specifies the maximum time, in hours, for a pre-scan operation to complete. If the pre-scan operation does not complete within the specified time, it is halted. A value of zero specifies there is no time limit.
- Minimum Idle Time before Background Scan specifies the minimum time, in milliseconds, that the drive must be idle before resuming a background media scan or pre-scan. A value of zero is treated as the default value of 1 second. Any value less than 100 milliseconds is treated as 100 milliseconds. The internal timer granularity is 50 milliseconds.
- Maximum Time to Suspend Background Scan is ignored.

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16.10 MODE SENSE (10) (5A)

The MODE SENSE (10) (5A) command enables the drive to report various device parameters to the initiator. See the MODE SENSE (1A) command for a description of the fields in this command.

Table 16 - 103: MODE SENSE (10) (5A)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 5Ah							
1	Reserved				DBD	Reserved		
2	PCF		Page Code					
3-6	Reserved							
7-8	Allocation Length							
9	Control Byte - Refer to SCSI Control Byte							

16.11 PERSISTENT RESERVE IN (5E)

PERSISTENT RESERVE IN (5E) is used to obtain information about persistent reservations and reservation keys active in the controller. This command is used in conjunction with the PERSISTENT RESERVE OUT command PERSISTENT RESERVE OUT (5F).

Table 16 - 104: Persistent Reserve In (5E)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 5Eh							
1	Reserved			Service Action				
2-6	Reserved							
7-8	Allocation Length							
9	Control Byte - Refer to SCSI Control Byte							

- Allocation Length indicates how much space has been allocated for the returned parameter data. If the length is not sufficient to contain all parameter data, the first portion of the data is returned. If the remainder of the data is required, the initiator should send a new PERSISTENT RESERVE IN command and an Allocation Length large enough to contain all data.

16.11.1 Service Action Codes

The following Service Action Codes are implemented. If a reserved service action code is specified, the drive returns a Check Condition status. The Sense Key is then set to Illegal Request, and the additional sense data is set to Invalid Field in the CDB.

Table 16 - 105: PERSISTENT RESERVE IN, Service Action Codes

Code	Name	Description
00h	Read Keys	Reads all registered Reservation Keys
01h	Read Reservations	Reads all current persistent reservations

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02h	Report Capabilities	Returns capability information
03h	Read Full Status	Reads complete information about all registrations and the persistent reservation, if any
04h-1Fh	Reserved	Reserved

16.11.2 Parameter Data for Read Keys

Table 16 - 106: PERSISTENT RESERVE IN, Parameter Data for Read Keys

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-3	Generation							
4-7	Additional length (n-7)							
8-15	First Reservation Key							
...								
(n-7)-n	Last Reservation Key							

- Generation is a counter that increments when the PERSISTENT RESERVE OUT command with “Register” or “Preempt and Clear” completes successfully. Generation is set to 0 as part of the power-on-reset process and hard reset process. It contains a 32-bit counter that the target increments each time a PERSISTENT RESERVE OUT command requests a Register, a Clear, a Preempt, or a Preempt and Abort service action. The counter is *not* incremented by
- A PERSISTENT RESERVE IN command
- A PERSISTENT RESERVE OUT command that performs a Reserve or Release service action
- A PERSISTENT RESERVE OUT command that is not performed due to an error or reservation conflict.
  Regardless of the APTPL value, the generation value is be set to 0 as part of the power-on reset process.
- Additional Length contains a count of the number of bytes in the reservation key list. If the allocation length specified by the PERSISTENT RESERVE IN command is not sufficient to contain the entire parameter list, then only the bytes from 0 to the maximum allowed allocation length are sent to the initiator. The incremental remaining bytes are truncated, although the Additional Length field still contains the actual number of bytes in the reservation key list. This is without consideration of any truncation resulting from an insufficient allocation length. This condition is not considered an error.
- Reservation Key list contains the 8-byte reservation keys for all initiators that have registered through all ports with the target.

16.11.3 Parameter Data for Read Reservations

Table 16 - 1107: PERSISTENT RESERVE IN, Parameter Data for Read Reservations

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-3	Generation							
4-7	(Additional Length (n-7)							
8-n	Reservation Descriptors							

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- Generation is as defined for the Persistent Reserve In Read Keys parameter data. The Additional Length field contains a count of the number of bytes to follow in the Reservation Descriptor(s).
- Allocation length is specified by the PERSISTENT RESERVE IN command. If it is not sufficient to contain the entire parameter list, then only the bytes from 0 to the maximum allowed allocation length are sent to the initiator. The remaining bytes are truncated, although the Additional Length field still contains the actual number of bytes of the Reservation Descriptor(s) and is not affected by the truncation. This condition is not considered an error.
- Reservation Descriptors' format is defined in the Persistent Reserve In Reservation Descriptor table. The Reservation Descriptor for the persistent reservation, if any, is present in a target that has a persistent reservation.

Table 16 - 108: PERSISTENT RESERVE IN, Read Reservation Descriptor

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-7	Reservation Key							
8-11	Scope-Specific Address							
12	Reserved							
13	Scope=0				Type			
14-15	Extent Length=0							

- The scope of each persistent reservation created by a PERSISTENT RESERVE OUT command is returned. See the PERSISTENT RESERVE OUT command section for details.

16.12 PERSISTENT RESERVE OUT (5F)

PERSISTENT RESERVE OUT (5F) is used to request service actions that reserve the drive for the exclusive or shared use of the initiator. The command uses other service actions to manage and remove such reservations. This command is used in conjunction with the PERSISTENT RESERVE IN command; it should not be used with the RESERVE and RELEASE commands.

Table 16 - 109: PERSISTENT RESERVE OUT (5F)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 5Fh							
1	Reserved			Service Action				
2	Scope=0				Type			
3-6	Reserved							
7-8	Parameter List Length = 18h							
9	Control Byte - Refer to SCSI Control Byte							

Note:

1. If a PERSISTENT RESERVE OUT command is received when a RESERVE is active for the drive, the command is rejected with a Reservation Conflict status.
2. Parameter List Length must be 18h. If not, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Parameter List Length Error.

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16.12.1 Service Action Codes

The following Service Action Codes are supported.

Table 16 - 110: PERSISTENT RESERVE OUT, Service Action Codes

Code	Name	Description
00h	Register	Register a reservation key.
01h	Reserve	Create a persistent reservation using a reservation key.
02h	Release	Release a persistent reservation.
03h	Clear	Clear all reservation keys and all persistent reservations.
04h	Preempt	Preempt persistent reservations from another initiator.
05h	Preempt and Abort	Preempt persistent reservations from another initiator and clear the task set for the preempted initiator.
06h	Register and Ignore existing key	Register a reservation key.
07h-1Fh	Reserved	Reserved

16.12.2 Type Codes

The Type field specifies the characteristics of the persistent reservation being established for all customer data sectors. The table below describes the supported types and how read and write commands are handled for each reservation type.

Table 16 - 111: PERSISTENT RESERVE OUT, Type Codes

Code	Name	Description
0h	Reserved	Reserved
1h	Write Exclusive	Reads Shared: Any initiator may execute commands that transfer from the media. Writes Exclusive: Only the initiator with the reservation may execute commands that transfer data to the media; the Reservation Conflict status is returned to other initiators.
2h	Reserved	Reserved
3h	Exclusive Access	Reads Exclusive: Only the initiator with the reservation may execute commands that transfer data from the media; the Reservation Conflict status is returned to other initiators. Writes Exclusive: Only the initiator with the reservation may execute commands that transfer data to the media; the Reservation Conflict status is returned to other initiators.
4h	Reserved	Reserved
5h	Write Exclusive Registrants Only	Reads Shard: Any initiator may execute commands that transfer from media. Writes Exclusive: Only registered initiators may execute commands that transfer data to the media; the Reservation Conflict status is returned to other initiators.

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6h	Exclusive Access Registrants Only	Reads Exclusive: Only registered initiators may execute commands that transfer data from the media; the Reservation Conflict status is returned to other initiators. Writes Exclusive: Only registered initiators may execute commands that transfer data to the media; the Reservation Conflict status is returned to other initiators.
7h-Fh	Reserved	Reserved

16.12.3 Parameter List

The Parameter List required to perform the PERSISTENT RESERVE OUT command is defined in the following table. All fields must be sent on all PERSISTENT RESERVE OUT commands, even if the field is not required for the specified service action.

Table 16 - 112: Parameter List

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-7	Reservation Key							
8-15	Service Action Reservation Key							
16-19	Reserved							
20	Reserved				SPEC_I_P	ALL_TG_PT	RSVD	APTPL
21-23	Reserved							

- Reservation Key contains an 8-byte value provided by the initiator and identifies the initiator that issued the PERSISTENT RESERVE OUT command. The Reservation Key must match the registered reservation key for the initiator, for all service actions except REGISTER and REGISTER AND IGNORE EXISTING KEY.
- Service Action Reservation Key contents vary based on the service action. For REGISTER and REGISTER AND IGNORE EXISTING KEY, the Service Action Reservation Key must contain the new reservation key to be registered. For PREEMPT and PREEMPT AND ABORT, the field contains the reservation key of the persistent reservation that is being preempted. This field is ignored for all other service actions.
- SPEC_I_PT bit: 0 = the device server applies the registration only to the I_T nexus that sent the PERSISTENT RESERVE OUT command. If the bit is set to 1 for any service action except the REGISTER service action, the command is terminated with a Check Condition status, with the Sense Key set to ILLEGAL REQUEST, and the Additional Sense Code is set to INVALID FIELD IN PARAMETER LIST. If the bit is set to 1 for the REGISTER service action, the additional parameter data includes a list of transport IDs, and the device server also applies the registration to the I_T nexus for each initiator port specified by a TransportID. If a registration fails for any initiator port (e.g., if the logical unit does not have enough resources available to hold the registration information), no registrations is made, and the command is terminated with a Check Condition status. For Transport IDs, refer to Table 218 on page 389 of Spc4r36.
- ALL_TG_PT (All Target Ports bit): This is valid only for REGISTER and REGISTER AND IGNORE EXISTING KEY and is ignored for all other service actions. Support for the ALL_TG_PT bit is optional. If the device server receives a REGISTER or REGISTER AND IGNORE EXISTING KEY service action, with the ALL_TG_PT bit set to 1, it creates the specified registration on all target ports in the identified SCSI target device. This is the same if the registration request had been received individually through each target port. If the device server receives a REGISTER rvice action or a REGISTER AND IGNORE EXISTING KEY service action with the ALL_TG_PT bit set to 0, it applies the registration only to the target port through which the PERSISTENT RESERVE OUT command was received.
- APTPL (Activate Persist through Power Loss bit): This is valid only for REGISTER and REGISTER AND IGNORE EXISTING KEY and is ignored for all other service actions. If the last valid APTPL bit value received is 0, power loss causes all persistent reservations to be released and all reservation keys to be removed. If the last valid APTPL bit value received is 1, any persistent reservation and all reservation keys for all initiators are retained across power cycles.

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16.12.4 Summary

Table 16 - 113: **PERSISTENT RESERVE OUT, Service Action, Parameters**

	Parameters						
Service Action	**Scope Type**	**Rsv Key**	**SvcAct RsvKey**	**S-Spec Addr**	**Extent Length**	**APTPL**	**Generation Counter**
(0) Register	Ignore	Verify	Save	Ignore	Ignore	Apply	+1
(1) Reserve	Apply	Verify	Ignore	Ignore	Ignore	Apply	---
(2) Release	Apply	Verify	Ignore	Ignore	Ignore	Ignore	---
(5) Preempt and Abort	Apply	Verify	Save	Ignore	Ignore	Ignore	+1

16.12.14.1 Scope,Type

The Scope and the Type are applied in the process for the Reserve, Release, and Preempted and Clear service actions. They are ignored in the process for the Register service action because they are not used.

16.12.14.2 Reservation Key

The Reservation Key is verified in each service action process. If the initiator that registered a key is different from the initiator requesting PERSISTENT RESERVE OUT command, the drive returns a Reservation Conflict status.

16.12.14.3 Service Action Reservation Key

On Register service action, the drive saves the key specified in the Service Action Reservation Key field as a key of the initiator requesting the PERSISTENT RESERVE OUT command. On a Preempt and Clear service action, the reservation with a key specified in the Service Action Reservation Key field is preempted. On other service actions, this field is ignored.

16.12.14.4 APTPL

The APTPL (Active Persist through Power Loss) bit is valid only for the Register service action. The drive ignores the APTPL in other service actions. The following table shows the relationship between the last valid APTPL value and information held by the drive.

Table 16 - 114: **APTPL and Drive Information**

Information Held by Drive	**Last Valid APTPL Value**	
	0	0
Registration	All Keys Set to 0	Retained
Persistent Reservation	All are removed	Retained
Generation Counter	Set to 0	Set to 0

16.12.14.5 Generation Counter

The drive increments the Generation counter when a Register service action or a Preempt and Clear service action complete successfully.

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16.13 PRE-FETCH (10) - (34)

The PRE-FETCH (10) (34) command requests the drive to transfer data to the cache. This command is implemented as a NOOP and returns a Good status on the SSD.

Table 16 - 115: PRE-FETCH (10) - (34)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 34h							
1	Reserved						Immed=0	Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Transfer Length							
9	Control Byte - Refer to SCSI Control Byte							

16.14 PRE-FETCH (16) - (90)

The PRE-FETCH (16) (90) command requests the drive to transfer data to the cache. This command is implemented as a NOOP and returns a Good status on the SSD.

Table 16 - 116: PRE-FETCH (16) - (90)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 90h							
1	Reserved						IMMED	RSVD
2-9	Logical Block Address							
10-13	Pre-fetch Length							
14	Reserved			Group Number				
15	Control Byte - Refer to SCSI Control Byte							

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16.15 READ (6) - (08)

READ (6) requests the drive to transfer the specified number of blocks (Transfer Length) from the medium to the initiator, starting at the specified Logical Block Address (LBA).

Table 16 - 117: READ (6) - (08)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 08h							
1	Reserved			Logical Block Address				
2-3	Logical Block Address (continued)							
4	Transfer Length							
5	Control Byte - Refer to SCSI Control Byte							

- Logical Block Address specifies the logical unit at which the READ operation begins.
- Transfer Length specifies the number of blocks to be transferred. A value of 0 implies 256 blocks are to be transferred.

16.16 READ (10) - (28)

READ (10) requests the drive to transfer data to the initiator. The larger LBA and Transfer Length fields permit greater quantities of data to be requested per command than with the READ command. These fields are required to access the full LBA range of the larger capacity drives.

Table 16 - 118: READ (10) - (28)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 28h							
1	RDPROTECT			DPO	FUA	RSVD	FUA_NV	Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Transfer Length							
9	Control Byte - Refer to SCSI Control Byte							

- FUA_NV (Force Unit Access Non-Volatile Cache bit) may be set to 0 or 1, but it is ignored as NV_SUP=0 in Inquiry Page 86h.
- Transfer Length is the number of contiguous blocks to be transferred. If the transfer length is 0, the seek occurs, but no data is transferred. This condition is not considered an error. If read ahead is enabled, a read ahead is started after the seek completes.

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- DPO Disable Page Out bit: Ignored.
- FUA Force Unit Access bit: Ignored.

o RDPROTECT defines how protection information read from drive is checked during command processing. Protection information is stored on the drive and may be transmitted to the drive's internal data buffer and to the initiator with the user data. If the drive is not formatted with protection information, RDPROTECT must be set to 000b. Otherwise, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.

- RDPROTECT=000b: Protection information is checked (if applicable), but not transmitted to the initiator. Logical Block Guard, Logical Block Application Tag (applies to 32-byte CDBs or when ATO=1), and Logical Block Reference Tag are checked.

Note: The Protection information is not checked if DPICZ = 1.

- RDPROTECT=001b: Protection information is transmitted to the initiator with the user data. Logical Block Guard, Logical Block Application Tag (applies to 32-byte CDBs or when ATO=1), and Logical Block Reference Tag are checked.

Note: If a SANITIZE (48) operation using Service Action 03h (Cryptographic Erase) was performed, then a READ command with the RDPROTECT bit set for T10-DIF Type 1 returns User Data Content = 0x00 and Tag Bytes = 0xFF.

- RDPROTECT=010b: Protection information is transmitted to the initiator with the user data. Logical Block Guard is *not* checked. Logical Block Application Tag (applies to 32-byte CDBs or when ATO=1) and Logical Block Reference Tag are checked.
- RDPROTECT=011b: Protection information is transmitted to the initiator with the user data. Logical Block Guard, Logical Block Application Tag, and Logical Block Reference Tag are *not* checked.
- RDPROTECT=100b: Protection information is transmitted to the initiator with the user data. Logical Block Guard is checked, but Logical Block Application Tag and Logical Block Reference Tag are *not* checked.
- RDPROTECT=101b: Protection information is transmitted to the initiator with the user data. Logical Block Guard, Logical Block Application Tag (applies to 32-byte CDBs or when ATO=1), and Logical Block Reference Tag are checked.
- RDPROTECT=110b, 111b: These values are reserved. A Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- If a check of the protection information fails, a Check Condition status is returned, with a Sense Key of Aborted Command and an Additional Sense Code indicating which protection field check failed.
- Refer to the ANSI T10 standards for additional details of protection information.
- If the transfer length is 0, no data is transferred. The CDB is validated and protocol checked and, if no problems are found, a Good status is returned immediately. This condition is not considered an error.

16.17 READ (12) - (A8)

READ (12) causes the drive to transfer data to the initiator. See the READ (10) description for the definitions of the fields in this command.

Table 16 - 119: Read (12) - (A8)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = A8h							
1	RDPROTECT			DPO	FUA	RSVD	FUA_NV	RSVD
2-5	Logical Block Address							
6-9	Transfer Length							
10	Reserved							
11	Control Byte - Refer to SCSI Control Byte							

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16.18 READ (16) - (88)

READ (16) causes the drive to transfer data to the initiator. See the READ (10) description for the definitions of the fields in this command.

Table 16 - 120: READ (16) - (88)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 88h							
1	RDPROTECT			DPO	FUA	RSVD	FUA_NV	RSVD
2-9	Logical Block Address							
10-13	Transfer Length							
14	Restricted for MMC-4	Reserved		Group Number				
15	Control Byte - Refer to SCSI Control Byte							

16.19 READ (32) - (7F/09)

READ (32) requests that the drive transfer data to the initiator. Each logical block transferred includes user data and may include protection information, based on the RDPROTECT field and the drive format.

Table 16 - 121: READ (32) - (7F/09)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 7Fh							
1	Control Byte - Refer to SCSI Control Byte							
2-5	Reserved							
6	Reserved			Group Number = 0				
7	Additional CDB Length = 18h							
8-9	Service Action = 0009h							
10	RDPROTECT			DPO	FUA	RSVD	FUA_NV	RSVD
11	Reserved							
12-19	Logical Block Address							
20-23	Expected Initial Logical Block Reference Tag							
24-25	Logical Block Application Tag							
26-27	Logical Block Application Tag Mask							
28-31	Transfer Length							

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If the drive is formatted with type 2 protection (PROT_EN=1 and P_TYPE=001b in the READ CAPACITY (16) parameter data), then this command is processed normally. Any other protection types return a Check Condition status, with Sense Key of Illegal Request and an Additional Sense Code of Invalid Command Operation Code.

The Expected Initial Logical Block Reference Tag field contains the value of the Logical Block Reference Tag field expected in the protection information. This information is in the first logical block accessed by the command.

If the ATO bit is set to 1 in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a bitmask value. This value enables checking the Logical Block Application Tag field in the protection information for each logical block accessed by the command. A Logical Block Application Tag Mask bit set to 1 enables the checking of the corresponding bit of the Expected Logical Block Application Tag field, with the corresponding bit of the Logical Block Application Tag field in the protection information.

If the ATO bit is set to 0, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

16.20 READ BUFFER (3C)

READ BUFFER (3C) is used in with WRITE BUFFER (3B) as a diagnostic function for testing the memory of the drive and the SCSI bus integrity. This command does not alter the medium.

Table 16 - 122: READ BUFFER (3C)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 3Ch							
1	Reserved			Mode				
2	Buffer ID = 0							
3-5	Buffer Offset							
6-8	Allocation Length							
9	Control Byte - Refer to SCSI Control Byte							

The function of this command and the meaning of fields in the command descriptor block depend on the contents of the Mode field.

Table 16 - 123: Mode Field Contents

Mode	Description
00010	Read Data
00011	Descriptor
01010	Read Data from Echo Buffer
01011	Echo Buffer Descriptor
11100	Error History
11010	Enable Expander Communications Protocol and Echo Buffer
All others	Not supported

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16.20.1 Read Data (Mode 00010b)

In this mode, the DATA IN phase contains buffer data.

- Buffer ID must be set to 0, indicating the data transfer buffer. If another value is specified, the command is terminated with a Check Condition status. The drive sets the Sense Key to Illegal Request and an Additional Sense Code to Illegal Field in the CDB.
- Buffer Offset indicates the offset of the memory space specified by the Buffer ID. The initiator should conform to the offset boundary requirements returned in the READ BUFFER descriptor. If the value exceeds the buffer specified, the command is terminated with a Check Condition status. The drive sets the Sense Key to Illegal Request and an Additional Sense Code to Illegal Field in the CDB.
- Allocation Length: The drive terminates the DATA IN phase when Allocation Length bytes of data have been transferred, or when the header and all available data have been transferred to the initiator, whichever occurs first.

If a download is in progress, the READ BUFFER command is terminated with a Check Condition status. The drive sets the Sense Key to Illegal Request and an Additional Sense Code to Operation In Progress.

16.20.2 Descriptor (Mode 00011b)

In this mode, a maximum of four bytes of READ BUFFER descriptor information is returned. The drive returns the descriptor information for the buffer specified by the Buffer ID.

- Buffer ID should normally be set to 0, indicating the drive data transfer buffer. If any other value is specified, the drive returns all zeros in the READ BUFFER descriptor.
- Buffer Offset is reserved.
- Allocation Length should be set to four or greater. The drive transfers the allocation length or four bytes of READ BUFFER descriptor, whichever is less. The allocation length of zero indicates no data is transferred. The allocation length of greater than zero and less than four (size of the Descriptor) is an invalid request and causes the command to be terminated with a Check Condition status. The drive sets the Sense Key to Illegal Request and an Additional Sense Code to Illegal Field in the CDB.

The READ BUFFER descriptor is defined below.

Table 16 - 124: Read Buffer Descriptor

	Bit						
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**
0	Offset Boundary = 0x09						
1-3	Buffer Capacity						

The value contained in the Buffer Offset field of subsequent WRITE BUFFER and READ BUFFER commands should be a multiple of 2 to the power of the offset boundary. The offset boundary is always set to nine, which indicates Sector Boundaries.

16.20.3 Read Data from Echo Buffer (Mode 01010b)

In this mode, the drive transfers data from the echo buffer. The echo buffer will transfer the same data as when the WRITE BUFFER command was issued, with the mode field set to Echo Buffer.

- A WRITE BUFFER command, with the mode field set to Echo Buffer should be sent prior to the READ BUFFER command; otherwise the READ BUFFER command will be terminated with a Check Condition status and Illegal Request.
- In this mode, READ BUFFER transfers the specified amount of data, or the amount previously written with a Write Buffer using mode 1010b from the echo buffer, whichever is less.
- Issuing a Read Buffer mode 1010b before a Write Buffer mode 1010b causes indeterminate data to be returned.
- The most significant two bytes of the Allocation Length are ignored. The specified amount of data transferred should not be larger than the echo buffer capacity. This capacity may be determined by using Read Buffer mode 1011b. Any additional data transferred above the echo buffer capacity is regarded as indeterminate.
- The Buffer ID and Buffer Offset fields are ignored in this mode.

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Notes:

1. The echo buffer is a separate buffer from the data buffer used with other read buffer modes. It is intended to be used for domain validation purposes.

16.20.4 Echo Buffer Descriptor (Mode 01011b)

In this mode, a maximum of four bytes of Read Buffer Descriptor information is returned. The drive returns the descriptor information for the echo buffer. The Buffer Offset field is reserved in this mode and must be zero. The drive transfers the lesser of the allocation length or four bytes that follow the Echo Buffer Descriptor.

Table 16 - 125: Echo Buffer Descriptor

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserve							EBOS
1	Reserved							
2	Reserve				Buffer			
3	Buffer Capacity							

- EBOS (Echo Buffer Overwritten Supported bit): 0 = the echo buffer is shared by all initiators.
- Buffer Capacity returns the size of the echo buffer in bytes, aligned to a 4-byte boundary.

16.20.5 Expander Communications and Echo Buffer (Mode 11010b)

Receipt of a READ BUFFER command with this mode (11010b) causes a communicative expander to enter the expanded communication protocol mode. SCSI target devices that receive a READ BUFFER command with this mode process it as if it were a READ BUFFER command with mode 01010b (see Read Data from Echo Buffer (Mode 01010b).

16.20.6 Error History (Mode 11100b)

This mode is used to manage and retrieve error history. If the device server is unable to process a READ BUFFER command with the Mode field set to 1Ch (11100b) due to a vendor-specific condition, then the device server terminates the command. A Check Condition status is returned, with the Sense Key set to Illegal Request, and the Additional Sense Code set to Command Sequence Error. The Code set in Buffer ID field specifies the action the device server performs, and the parameter data, if any, that the device server returns.

- Buffer ID must be set to 0, indicating the data transfer buffer. If another value is specified, the command is terminated with a Check Condition status. The drive sets Sense Key to Illegal Request and an Additional Sense Code to Illegal Field in the CDB.
- Buffer Offset indicates the byte offset from the start of the buffer specified by the Buffer ID field. This is thefield from which the device server returns data. The application client should conform to the offset boundary requirements as indicated by the Read Buffer Descriptor. The Buffer Offset must be set to 0000h for Error History I_T Nexus Constrained.
- Allocation Length should be set to four or greater. The drive transfers the allocation length, or four bytes of the READ BUFFER descriptor, whichever is less.
- Whenever allowed by an established Error History I_T Nexus constraint, all error history device server actions return an Error History Directory as shown in the table below.

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Table 16 - 126: **Error History Directory**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	(MSB)	T10 Vendor Identification						
…								
7								(LSB)
8	Version							
9	Reserved			EHS_Retrieved		EHS_Source		CLR_SUP
10		Reserved						
…								
29								
30	(MSB)	Directory Length (n-31)						
31								(LSB)
	Error History Directory List							
32		Error History Directory Entry [First]						
…								
39								
	. . .							
n-7		Error History Directory Entry [Last]						
…								
n								

- T10 Vendor Identification identifies the manufacturer of the logical unit.
- Version indicates the version and format of the vendor specific error history.
- EHS_Retrieved (Error History Retrieved) indicates whether a clear error history device server action has been requested for the error history snapshot. The field is set to 00b or 10b if the error history snapshot has been created. Code values are shown in the table below.

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Table 16 - 127: **Error History Retrieved**

Code	Description
00b	No information.
01b	The Error History I_T Nexus has requested Buffer ID FEh (Clear Error History I_T Nexus) or Buffer ID FFh (Clear Error History I_T Nexus and Release Snapshot) for the current error history snapshot.
10b	The Error History I_T Nexus has not requested Buffer ID FEh (Clear Error History I_T Nexus) or Buffer ID FFh (Clear Error History I_T Nexus and Release Snapshot) for the current error history snapshot.
11b	Reserved

- EHS_Source (Error History Source) indicates the source of the error history snapshot:

Code	Description
00b	The error history snapshot was created by the device server, not due to processing a Read Buffer command.
01b	The error history snapshot was created due to processing the current Read Buffer command.
10b	The error history snapshot was created due to processing a previous Read Buffer command.
11b	Reserved

- CLR_SUP (Clear Support) bit:
- If the bit is set to one, the CLR bit is supported in the Write Buffer command download history mode.
- If the bit is set to 0, the CLR bit is not supported.
- Directory Length indicates the number of bytes that follow in the error history directory list. The value does not change, even if the allocation length is not sufficient to transfer the entire error history directory list.
- The Error History Directory List contains an Error History Directory Entry for each supported Buffer ID in the range of 00h to EFh. The first entry is for Buffer ID 00h, and the subsequent entries are in order of ascending Buffer IDs greater than or equal to F0h.

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Table 16 - 128: **Error History Directory List**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Supported Buffer ID							
1								
…	Reserved							
3								

	(MSB)	Maximum Available Length	
…			
7			(LSB)

- Supported Buffer ID indicates the error history Buffer ID associated with this entry.
- Maximum Available Length indicates the maximum number of data bytes contained in the buffer as indicated by the Supported Buffer ID field. The actual number of bytes available for transfer may be smaller.

16.21 READ CAPACITY (10) - (25)

READ CAPACITY (10) returns information about the capacity of the drive.

Table 16 - 129: **READ CAPACITY (10) - (25)**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 25h							
1	Reserved							
2-5	Reserved							
6-7	Reserved							
8	Reserved							
9	Control Byte - Refer to SCSI Control Byte							

16.21.1 Returned Data Format

The data returned to the initiator in response to the READ CAPACITY command is described below. The data is returned in the DATA IN phase. The Block Length specifies the length in bytes of each block of user data (not including protection information).

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Table 16 - 130: **Format of READ CAPACITY Command Reply**

	Bit							
Byte	**6**	**7**	**5**	**4**	**3**	**2**	**1**	**0**
0-3	Maximum Logical Block Address							
4-7	Block Length							

16.22 READ CAPACITY (16) (9E/10)

READ CAPACITY (16) (9E/10) returns information about the capacity of the drive. This command is processed like the standard READ CAPACITY (10) command. The contents of the CONTROL byte are defined in SAM-4.

Table 16 - 131: **Read Capacity (16) (9E/10)**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 9Eh							
1	Reserved			Service Action = 10h				
2-9	Reserved							
10-13	Allocation Length							
14	Reserved							
15	Control Byte - Refer to SCSI Control Byte							

16.22.1 Returned Data Format

Table 16 - 132: **Returned Data Format**

	Bit							
Byte	**6**	**7**	**5**	**4**	**3**	**2**	**1**	**0**
0-7	Returned Logical Block Address							
8-11	Logical Block Length in Bytes							
12	Reserved				P_Type			Prot_En
13	P_I_Exponent				Logical Block Per Physical Block Exponent			
14	LBPME=1	LBPRZ=1	Lowest Aligned Logical Block Address					
15	Lowest Aligned Logical Block Address							
16-31	Reserved							

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- Returned Logical Block Address and Logical Block Length in Bytes fields: These fields in the READ CAPACITY (16) parameter data are the same as in the READ CAPACITY (10) parameter data. The maximum value in Returned Logical Block Address is FFFF_FFFF_FFFF_FFFEh.
- P_Type Protection Type and Prot_En Protection Enable indicate the logical unit's current type of protection. See the following table.

Table 16 - 133: P_TYPE Field and PROT_EN Bit

PROT_EN	P_TYPE	Description
0	xxxb	The logical unit is formatted to type 0 protection.
1	000b	The logical unit is formatted to type 1 protection.
1	001b	The logical unit is formatted to type 2 protection.
1	010b	The logical unit is formatted to type 3 protection.
1	011b to 111b	Reserved

- P_I_Exponent may be used to determine the number of protection information intervals placed within each logical block. The number of protection information intervals is calculated as follows:

  number of protection information intervals = 2*(p_iexponent), where p_i exponent is the contents of the P_I EXPONENT field
- Logical Block Per Physical Block Exponent is defined below.

Table 16 - 134: LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT Field

Code	Description
0	One or more physical blocks per logical block.[(a)]
n > 0	2n Logical Blocks per Physical Block
1	The logical unit is formatted to Type 2 Protection.

The number of physical blocks per logical block is not reported.

- LBPME Logical Block Provisioning Management Enabled is set to 1. The drive implements logical block provisioning management.
- LBPRZ Logical Block Provisioning Read Zeros is set to 1. For an unmapped LBA specified by a read operation, the drive sends user data with all bits set to 0 in the Data-In Buffer. If protection information is also transferred on the read operation, it is all 0xFFs.
- Lowest Aligned Logical Block Address indicates the LBA of the first logical block located at the beginning of a physical block.

Notes:

1. The highest LBA that the lowest aligned logical block address field supports is 3FFFh (16,383).

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16.23 READ DEFECT DATA (10)

READ DEFECT DATA (10) requests that the target transfer the medium defect data to the initiator.

Table 16 - 135: READ DEFECT DATA (10)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 37h							
1	Reserved							0
2	Reserved			Plist	Glist	Defect List Format		
3-6	Reserved							
7-8	Allocation Length							
9	Control Byte - Refer to SCSI Control Byte							

If the target is unable to access any medium defect data, it returns a Check Condition status with the appropriate Sense Key. The Sense Key will be set to Medium Error (03h), if a medium error occurred, or No Sense (00h) if the list does not exist and the Additional Sense Code will be set to Defect List Error (19h).

- Plist bit: 1 = the target returns the Plist; 0 = the target does not return the Plist of defects.
- Glist bit: 1 = the target returns the Glist; 0 = the target shall not return the Glist of defects. Note: With both bits set to 1 for Plaist and Glist, the target returns both the primary and grown defect lists. With both bits set to 0, the target returns only a 4-byte Defect List Header.
- Defect List format of '110 (Vendor-unique Format)' is supported. If the requested format is not supported by the drive, it returns the defect list in its default format '110' and then terminate the command with Success status.

The Target transfers all the Read Defect Data, up to the number of bytes allocated by the initiator.

Notes:

1. The drive terminates the Data-In phase when the Allocation Length has been transferred, or when all available Defect Data has been transferred to the initiator, whichever occurs first.

2. Read Defect Data contains a 4-byte header followed by zero or more defect descriptors.

16.23.1 Defect List Header

Table 16 - 136: Defect List Header

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	Defect List Header							
0	Reserved							
1	Reserve			Plist	Glist	Defect List Format		
2-3	Defect List length							

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16.23.2 Defect List Descriptor

Table 16 - 137: Defect List Descriptor

Byte	Bit							
	7	6	5	4	3	2	1	0
	Defect List Descriptor							
0-7	Defect Descriptor 0							
...								
8n - (8n+7)	Defect Descriptor n							

- Defect List Format specifies the format of the defect list data returned by the target.
- Defect List Length specifies the length in bytes of the defect descriptors that follow. The Defect List Length is equal to eight times the number of defect descriptors.

Normally, the target sets the Defect List Length field to the amount of space needed to contain the entire defect list. However, the target can build a defect list with a length such that the entire list cannot be transferred using the maximum allocation length. If the defect list grows beyond 8191 entries, the defect data cannot be transferred with an allocation length of 0FFFFh. In that case, the Target transfers a partial defect list and returns a Check Condition status with the Sense Key set to Recovered Error and the Additional Sense Code set to Partial Defect List Transferred. The defect list length is set to 0FFF8h, indicating the maximum number of defect descriptors that can be transferred. Defects beyond this number cannot be read by the initiator.

16.24 READ DEFECT DATA (12)

Table 16 - 138: READ DEFECT DATA (12)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = B7h							
1	Reserved			Plist	Glist	Defect List Format		
2-5	Reserved							
6-9	Allocation Length							
10	Reserved							
11	Control Byte - Refer to SCSI Control Byte							

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16.24.1 Defect List Header

Table 16 - 139: Defect List Header

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	Defect List Header							
0	Reserved							
1	Reserved			Plist	Glist	Defect List Format		
2-3	Reserved							
4-7	Defect List Length							

See READ DEFECT DATA (10) in Section Table Defect List Header.

16.24.2 Defect List Descriptor

Table 16 - 140: Defect List Descriptor

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	Defect List Descriptor							
0-7	Defect Descriptor 0							
...								
8n - (8n+7)	Defect Descriptor n							

See READ DEFECT DATA (10) in Section Defect List Descriptor

16.25 Read Long (10) (3E)

READ LONG (3E) requests the drive to transfer one block of data to the initiator. The transfer data also includes ECC field data.

Table 16 - 141: READ LONG (10) (3E)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 3Eh							
1	Reserved					Reserved	Correct = 0	Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Byte Transfer Length							

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9	Control Byte - Refer to *SCSI Control Byte*

- Correct bit is ignored. ECC correction is always performed. If ECC correction fails, the target terminates the command with a Check Condition status, the Sense Key is set to Medium Error, and an Additional Sense Code set to Unrecovered Read Error.
- Logical Block Address specifies the logical block where the read operation occurs.
- Byte Transfer Length must specify exactly the number of bytes of data available for transfer. If a non-zero byte transfer length does not match the available data length, the target terminates the command with a Check Condition status, the Sense Key is set to Illegal Request, and an Additional Sense Code set to Invalid Field in the CDB. The valid and ILI bits are set to 1, and the information field is set to the difference of the requested length minus the actual length in bytes. Negative values are indicated by two's complement notation.

The Transfer Length is calculated as follows:

Transfer Length = Logical Block Size + Protection Information Size + CRC size

… where protection information size is either 0 (Protection Mode 0) or 8 (Protection Mode 1 or 2) and CRC Size is 4.

Notes:

1. The data read by this command is neither read from nor retained in the cache.

16.26 READ LONG (16) - (9E/11) 16-Byte CDB

Refer to the 10-byte CDB for READ LONG (3E).

Table 16 - 142: READ LONG (16) - (9E/11) 16-Byte CDB

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Operation Code (9Eh)							
1	Reserved			Service Action (11h)				
2-9	Logical Block Address							
10-11	Reserved							
12-13	Byte Transfer Length							
14	Reserved						Reserved	CORRCT
15	Control							

16.27 REASSIGN BLOCKS (07)

REASSIGN BLOCKS (07) reads the specified blocks to ensure there are no read errors. Should a read error occur, that LBA is then unmapped for subsequent use.

Table 16 - 143: REASSIGN BLOCKS (07)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 07h							
1	Reserved							

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2-4	Reserved
5	Control Byte - Refer to *SCSI Control Byte*

Following is the format of the data sent by the initiator during the DATA OUT phase:

Table 16 - 144: Format of Reassign Blocks Data

	Bit						
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**
0	Reserved						
1	Reserved						
2-3	Defect List Length = 4/8/12/16						
4-7	Defect Logical Block Address 1						
8-11	Defect Logical Block Address 2						
12-15	Defect Logical Block Address 3						
16-19	Defect Logical Block Address 4						

- Defect List Length must be 4, 8, 12, or 16. Otherwise, the drive returns a Check Condition with a Sense Key of Illegal Request.
- Defective Logical Block Address is four bytes in length. The initiator can specify from 1 to 4 Defective Logical Block Addresses according to the Defect List Length from 4 to 16, respectively. LBAs are not required to be in ascending order. If the Defective Logical Block Address is greater than the maximum LBA of the drive, the command is terminated with a Check Condition and a Sense Key of Illegal Request.

16.28 RECEIVE DIAGNOSTICS RESULTS (1C)

RECEIVE DIAGNOSTIC RESULTS (1C) requests that analysis data requested by a SEND DIAGNOSTIC command be sent to the initiator.

Table 16 - 145: RECEIVE DIAGNOSTICS RESULTS (1C)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 1Ch							
1	Reserved							PCV
2	Page Code							
3-4	Allocation Length							
5	Control Byte - Refer to *SCSI Control Byte*							

- PCV Page Code Valid bit: 0 = the most recent SEND DIAGNOSTIC command defines the data returned by this command; 1 = the contents of the Page Code field defines the data returned by this command.
- Allocation Length specifies the amount of data to be returned to the initiator. This value may be zero, which is not considered an error. The Target terminates the Data In phase when all available data has been transferred, or when the number of bytes transferred equals the Parameter List Length.

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16.28.1 Receive Diagnostic Results Page 0

This page contains a list of supported pages. The supported diagnostic page returns a list of supported pages in ascending order.

Table 16 - 146: Receive Diagnostic Results Page 0

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Page Code = 0							
1	Reserved							
2-3	Page Length = 03h							
4	(Supported Pages) Page = 0h							
5	CJTPAT page = 3Fh							

16.29 RELEASE (6) (17)

RELEASE (6) (17) is used to release a LUN that was previously reserved. It is not an error for an initiator to release a LUN that is not currently active. The drive returns Good status without altering the reservation.

Table 16 - 147: RELEASE (6) (17)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 17h							
1	Reserved			3rdPty=0	3rd Party ID			Ext=0
2	Reservation Identification							
3-4	Reserved							
5	Control Byte - Refer to *SCSI Control Byte*							

- 3rdPty must be 0. Third Party reservations are not supported. If the 3rdPty bit is not zero, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- 3rd Party ID is ignored.
- Ext Extents must be 0. Extension is not supported by the drive.
- Reservation Identification is ignored.

16.30 RELEASE (10) (57)

RELEASE (10) (57) is used to release a LUN that was previously reserved. It is not an error for an initiator to release a LUN that is not currently active. The drive returns Good status without altering the reservation.

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Table 16 - 148: **RELEASE (10) (57)**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 57h							
1	Reserved			3rdPty=0	Reserved			Ext = 0
2	Reservation Identification							
3	3rd Party Device ID							
4-8	Reserved							
9	Control Byte - Refer to *SCSI Control Byte*							

- 3rdPty must be 0. Third Party reservations are not supported. If the 3rdPty bit is not 0, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- 3rd Party ID is ignored.
- Ext Extent must be 0. Extension is not supported by the drive.
- Reservation Identification is ignored.

16.31 REPORT DEVICE IDENTIFIER (A3/05)

REPORT DEVICE IDENTIFIER (A3/05) requests that the device server send device identification information to the application client.

Table 16 - 149: **REPORT DEVICE IDENTIFIER (A3/05)**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = A3h							
1	Reserved				Service Action = 05h			
2	Reserved							
3	Reserved							
4-5	LUN=0							
6-9	Allocation Length							
10	Reserved							
11	Vendor specific		Reserved			NACA	Obsolete	

- LUN Logical Unit number is expected to be 0. Any other value for this parameter causes the command to terminate with a Check Condition status. The Sense Key is then set to ILLEGAL REQUEST, and the Additional Sense Code is set to Invalid Field in the CDB.
- Allocation Length indicates how much space has been reserved for the returned parameter data. If the length is not sufficient to contain all the parameter data, the first portion of the data is returned. This is not considered an error. The actual length of the parameter data is available in the IDENTIFIER LENGTH field in the parameter data. If the remainder of the parameter data is required, the application client should send a new REPORT DEVICE IDENTIFIER command with an Allocation Length field large enough to contain all the data.

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The REPORT DEVICE IDENTIFIER parameter list contains a 4-byte field that contains the length in bytes of the parameter list and the logical unit's identifier.

Table 16 - 150: Report Device Identifier Parameter List

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-3	Identifier Length = n – 3							
4-n	Identifier							

- Identifier Length specifies the length in bytes of the Identifier field. If the Allocation Length field in the CDB is too small to transfer all of the identifier, the length is not adjusted to reflect the truncation. The identifier length initially equals zero and is changed only by a successful SET DEVICE IDENTIFIER command.
- Identifier contains a vendor-specific value. The value reported is the last value written by a successful SET DEVICE IDENTIFIER command. The value of the identifier is changed only by a SET DEVICE IDENTIFIER command. The identifier value persists through resets, power cycles, and media format operations.
- The Target returns the same Identifier to all initiators on all ports.
- The execution of a REPORT DEVICE IDENTIFIER requires the enabling of a nonvolatile memory within the logical unit. If the nonvolatile memory is not ready, the device server returns a Check Condition status rather than waiting for the device to become ready. The Sense Key is set to Not Ready, and the additional sense data is set as described in the TEST UNIT READY command. This information should allow the application client to determine the action required to cause the device server to become ready.

16.32 REPORT LUNS (A0)

REPORT LUNS (A0) requests that the target return the known LUN to the initiator. The REPORT LUNS command should always be available and is unaffected by any reservations.

Table 16 - 151: REPORT LUNS (A0)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = A0h							
1-5	Reserved							
6-9	Allocation Length							
10	Reserved							
11	Vendor specific		Reserved			NACA	Obsolete	

- Allocation Length must be at least 16 bytes. If the Allocation Length is less than 16 bytes, the target returns a Check Condition status with Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- If the Allocation Length is not sufficient to contain the LUN values for all configured logical units, the target shall report as many LUN values as will fit in the specified Allocation Length. This is not considered an error.

The REPORT LUNS command sends the LUN list in the subsequent Data Out Phase. The format of the LUN list is shown in the following table. LUN List Length contains the length in bytes of the LUN list that is available to be transferred. This drive supports only one LUN; therefore, the LUN list length must be set to 8. The only supported LUN is zero.

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Table 16 - 152: **UN Reporting Parameter List Format**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-3	LUN List Length = 8							
4-7	Reserved							
8-15	LUN = 0							

16.33 REPORT SUPPORTED OPERATION CODES (A3/0C)

REPORT SUPPORTED OPERATION CODES (A3/0C) requests information on commands that the drive supports. The initiator may request a list of all operation codes and service actions supported, or the command support data for a specific command.

Table 16 - 153: **REPORT SUPPORTED OPERATION CODES (A3/0C)**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = A3h							
1	Reserved				Service Action = 0Ch			
2	RCTD	Reserved				Reporting Options		
3	Requested Operation Code							
4-5	Requested Service Action							
6-9	Allocation Length							
10	Reserved							
11	Control Byte - Refer to *SCSI Control Byte*							

- RCTD Return Command Timeouts Descriptor bit: 1 = the command timeouts descriptor is included in each command descriptor that is returned, or in the one_command parameter data that is returned.
- A RCTD bit: 0 = the command timeouts descriptor is not included in any parameter data returned. Reporting Options specifies the information to be returned in the parameter data.

Table 16 - 154: **Reporting Options**

Reporting Option	Description
000b	A list of all operation codes and service actions supported by the drive is returned in the all_commands parameter data format. The Requested Operation Code field and Requested Service Action field are ignored.
001b	The command support data for the operation code specified in the Requested Operation Code field is returned in the one_command parameter data format. The Requested Service Action field is ignored. If the Requested Operation Code field specifies an operation code that has service actions, a Check Condition status is reported with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.

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010b	The operation code and service action specified in the Requested Operation Code field and Requested Service Action field have command support data. This data is returned in the one_command parameter data format. If the Requested Operation Code field specifies an operation code that does not have service actions, a Check Condition status is reported, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
011b-111b	Reserved

- Requested Operation Code specifies the operation code of the command be returned in the one_command parameter data format.
- Requested Service Action specifies the service action of the command be returned in the one_command parameter data format.
- Allocation Length specifies the number of bytes that have been allocated for the returned parameter data. If the length is not sufficient to contain all the parameter data, the first portion of the data is returned. The actual length of the parameter data may be determined from the Additional Length field in the parameter data.

16.33.1 all_commands Parameter Data Format

In the Report Supported Operation Codes, the all_command parameter data format begins with a four-byte header that contains the length in bytes of the parameter data. It is followed by a list of supported commands. Each command descriptor contains information about a single supported command CDB (one operation code and service action combination, or one non-service action operation code).

Table 16 - 155: all_commands Parameter Data Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-3	Command Data Length (n-3)							
4	Command Descriptor 0							
N	Command Descriptor X							

Each Command Descriptor contains information about a single supported command CDB.

Table 16 - 156: Command Descriptor Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Operation Code							
1	Reserved							
2-3	Service Action							
4	Reserved							
5	Reserved						CTDP	Servactv
6-7	CDB Length							
8-19	Command Timeouts Descriptor, if any (see Command Timeouts Descriptor Format)							

- Operation Code contains the operation code of a supported command.

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- Service Action contains a supported service action of the supported operation. If the operation code does not have a service action, the Service Action field is set to 0.
- CTDP (Command Timeouts Descriptor Present bit): 1 = the command timeouts descriptor Command Timeouts Descriptor Format is included in this command descriptor. A CTDP bit set to 0 indicates that the command timeouts descriptor is not included in this command descriptor.
- Servactv: 0 = the operation code does not have service actions, and the Service Action field should be ignored; 1 = the operation code field has service actions, and the contents of the Service Action field are valid.
- CDB Length contains the length of the command CDB in bytes.

16.33.2 one_command Parameter Data Format

The one_command parameter data format in the Report Supported Operation Codes contains information about the CDB. It also contains a usage map for the command specified by the Reporting Options, Requested Operation Code, and Requested Service Action fields, in the Reported Supported Operation Codes CDB.

Table 16 - 157: one_command Parameter Data Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved							
1	CTDP	Reserved				Support		
2-3	CDB Size (n-3)							
4-n	CDB Usage Data							
n+1 – n+12	Command Timeouts Descriptor, if any (see Command Timeouts Descriptor Format)							

- CTDP (Command Timeouts Descriptor Present bit): 1 = the command timeouts descriptor is included in this command descriptor (see Command Timeouts Descriptor Format); 0 = indicates that the command timeouts descriptor is not included in this command descriptor.
- Support is defined in Mode Sense (6) (1A).

Table 16 - 158: one_command Parameter Support Field

Recording Option	Description
000b	Data about the requested command is not currently available. All data after byte 1 is not valid. A subsequent request for command support data may be successful.
001b	The requested command is not supported. All data after byte 1 is not valid.
010b	Reserved
011b	The requested command is supported in conformance with the standard.
100b	Reserved
101b	The requested command is supported in a vendor specific manner.
110b-111b	Reserved

- CDB Size contains the size of the CDB Usage Data field in the parameter data, and the number of bytes in the CDB for the requested command.

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- CDB Usage Data contains information about the CDB for the command requested. The first byte of the CDB Usage Data field contains the operation code for the command. If the command contains a service action, the service action code is returned in the same location as the Service Action field of the command CDB. All other bytes of the CDB Usage Data field contain a usage map for bits in the CDB for the command requested. The bits in the usage map have a one-to-one correspondence to the CDB for the command requested. If the drive evaluates a bit in the CDB, the usage map containa a 1 in the corresponding bit position. The usage map contains zero in the corresponding bit position for any field treated as ignored or reserved.

16.33.3 Command Timeouts Descriptor Format

16.33.3.1 Overview

The command timeouts descriptor returns timeout information for commands supported by the logical unit. This is based on the time from the start of processing for the command to its reported completion. Values returned in the command timeouts descriptor do not include times outside the control of the device server. Examples of these include prior commands with the IMMED bit set to 1 in the CDB, concurrent commands from the same or different I_T nexuses, manual unloads, power-on self tests, prior aborted commands, commands that force cache synchronization, and delays in the service delivery subsystem.

For commands that cause a change in power condition (Idle/Standby Powersave Modes), values returned in the command timeouts descriptor do not include the power condition transition time, such as the time to spin up rotating media.

Values returned in the command timeouts descriptor should not be used to compare products.

Table 16 - 159: Command Timeouts Descriptor Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Descriptor Length (0Ah)							
2	Reserved							
3	Command Specific							
4-7	Nominal Command Processing Timeout							
8-11	Recommended Command Timeout							

- Descriptor Length indicates the number of bytes that follow in the command timeouts descriptor.
- Command Specific contains timeout information (see <XREF>) that is specific to one or more commands.
- If no command-specific timeout information is defined by this or the applicable command standard, the COMMAND SPECIFIC field is reserved.

16.33.3.2 WRITE BUFFER: Command Timeouts Descriptor COMMAND SPECIFIC Field Usage

For the WRITE BUFFER command, the COMMAND SPECIFIC field usage is reserved for all modes except the following:

- Download microcode mode (04h);
- Download microcode and save mode (05h);
- Download microcode with offsets and save mode (07h);
- Download microcode with offsets and defer activation mode (0Eh) only if the microcode is activated by an event other than an activate deferred microcode mode; and
- Activate deferred microcode mode (0Fh).

If the command timeouts descriptor describes one of the WRITE BUFFER modes listed in this sub-clause, then the COMMAND SPECIFIC field indicates the maximum time, in one second increments, that access to the SCSI device is limited or not possible. This refers to any SCSI ports associated with a logical unit that processes a WRITE BUFFER command specifying one of the named modes. A value of zero in the COMMAND SPECIFIC field indicates that no maximum time is indicated.

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16.34 REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS (A3/0D)

REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS (A3/0D) requests information on task management functions supported by the drive.

Table 16 - 160: REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS (A3/0D)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = A3h							
1	Reserved			Service Action = 0Dh				
2-5	Reserved							
6-9	Allocation Length							
10	Reserved							
11	Control Byte - Refer to SCSI Control Byte							

- Allocation Length specifies the number of bytes that have been allocated for the returned parameter data. The Allocation Length must be at least four; otherwise, a Check Condition status is returned, with Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- The format of the returned parameter data is shown below.

Table 16 - 161: Allocation Length Parameter Data

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	ATS	ATSS	CACAS	CTSS	LURS	QTS	TRS	WAKES
1	Reserved					QUAS	QTSS	ITNRS
2	Reserved							
3	Reserved							

- ATS (Abort Task) bit: 1 = ABORT TASK is supported; 0 = not supported.
- ATSS (Abort Task Set) bit: 1 = ABORT TASK SET is supported; 0 = not supported.
- CACAS (Clear ACA) bit: 1 = CLEAR ACA is supported; 0 = not supported.
- CTSS (Clear Task Set) bit: 1 = CLEAR TASK SET is supported; 0 = not supported.
- LURS (Logical Unit Reset) bit: 1 = LOGICAL UNIT RESET is supported; 0 = not supported.
- QTS (Query Task) bit: 1 = QUERY TASK is supported; 0 = not supported.
- TRS (Target Reset) bit: 1 = TARGET RESET is supported; 0 = not supported.
- WAKES (Wakeup) bit: 1 = WAKEUP is supported; 0 = not supported.
- QUAS (Query Unit Attention Supported) bit: 1 = QUERY UNIT ATTENTION task management function (see SAM-4) is supported by the logical unit; 0 = not supported.
- QTSS (Query Task Set Supported) bit: 1 = QUERY TASK SET task management function (see SAM-4) is supported by the logical unit; 0 = not supported.

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- ITNRS (I_T Nexus Reset Supported) bit: 1 = I_T NEXUS RESET task management function (see SAM-4) is supported by the logical unit; 0 = not supported.

16.35 REQUEST SENSE (03)

REQUEST SENSE (03) requests that the drive transfer sense data.

Table 16 - 162: REQUEST SENSE (03)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 03h							
1	Reserved							
2-3	Reserved							
4	Allocation Length							
5	Control Byte - Refer to SCSI Control Byte							

- If a REQUEST SENSE command with an invalid LUN is received, the drive returns a Good status. It reports a Sense Key of Illegal Request and an Additional Sense Code of Logical Unit Not Supported.
- If the drive has no sense data available to return, it returns a Sense Key of No Sense and an Additional Sense Code of No Additional Sense Information.
- Separate sense data is maintained by the device for each initiator. Therefore, there is no requirement for an initiator to expeditiously clear a Check Condition, as this will not affect other initiators in a multi-initiator system.
- The drive returns the number of bytes in the allocation length, or 32 bytes, whichever is less.

16.36 RESERVE (16)

RESERVE (16) is used to reserve a LUN for an initiator. This reservation can be either for the initiator sending the command or for a third party as specified by the initiator.

Table 16 - 163: RESERVE (16)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 16h							
1	Reserved			3rdPty=0	3rd Party ID			Ext=0
2	Reservation Identification							
3-4	Extent List Length = 0							
5	Control Byte - Refer to SCSI Control Byte							

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- Extents are not supported by the drive. The Ext bit must be zero. If Ext bit is set to one, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB. The Reservation Identification and Extent List Length fields are ignored.
- The Reserve command requests that the entire LUN be reserved for the initiator until any of these occur:
- The reservation is superseded by another valid Reserve command from the initiator that made the reservation.
- The reservation is released by a RELEASE command from the same initiator.
- A hard Reset condition occurs.
- A Target Reset message is received from any initiator.
- A power off/on cycle occurs.
- 3rdPty must be 0. Third Party reservations are not supported. If the 3rdPty bit is not 0, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- 3rd Party ID is ignored.
- Only the initiator that issued the Reserve command for a LUN may release the LUN, regardless of the 3rdPty option. This initiator may also release the LUN by issuing another RESERVE command. This superseding RESERVE command releases the previous reservation when the new reservation is granted.
- Reservation queuing is not supported by the drive. If a LUN is reserved, and a RESERVE command is issued from a different initiator, the target responds with a RESERVATION CONFLICT.

16.37 RESERVE (56)

RESERVE (56) reserves a LUN for an initiator. This reservation can be either for the initiator sending the command or for a third party as specified by the initiator.

Table 16 - 164: RESERVE (56)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 56h							
1	Reserved			3rdPty=0	Reserved			Ext=0
2	Reservation Identification							
3	Third Party Device ID							
4-6	Reserved							
7-8	Extent List Length = 0							
9	Control Byte - Refer to SCSI Control Byte							

- Extents are not supported by the drive. The Ext bit must be zero. If Ext bit is set to one, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB. The Reservation Identification and Extent List Length fields are ignored.
- The Reserve command requests that the entire LUN be reserved for the initiator until any of these occur:
- The reservation is superseded by another valid Reserve command from the initiator that made the reservation.
- The reservation is released by a RELEASE command from the same initiator.
- A hard Reset condition occurs.
- A Target Reset message is received from any initiator.
- A power off/on cycle occurs.

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- 3rdPty must be 0. Third Party reservations are not supported. If the 3rdPty bit is not 0, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- 3rd Party ID is ignored.
- Only the initiator that issued the Reserve command for a LUN may release the LUN, regardless of the 3rdPty option. This initiator may also release the LUN by issuing another RESERVE command. This superseding RESERVE command releases the previous reservation when the new reservation is granted.
- Reservation queuing is not supported by the drive. If a LUN is reserved, and a RESERVE command is issued from a different initiator, the target responds with a RESERVATION CONFLICT.

16.38 REZERO UNIT (01)

REZERO UNIT (01) command is implemented as a NOOP for the SSD.

Table 16 - 167: REZERO UNIT (01)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 01h							
1	Reserved							
2-4	Reserved							
5	Control Byte - Refer to SCSI Control Byte							

16.39 SANITIZE (48)

SANITIZE (48h) requests that the device server perform a sanitize operation on the target device.

Table 16 - 168: SANITIZE (48)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 48h							
1	Immed	RSVD	AUSE	Service Action				
2-6	Reserved							
7-8	Parameter List Length							
9	Control Byte - Refer to SCSI Control Byte							

- Immed bit: 0 status is to be returned at the end of the operation; 1 (Good status) is always returned immediately after command has been received.
- The TEST UNIT READY command may be used to determine when the drive becomes ready.
- AUSE bit: 1 = EXIT FAILURE MODE service action on a subsequent SANITIZE is allowed. If set to 0, and the sanitize fails, a subsequent SANITIZE with EXIT FAILURE MODE will be rejected.

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- The Parameter List Length must be 0. If a non-zero Parameter List Length is specified, the drive returns a Check Condition status. The Sense Key is set to Illegal Request, and the additional sense data is set to Invalid Field in the CDB.

16.39.1 SANITIZE (48) Service Action Codes

The following service action codes are implemented. If a reserved service action code is specified, the drive returns a Check Condition status. The Sense Key is set to Illegal Request and the additional sense data is set to Invalid Field in the CDB.

Table 16 - 167: SANITIZE (48) Service Action Codes

Code	Name	Descriptions
00h	Reserved	Returns a Check Condition.
02h	Block Erase	Places all blocks on the NAND allocated to user data/information in the erased state.
03h	Cryptographic Erase	Alters the drive internal encryption key to make user data/information unreadable.
04h-1Eh	Reserved	Returns a Check Condition.
1Fh	Exit Failure Mode	If a prior Sanitize operation was issued with AUSE = 1. and it failed, the drive is taken out of degraded mode (Sanitize Failed state). The condition of the NAND blocks is not guaranteed in this case.

16.40 SECURITY PROTOCOL IN (A2)

SECURITY PROTOCOL IN (A2) requests the device server to return security protocol information or the results of one or more SECURITY PROTOCOL OUT (B5) commands.

Table 16 - 17068 SECURITY PROTOCOL IN (A2)

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Operation Code = A2h							
1	Security Protocol							
2		Security Protocol Specific						
3								
4	INC_512	Reserved						
5	Reserved							
6	(MSB)	Allocation Length						
. . .								
9								(LSB)
10	Reserved							
11	Control							

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The Security Protocol field specifies the security protocol being used. See Table 209: Security Protocol Field Codes – SECURITY PROTOCOL IN (A2).

Table 16 - 169: Security Protocol Field Codes – SECURITY PROTOCOL IN (A2)

Code	Description
00h	Security Protocol Information
01h to 06h	As defined by TCG.
07h to FFh	Reserved

If the Security Protocol field is assigned with 0, the Security Protocol Specific field will specify the different kind of requests.

Table 16 - 170: Security Protocol Specific Field Codes – SECURITY PROTOCOL IN (A2)

Code	Description (Type of request)
00h	Return list of supported protocols
01h	Return certificate data
02h	Return FIPS compliance information

- The contents of the Security Protocol Specific field are defined by the protocol in by the Security Protocol field.
- INC_512 (512 Increment) bit: 1 = Allocation Length field expresses the maximum number of bytes available to receive data in 512-byte increments. For example, a value of 1 in Allocation Length means 512 bytes, a value of 2 means 1,024 bytes, etc.). Pad Bytes (00h) may or may not be appended to meet this length. A value of 0 for INC_512 specifies that the Allocation Length field expresses the maximum number of bytes available to receive data in increments of 1 byte.
- The Control byte is defined in SAM-5.
- Security Protocol indicates the protocol for handling any data overrun or underrun and the mechanism, if any, for processing retries.
- Any association between a previous SECURITY PROTOCOL OUT command and the data transferred by a SECURITY PROTOCOL IN command depends on the protocol specified by the Security Protocol field. If the device server has no data to transfer (e.g., the results for any previous SECURITY PROTOCOL OUT commands are not yet available), the device server may transfer data indicating that it has no other data to transfer.
- The format of the data transferred depends on the protocol specified by the Security Protocol field.
- The device server shall retain data resulting from a SECURITY PROTOCOL OUT command, if any, until one of the following events is processed:
- Transfer of the data via a SECURITY PROTOCOL IN command, from the same I_T_L nexus as defined by the protocol specified by the Security Protocol field;
- Logical unit reset; or,
- I_T Nexus loss associated with the I_T Nexus that sent the SECURITY PROTOCOL OUT command.

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16.41 SECURITY PROTOCOL OUT (B5)

SECURITY PROTOCOL OUT (B5) requests that the device server process the specified parameter list, using the specified security protocol. The application client may use the SECURITY PROTOCOL IN (A2) command to retrieve data that results from the processing of one or more SECURITY PROTOCOL OUT (B5) commands.

Table 16 - 171: SECURITY PROTOCOL OUT (B5)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Operation Code = B5h							
1	Security Protocol							
2		Security Protocol Specific						
3								
4	INC_512	Reserved						
5	Reserved							
6	(MSB)	Transfer Length						
. . .								
9								(LSB)
10	Reserved							
11	Control							

The Security Protocol field will specify the security protocol being used. See Table 211: Security Protocol Field Codes – SECURITY PROTOCOL OUT (B5).

Table 16 - 172: Security Protocol Field Codes – SECURITY PROTOCOL OUT (B5)

Code	Description
00h	Security Protocol Information
01h to 06h	As defined by TCG.
07h to FFh	Reserved

- The contents of the Security Protocol Specific field are defined by the protocol in by the Security Protocol field.
- INC_512 (512 Increment) bit: 1 = Allocation Length field expresses the maximum number of bytes available to receive data in 512-byte increments. For example, a value of 1 in Allocation Length means 512 bytes, a value of 2 means 1,024 bytes, etc.). Pad Bytes (00h) may or may not be appended to meet this length. A value of 0 for INC_512 specifies that the Allocation Length field expresses the maximum number of bytes available to receive data in increments of 1 byte.
- The Control byte is defined in SAM-5.
- Any association between a SECURITY PROTOCOL OUT command and a subsequent SECURITY PROTOCOL IN command is defined by the protocol specified by the Security Protocol field. Each protocol shall define whether:

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- The device server completes the command with a Good status as soon as it determines the data has been correctly received. An indication that the data has been processed is obtained by sending a SECURITY PROTOCOL IN command and receiving the results in the associated data transfer; or
- The device server completes the command with a Good status only after the data has been successfully processed and an associated SECURITY PROTOCOL IN command is not required.

- The format of the data transferred depends on the protocol specified by the Security Protocol field.

16.42 SEEK (6) - (0B)

The SEEK (6) and SEEK (10) commands are implemented as NOOP on the SSD. No checking is performed on the LBA in the CDB.

Table 16 - 173: SEEK (6) - (0B)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 0Bh							
1	Reserved			Logical Block Address				
2-3	Logical Block Address (continued)							
4	Reserved							
5	Control Byte - Refer to SCSI Control Byte							

16.43 SEEK (10) - (2B)

Table 16 - 174: SEEK (10) - (2B)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 2Bh							
1	Reserved							0
2-5	Logical Block Address							
6-8	Reserved							
9	Control Byte - Refer to SCSI Control Byte							

16.44 SEND DIAGNOSTIC (1D)

SEND DIAGNOSTIC (1D) requests the drive to perform its self-diagnostic test or to perform a function based on a page of information sent in a Data Out phase during the command.

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Table 16 - 175: SEND DIAGNOSTIC (1D)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 1Dh							
1	Function Code			PF	RSVD	SlfTst	Dev0fl	Unt0fl
2	Reserved							
3-4	Parameter List Length							
5	Control Byte - Refer to SCSI Control Byte							

- PF (Page Format) bit: 1 = data sent by the initiator conforms to the page structure as specified in SCSI standard. This bit is ignored by the target if the SlfTst bit is set.
- SlfTst set to 0 indicates that the device performs its default self-test. If SlfTst is 1, the Function code field is ignored. If SlfTst is set to 0, the action to perform is specified in Function code field.

Table 16 - 176: SEND DIAGNOSTIC Function Code (1D)

Value	Function Name	Description
000b	NA	Value to be used when the SlfTst bit is set to one or if the SEND DIAGNOSTIC command is not invoking one of the other self-test function codes.
001b	Background Short Self-Test	The device server starts its short self-test routine in background mode.
010b	Background Extended Self-Test	The device server starts its extended self-test routine in background mode.
011b	NA	Reserved
100b	Abort Background Self-Test	Abort the current self-test in the background mode. This value is only valid if a previous SEND DIAGNOSTIC command specified a background self-test function and that function has not been completed.
101b	Foreground Short Self-Test	The device server starts its short self-test routine in the foreground mode. This self-test will complete in two minutes or less.
110b	Foreground Extended Self-Test	The device server starts its extended self-test routine in the foreground mode .The completion time for this test is reported in Mode Page 0Ah (refer to section 17.11.9 "Mode Page 0A).
111b		Reserved

- DevOfl is ignored by the target for compatibility.
- UntOfl is ignored by the target for compatibility.
- Parameter List Length must be 0 when the SlfTst bit is one. Otherwise, a Check Condition status is generated, with a Sense Key of Illegal Request and additional sense of Invalid Field in the CDB. If the SlfTst bit is 0, it should be set to the length of the page to be transferred in the Data Out phase of the command. If it does not match the expected length of the page, a Check Condition status is also generated, with a Sense Key of Illegal Request and an additional sense of Invalid Field in the CDB.
- If a fault is detected during the default or foreground self-test, a Check Condition is reported as an end status. If a fault is detected during the background self-test, it is logged in the log page for later retrieval by a LOG SENSE command.

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16.44.1 Send Diagnostic Page 0

This page requests that the drive return a list of supported pages on the next RECEIVE DIAGNOSTICS command.

Table 16 - 177: Diagnostic Page 0

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Page Code = 0							
1	Reserved							
2-3	Page Length = 0							

16.44.2 Send Diagnostic Page 3F

Table 16 - 178: Send Diagnostic Page 3F

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Page Code = 3F							
1	Reserved				Protocol Identifier = 6			
2-3	Page Length = 1Ch							
4	Phy Identifier							
5	Phy Test Function							
6	Phy Test Pattern							
7	RSVD	Phy Test Pattern SATA = 0	Phy Test Pattern SSC		Phy Test Pattern Physical Link Rate			
8-10	Reserved							
11	Phy Test Pattern Dwords Control							
12-19	Phy Test Pattern Dwords							
20-31	Reserved							

- Phy Identifier specifies the selected Phy that is to perform or stop performing a Phy test function. If the Phy does not exist, a Check Condition status is returned, with a Sense Key of Illegal Request and an additional sense of Invalid Field in Parameter List.
- Phy Test Function specifies the Phy test function to be performed. If an unsupported function is requested, a Check Condition status is returned, with a Sense Key of Illegal Request and an additional sense of Invalid Field in Parameter List.

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Table 16 - 179: **Phy Test Function**

Phy Test Function	Description
00h	If the selected Phy is performing a Phy-test function, then the selected Phy stop performing the Phy test function and originate a link reset sequence. If the selected Phy is not performing a Phy test function, then this function as no effect on the selected Phy.
01h	If the selected Phy is not performing a Phy test function, the selected Phy will be set to transmit the Phy test pattern specified by the Phy Test Pattern field at the physical link rate specified by the Phy Test Pattern Physical.
02h-FEh	Not supported.
FFh	Retime Loopback. If the selected Phy is not performing a Phy test function, the selected Phy will be set to retransmit the retimed data pattern received by the Phy receiver.

- Phy Test Pattern specifies the Phy test pattern to be transmitted when the Phy Test Function is set to 01h. If an unsupported value is specified, a Check Condition status is returned, with a Sense Key of Illegal Request and an additional sense of Invalid Field in Parameter List.

Table 16 - 180: **Phy Test Pattern**

Phy Test Pattern	Description
00h	Reserved
01h	JTPAT
02h	CJTPAT
03h-0Fh	Reserved
10h	TRAIN (Not Supported)
11h	TRAIN_DONE (Not Supported)
12h	IDLE
13h	SCRAMBLE_0
14h - 3Fh	Reserved
40h	TWO_DWORDS
41h - EFh	Reserved
F0h	PRBS7
F1h	PRBS15
F2h	PRBS23
F3h	PRB31
F4h-FFh	Reserved

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- PhyTest Pattern - Physical Link Rate specifies the physical link rate at which the Phy test pattern is transmitted. Supported values are 9h for 3.0 Gbps, Ah for 6.0 Gbps and Bh for 12.0 Gbps. If an unsupported value is specified, a Check Condition status is returned, with a Sense Key of Illegal Request and an additional sense of Invalid Field in Parameter List.
- Phy Test Pattern - SATA bit: 0 = the Phy transmits the Phy test pattern as a SAS Phy; 1 = a Check Condition status is returned with a Sense Key of Illegal Request and an additional sense of Invalid Field in Parameter List
- Phy Test Pattern SSC specifies the SSC modulation type which the Phy test pattern will be transmitted. If an unsupported SSC modulation type is specified, a Check Condition status is returned, with a Sense Key of Illegal Request and an additional sense of Invalid Field in Parameter List.

Notes:

1. The SSC hardware of the drive is shared between both ports. In order for the drive to transmit SSC, both ports must be configured with SSC enabled. When Phy Test Pattern SSC is specified, the drive applies the SSC modulation type to both ports so spreading can occur. This could cause link disruption if the connected HBA is unable to receive a SSC signal.

Table 16 - 181: Phy Test SSC Code

Phy Test Pattern SSC Code	Description
00h	No SSC.
01h	Center-Spreading SSC (Not supported).
10h	Down-Spreading SSC.
11h	Reserved

- Phy Test Pattern Dwords Control determines whether the bytes in the Phy Test Pattern Dwords field are sent as control characters or data characters.

Table 16 - 184: Phy Test Pattern Dwords Control

Phy Test Pattern Dwords Control	Description
00h	Each byte in the Phy Test Pattern Dwords field is sent as a data character (i.e., Dxx.y) without scrambling.
08h	The fifth byte in the Phy Test Pattern Dwords field is sent as a control character (i.e., Kxx.y). Each other byte is sent as a data character without scrambling.
80h	The first byte in the Phy Test Pattern Dwords field is sent as a control character. Each other byte is sent as a data character without scrambling.
88h	The first and fifth bytes in the Phy Test Pattern Dwords field are sent as control characters. Each other byte is sent as a data character without scrambling.
All others	Reserved

- Phy Test Pattern Dwords contains the two Dwords that are sent during a TWO_DWORDS test pattern.

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16.45 SET DEVICE IDENTIFIER (A4/06)

The SET DEVICE IDENTIFIER (A4/067) command requests that the device identifier information be set to the value received in the SET DEVICE IDENTIFIER parameter list.

Table 16 - 183: SET DEVICE IDENTIFIER (A4/06)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = A4h							
1	Reserved			Service Action = 06h				
2	Reserved							
3	Reserved							
4-5	Restricted = 0							
6-9	Parameter List Length							
10	Reserved							
	Vendor-Specific		Reserved			NACA	Obsolete	

- On successful completion of a SET DEVICE IDENTIFIER command, a Unit Attention is generated for all initiators except the one that issued the service action. When the Unit Attention condition is reported, the Additional Sense Code is set to Device Identifier Changed.
- Parameter List Length specifies the length in bytes of the Identifier that is transferred from the host system to the target. The maximum value for this field is 512 bytes. A parameter list length of 0 indicates that no data is transferred; subsequent REPORT DEVICE IDENTIFIER commands return an Identifier length of 0.
- The SET DEVICE IDENTIFIER parameter list contains the identifier to be set by the addressed logical unit.

Table 16 - 184: SET DEVICE IDENTIFIER Parameter List

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-n	Identifier							

- The IDENTIFIER field is a vendor-specific value, to be returned in subsequent REPORT DEVICE IDENTIFIER commands.

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16.46 START STOP UNIT (1B)

START STOP UNIT (1B) makes the media accessible or inaccessible. The SSD automatically makes the media accessible at power-on; the command only emulates HDD behavior by making the SSD ready or not ready.

Table 16 - 185: START STOP UNIT (1B)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 1Bh							
1	Reserved							Immed
2	Reserved							
3	Reserved				Power Condition Modifier			
4	Power Condition				Reserved		LoEj = 0	Start
5	Control Byte - Refer to SCSI Control Byte							

- Immed bit: 0 = Status is returned at the end of the operation; 1 = Good status is always returned immediately after command has been received. The TEST UNIT READY command may be used to determine when the drive becomes ready.
- Power Conditions and Power Condition Modifier fields are ignored. Power save modes are not supported. If a non-zero Power Condition is set, the Start bit is ignored. The Power Condition must be set to 0 to allow the Start bit setting to affect the state of the drive.
- Start bit: 0 = Make the media inaccessible; 1 = make the media accessible.

Notes:

1. NOTIFY (ENABLE_SPINUP) is not required for the SSD to come ready after power on. Once the drive is ready, the START STOP UNIT command can be used without any errors, regardless of the current state. Note that NOTIFY (ENABLE_SPINUP) is required to transition from the Stopped state to the Ready state.

16.47 SYNCHRONIZE CACHE (10) - (35)

SYNCHRONIZE CACHE (10) is implemented as a NOOP on the SSD. Data integrity is maintained across power cycles by PLI circuitry.

Table 16 - 186: SYNCHRONIZE CACHE (10) - (35)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 35h							
1	Reserved					SYNC_NV	Immed	Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Number of Blocks							

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9	Control Byte - Refer to SCSI Control Byte

- Logical Block Address must be a valid LBA on the drive, but otherwise it is ignored and has no impact on command execution.
- SYNC_NV is ignored. It may be set to 0 or 1 with no impact on the command execution.
- Immed is ignored. It may be set to 0 or 1 with no impact on the command execution.
- Number of Blocks specifies the total number of contiguous logical blocks within the range. A value of 0 means remaining logical blocks on the logical unit are within the range.

16.48 SYNCHRONIZE CACHE (16) - (91)

SYNCHRONIZE CACHE (16) is implemented as a NOOP on the SSD. Data integrity is maintained across power cycles by the PLI circuitry. See the SYNCHRONIZE CACHE (10) description for definitions of the fields in this command.

Table 16 - 187: SYNCHRONIZE CACHE (16) - (91)

	BIT							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 91h							
1	Reserved					SYNC_NV	Immed	RSVD
2-9	Logical Block Address							
10-13	Number of Blocks							
14	Reserved							
15	Control Byte - Refer to SCSI Control Byte							

16.49 TEST UNIT READY (00)

TEST UNIT READY (00) command allows the initiator to check if the drive is ready. The SCSI specification defines Ready as the condition where the device will accept a media-access command without returning Check Condition status.

Table 16 - 188: TEST UNIT READY (00)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 00h							
1	Reserved							
2-4	Reserved							
5	Control Byte - Refer to SCSI Control Byte							

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- The drive verifies that the media is accessible. If the media is not accessible, a Check Condition status is returned with a Sense Key of Not Ready. If the media is accessible, the drive returns Good status and will execute media access commands.
- The TEST UNIT READY command is not intended as a diagnostic. No self-diagnostic is performed by the device as a result of this command.
- The TEST UNIT READY command has special significance for power sequencing using the UNIT START command with an Immediate bit of 1. In this mode, the UNIT START command returns Task Complete status immediately and expects the initiator to issue TEST UNIT READY commands to determine when the media is accessible.

Notes:

1. The Power On sequence automatically transitions the drive to the Ready state. The drive does not execute any commands, other than TEST UNIT READY, REPORT LUNS, INQUIRY, or REQUEST SENSE, until the Power On sequence is complete. The drive returns a Check Condition status with a Not Ready Sense Key and an In Process of Becoming Ready sense code for all other commands during the Power On period.

16.50 UNMAP (42)

UNMAP (42) command requests that the drive cause one or more LBAs to be unmapped. When an LBA is "unmapped", subsequent reads to the LBA returns all 0x00s. Protection information for the LBA (if applicable) will be 0xFFFFFFFF_FFFFFFFF. For additional information, refer to section 18.x Logical Block Provisioning.

Table 16 - 189: UNMAP (42)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Operation Code (42h)							
1	Reserved							Anchor
2-5	Reserved							
6	Reserved			Group Number				
7-8	Parameter List Length							
9	Control							

- Anchor bit is ignored. Since the drive is resource-provisioned, any LBA on which an unmap operation is performed is anchored (regardless of the setting of the ANCHOR bit in the UNMAP command).
- Group Number is 0.

16.50.1 UNMAP Parameter List

The UNMAP parameter list contains the data sent by an application client along with an UNMAP command. The data includes an UNMAP parameter list header and block descriptors, for LBA extents to be processed by the device server for the UNMAP command. The LBAs specified in the block descriptors may contain overlapping extents and may be in any order. For each specified LBA, the LBA becomes anchored (regardless of previous state).

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Table 16 - 190: UNMAP Parameter list

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-1	Unmap Data Length (n - 1)							
2-3	Unmap Block Descriptor Data Length (n - 7)							
4-7	Reserved							
UNMAP Block Descriptors								
8-23	UNMAP Block Descriptor [First] (see Table 185)							
...								
n-15	UNMAP Block Descriptor [Last] (see SANITIZE (48) Service Action Codes)							
...								
N								

- Unmap Data Length specifies the length in bytes of the following data that is available to be transferred from the Data Out Buffer. The unmap data length does not include the number of bytes in the UNMAP DATA LENGTH field.
- Unmap Block Descriptor Data Length specifies the length in bytes of the Unmap Block Descriptors that are available to be transferred from the Data Out Buffer. The Unmap Block Descriptor data length should be a multiple of 16; otherwise, the last Unmap Block Descriptor is incomplete and is ignored. If the data length is set to 0, no Unmap Block Descriptors are included in the UNMAP parameter data. This condition is not considered an error.

Table 16 - 191: UNMAP Block Descriptor

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0-7	Unmap Logical Block Address							
8-11	Number of Logical Blocks							
12-15	Reserved							

- Unmap Logical Block Address contains the first LBA of the UNMAP block descriptor to be unmapped.
- Number of Logical Blocks contains the number of LBAs to be unmapped beginning with the LBA specified by the UNMAP LOGICAL BLOCK ADDRESS field. If the NUMBER OF LOGICAL BLOCKS is set to 0, then no LBAs is unmapped for this UNMAP block descriptor. This condition shall not be considered an error.
- The LBA specified by the UNMAP LOGICAL BLOCK ADDRESS field, plus the number of logical blocks, may exceed the capacity of the medium. In that case, the device server terminates the command with a Check Condition status, with the Sense Key set to ILLEGAL REQUEST, and the Additional Sense Code set to LOGICAL BLOCK ADDRESS OUT OF RANGE.
- The total number of logical blocks specified in the UNMAP block descriptor data may exceed the value indicated in the MAXIMUM UNMAP LBA COUNT field (in the Block Limits VPD page - see Inquiry Data - EVPD = 1, Page Code = B0h - Block Limits VPD Page). If that occurs, or if the number of UNMAP block descriptors exceeds the value of the MAXIMUM UNMAP BLOCK DESCRIPTOR COUNT field (Block Limits VPD page), then the device server terminates the command with a Check Condition status. The Sense Key is set to ILLEGAL REQUEST, and the Additional Sense Code set to INVALID FIELD IN PARAMETER LIST.

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16.51 VERIFY (10) - (2F)

VERIFY (10) requests that the drive verify the data written on the media. A verification length of zero indicates that no data will be transferred. This condition is not considered an error.

Table 16 - 192: VERIFY (10) - (2F)

	BIT							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 2Fh							
1	VRPROTECT			DPO	Reserved	ByteChk		RSVD
2-5	Logical Block Address							
6	Reserved							
7-8	Verification Length							
9	Control Byte - Refer to SCSI Control Byte							

- The application client uses the ByteChk field in the CDB to specify the contents of the Data Out Buffer:

Table 16 - 193: ByteChk Field

ByteChk Field	Data-Out Buffer Contents
00b	Not used
01b	Logical block data for the number of logical blocks specified in the Verification Length field
10b*	Not defined
11b	Logical block data for a single logical block

- A ByteChk field set to 10b is reserved.
- DPO Disable Page Out bit is ignored.
- The command implies FUA.
- The command stops on Check Condition and reports the LBA in error. The command must be reissued, starting with the next LBA, to verify the remainder of the Drive.
- Verification Length is the number of blocks to check.
- The data (if any) from the data-out phase and the data from the media are not retained in the cache. Therefore, the DPO bit has no effect on this command and is ignored.
- VRPROTECT defines how protection information read from drive is checked during command processing. Protection information is stored on drive and may be validated using the drive's internal checking algorithms. It may also be byte-by-byte compared using data from the initiator when ByteChk=01b or 11b.
- If the drive is not formatted with protection information, VRPROTECT must be set to 000b. Otherwise, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.

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- VRPROTECT=000b
  - If the drive is not formatted with protection information, only user data is verified.
  - If the drive is formatted with protection information:
  - Logical Block Guard is checked.
  - Logical Block Application Tag is checked (applies to 32-byte CDBs or when ATO=1).
  - Logical Block Reference Tag is checked.
- VRPROTECT=001b
  - Logical Block Guard is checked.
  - Logical Block Application Tag is checked (applies to 32-byte CDBs or when ATO=1).
  - Logical Block Reference Tag is checked.
- VRPROTECT=010b
  - Logical Block Guard is not checked.
  - Logical Block Application Tag is checked (applies to 32-byte CDBs or when ATO=1).
  - Logical Block Reference Tag is checked.
- VRPROTECT=011b
  - Logical Block Guard is not checked.
  - Logical Block Application Tag is not checked.
  - Logical Block Reference Tag is not checked.
- VRPROTECT=100b
  - Logical Block Guard is checked.
  - Logical Block Application Tag is not checked.
  - Logical Block Reference Tag is not checked.
- VRPROTECT=101b
  - Logical Block Guard is checked.
  - Logical Block Application Tag is checked (applies to 32-byte CDBs or when ATO=1).
  - Logical Block Reference Tag is checked.
- VRPROTECT=110b, 111b
  - These values are reserved.
  - A Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
  - If a check of the protection information fails, a Check Condition status is returned, with a Sense Key of Aborted Command and an Additional Sense Code indicating which protection field check failed.
- Refer to the ANSI T10 standards for additional details of protection information.

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16.52 VERIFY (12) - (AF)

VERIFY (12) causes the drive to verify data written on the media. See the VERIFY (10) description for the definitions of the fields in this command.

Table 16 - 194: VERIFY (12) - (AF)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = AFh							
1	VRPROTECT			DPO	Reserved	ByteChk		RSVD
2-5	Logical Block Address							
6-9	Verification Length							
10	Reserved							
11	Control Byte - Refer to SCSI Control Byte							

16.53 VERIFY (16) - (8F)

VERIFY (16) requests that the drive verify the data written on the media. See the VERIFY (10) description for the definitions of the fields in this command.

Table 16 - 195: VERIFY (16) - (8F)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 8Fh							
1	VRPROTECT			DPO	Reserved	ByteChk		RSVD
2-9	Logical Block Address							
10-13	Verification Length							
14	Reserved							
15	Control Byte - Refer to SCSI Control Byte							

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16.54 VERIFY (32) - (7F/0A)

VERIFY (32) requests that the drive verify the data written on the media. Each logical block includes user data and may include protection information, based on the VPROTECT field and the drive format.

Table 16 - 196: VERIFY (32) - (7F/0A)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 07Fh							
1	Control Byte - Refer to SCSI Control Byte							
2-5	Reserved							
6	Reserved			Group Number = 0				
7	Additional CDB Length = 18h							
8-9	Service Action = 000Ah							
10	RDPROTECT			DPO	Reserved	ByteChk		RSVD
11	Reserved							
12-19	Logical Block Address							
20-23	Expected Initial Logical Block Reference Tag							
24-25	Expected Logical Block Application Tag							
26-27	Logical Block Application Tag Mask							
28-31	Verification Length							

- If the drive is formatted with type 2 protection (PROT_EN=1 and P_TYPE=001b in the READ CAPACITY (16) parameter data), this command is processed normally. Any other protection types return in a Check Condition status, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Command Operation Code.
- Expected Initial Logical Block Reference Tag contains the value of the Logical Block Reference Tag field expected in the protection information of the first logical block accessed by the command.
- If the ATO bit is set to 1 in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a bitmask value. This value enables checking the Logical Block Application Tag field in the protection information for each logical block accessed by the command. A Logical Block Application Tag Mask bit set to 1 enables the checking of the corresponding bit of the Expected Logical Block Application Tag field, with the corresponding bit of the Logical Block Application Tag field in the protection information.
- If the ATO bit is set to 0, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

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16.55 WRITE (6) - (0A)

The WRITE (6) command requests the drive to write the specified number of blocks of data (Transfer Length) from the initiator to the medium, starting at the specified Logical Block Address (LBA).

Table 16 - 197: WRITE (6) - (0A)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 0Ah							
1	Reserved			Logical Block Address				
2-3	Logical Block Address (continued)							
4	Transfer Length							
5	Control Byte - Refer to SCSI Control Byte							

- Logical Block Address specifies the logical unit at which the WRITE operation begins.
- Transfer Length specifies the number of blocks to be transferred. A value of zero implies 256 blocks.

16.56 WRITE (10) - (2A)

The WRITE (10) command requests that the drive write the data transferred from the initiator. This command is processed like the standard WRITE (6) - (0A) command except for the longer transfer length.

Table 16 - 198: WRITE (10) - (2A)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 2Ah							
1	WRPROTECT			DPO	FUA	RSVD	FUA_NV	Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Transfer Length							
9	Control Byte - Refer to SCSI Control Byte							

- Transfer Length is the number of contiguous blocks to be transferred. If the transfer length is zero, the seek occurs, but no data is transferred. This condition is not considered an error.
- DPO Disable Page Out bit is ignored.
- FUA bit is ignored.
- FUA_NV Force Unit Access Non-Volatile Cache may be set to 0 or 1 but is ignored because NV_SUP=0 in Inquiry Page 86h.
- If a WRITE command is received after protection information is enabled, the drive sets the protection information as it writes each block to the drive, as follows:

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- The Logical Block Guard field is set to a properly generated CRC.
- The Logical Block Reference Tag field is set to:
  - The least significant four bytes of the LBA, if the drive is formatted with type 1 protection (PROT_EN=1 and P_TYPE=000b in the READ CAPACITY (16) parameter data); or,
  - FFFFFFFFh, if the drive is formatted with type 2 protection (PROT_EN=1 and P_TYPE=001b in the READ CAPACITY (16) parameter data)
- The Logical Block Application Tag field is set to:
  - FFFFh, if the ATO bit is set to 1 in Mode Page 0Ah; or,
  - Any other value, if the ATO bit is set to 0

- WRPROTECT defines how protection information written to the drive is checked during processing of the command. Protection information may be transmitted to the drive with the user data, based on the WRPROTECT bit and the drive format.
- If the drive is not formatted with protection information, WRPROTECT must be set to 000b. Otherwise, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- WRPROTECT=000b
  - Protection information is not transmitted to the drive.
  - If the drive is formatted with protection information, the drive writes this information based on its internal algorithms.
- WRPROTECT=001b
  - Protection information is transmitted to the drive with the user data.
  - Logical Block Guard is checked.
  - Logical Block Application Tag is checked (applies to 32-byte CDBs or when ATO=1).
  - Logical Block Reference Tag is checked.
- WRPROTECT=010b
  - Protection information is transmitted to the drive with the user data.
  - Logical Block Guard is not checked.
  - Logical Block Application Tag is checked (applies to 32-byte CDBs or when ATO=1).
  - Logical Block Reference Tag is checked.
- WRPROTECT=011b
  - Protection information is transmitted to the drive with the user data.
  - Logical Block Guard is not checked.
  - Logical Block Application Tag is not checked.
  - Logical Block Reference Tag is not checked.
- WRPROTECT=100b
  - Protection information is transmitted to the drive with the user data.
  - Logical Block Guard is checked.
  - Logical Block Application Tag is not checked.
  - Logical Block Reference Tag is not checked.
- WRPROTECT=101b
  - Protection information is transmitted to the drive with the user data
  - Logical Block Guard is checked
  - Logical Block Application Tag is checked (applies to 32-byte CDBs or when ATO=1)
  - Logical Block Reference Tag is checked
- WRPROTECT=110b, 111b
  - These values are reserved.
  - A Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.

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- If a check of the protection information fails, a Check Condition status is returned, with a Sense Key of Aborted Command and an Additional Sense Code indicating which protection field check failed.
- Refer to the ANSI T10 standards for additional details of protection information.

16.57 WRITE (12) - (AA)

WRITE (12) causes the drive to write data from the initiator to the media. See the WRITE (10) description for the definitions of the fields in this command.

Table 16 - 199: WRITE (12) - (AA)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = AAh							
1	WRPROTECT			DPO	FUA	RSVD	FUA_NV	RSVD
2-5	Logical Block Address							
6-9	Transfer Length							
10	Reserved							
11	Control Byte - Refer to SCSI Control Byte							

16.58 WRITE (16) - (8A)

WRITE (16) causes the drive to write data from the initiator to the media. See the WRITE (10) description for the definitions of the fields in this command.

Table 16 - 200: WRITE (16) - (8A)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 8Ah							
1	WRPROTECT			DPO	FUA	RSVD	FUA_NV	RSVD
2-9	Logical Block Address							
10-13	Transfer Length							
14	Reserved							
15	Control Byte - Refer to SCSI Control Byte							

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16.59 WRITE (32) - (7F/0B)

WRITE (32) requests that the drive write data transferred from the initiator to drive. Each logical block transferred includes user data and may include protection information according to the WRPROTECT field and the drive format. Each logical block written includes user data and, if the drive is formatted with protection information enabled, protection information.

Table 16 - 201: WRITE (32) - (7F/0B)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 7Fh							
1	Control Byte - Refer to SCSI Control Byte							
2-5	Reserved							
6	Reserved			Group Number = 0				
7	Additional CDB Length = 18h							
8-9	Service Action = 000Bh							
10	WRPROTECT			DPO	FUA	RSVD	FUA_NV	RSVD
11	Reserved							
12-19	Logical Block Address							
20-23	Expected Initial Logical Block Reference Tag							
24-25	Expected Logical Block Application Tag							
26-27	Logical Block Application Tag Mask							
28-31	Verification Length							

- If the drive is formatted with type 2 protection (PROT_EN=1 and P_TYPE=001b in the READ CAPACITY (16) parameter data), this command is processed normally. Any other protection types return a Check Condition status, with Sense Key of Illegal Request and an Additional Sense Code of Invalid Command Operation Code
- Expected Initial Logical Block Reference Tag contains the value of the Logical Block Reference Tag field expected in the protection information of the first logical block accessed by the command.
- If the ATO bit is set to 1 in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a bitmask value. This value enables checking the Logical Block Application Tag field in the protection information for each logical block accessed by the command. A Logical Block Application Tag Mask bit set to 1 enables the checking of the corresponding bit of the Expected Logical Block Application Tag field, with the corresponding bit of the Logical Block Application Tag field in the protection information.
- If the ATO bit is set to 0, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

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16.60 WRITE AND VERIFY (10) - (2E)

The WRITE AND VERIFY (10) command requests that the drive writes the data transferred from the initiator to the medium and then verify that the data is correctly written. An implied FUA (Force Unit Access) and an implied Synchronize Cache are performed before starting the operation. This insures that data from the drive, not the cache, is verified.

Table 16 - 202: WRITE AND VERIFY (10) - (2E)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 2Eh							
1	WRPROTECT			DPO	Reserved	ByteChk		Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Transfer Length							
9	Control Byte - Refer to SCSI Control Byte.							

- See the WRITE (10) command description for the definition of the WRPROTECT field.
- Transfer Length is the number of contiguous blocks to be transferred. If the transfer length is 0, the seek occurs, but no data is transferred. This condition is not considered an error.
- ByteChk bit: 00b = data is read back from the drive and verified using ECC after the successful write operation.
  - If an ECC error is detected in the verify process, a Check Condition status is returned, with a Sense Key set to Medium Error. ByteChk bit set to 01b indicates that byte-by-byte comparison is performed between data on the drive starting the block specified in LBA field and data transferred from the initiator.
  - If the comparison is unsuccessful, the command is terminated with a Check Condition status, and the Sense Key is set to Miscompare.
- ByteChk values of 10b and 11b are reserved.
- DPO Disable Page Out is ignored.

16.61 WRITE AND VERIFY (12) - (AE)

WRITE AND VERIFY (12) requests that the drive write the data transferred from the initiator to the medium and then verify that the data is correctly written. See the WRITE AND VERIFY (10) description for the definitions of the fields in this command.

Table 16 - 203: WRITE AND VERIFY (12) - (AE)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = AEh							
1	WRPROTECT			DPO	Reserved	ByteChk		Obsolete
2-5	Logical Block Address							
6-9	Transfer Length							
10	Reserved							

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11	Control Byte - Refer to SCSI Control Byte

16.62 WRITE AND VERIFY (16) - (8E)

WRITE AND VERIFY (16) requests that the drive write the data transferred from the initiator to the medium and then verify that the data is correctly written. See the WRITE AND VERIFY (10) description for the definitions of the fields in this command.

Table 16 - 204: WRITE AND VERIFY (16) - (8E)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 8Eh							
1	WRPROTECT			DPO	Reserved	ByteChk		Obsolete
2-9	Logical Block Address							
10-13	Transfer Length							
14	Reserved							
15	Control Byte - Refer to SCSI Control Byte							

16.63 WRITE AND VERIFY (32) - (7F/0C)

WRITE AND VERIFY (32) requests that the drive write the data transferred from the initiator to drive and then verify that the data is correctly written.

Table 16 - 205: WRITE AND VERIFY (32) - (7F/0C)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 7Fh							
1	Control Byte - Refer to SCSI Control Byte							
2-5	Reserved							
6	Reserved			Group Number = 0				
7	Additional CDB Length = 18h							
8-9	Service Action = 000Ch							
10	WRPROTECT			DPO	Reserved	ByteChk		RSVD
11	Reserved							
12-19	Logical Block Address							
20-23	Expected Initial Logical Block Reference Tag							
24-25	Expected Logical Block Application							
26-27	Logical Block Application Tag Mask							

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28-31	Transfer Length

- If the drive is formatted with type 2 protection (PROT_EN=1 and P_TYPE=001b in the READ CAPACITY (16) parameter data), this command is processed normally. Any other protection types return a Check Condition status, with Sense Key of Illegal Request and an Additional Sense Code of Invalid Command Operation Code
- Expected Initial Logical Block Reference Tag contains the value of the Logical Block Reference Tag field expected in the protection information of the first logical block accessed by the command.
- If the ATO bit is set to 1 in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a bitmask value. This value enables checking the Logical Block Application Tag field in the protection information for each logical block accessed by the command. A Logical Block Application Tag Mask bit set to 1 enables the checking of the corresponding bit of the Expected Logical Block Application Tag field, with the corresponding bit of the Logical Block Application Tag field in the protection information.
- If the ATO bit is set to 0, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

16.64 WRITE BUFFER (3B)

WRITE BUFFER (3B) is used with the READ BUFFER (3C) command as a diagnostic function for testing the memory of the drive and the SCSI bus integrity. This command does not alter the medium of the drive. Additional modes are provided for downloading microcode and saving microcode.

Table 16 - 206: WRITE BUFFER (3B)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 3Bh							
1	Reserved			Mode				
2	Buffer ID							
3-5	Buffer Offset							
6-8	Parameter List Length							
9	Control Byte - Refer to SCSI Control Byte							

- The function of this command and the meaning of fields in the command descriptor block depend on the Mode field contents:

Mode	Description
00010	Data.
00100	Download Microcode.
00101	Download Microcode and Save - single binary file.
00111	Download Microcode and Save - multiple binary files.
01010	Write Data to Echo Buffer.
01101	Download microcode with offsets, select activation, save, and defer activate
01110	Download microcode with offsets, save, and defer activate.

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01111	Activate deferred microcode.
11010	Enable expander Communications Protocol.
All Others	Not Supported.

- If any values other than shown above are specified, a Check Condition status is returned, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.

16.64.1 Write Data (Mode 00010b)

In this mode, the Data Out phase contains buffer data.

- Buffer ID must be 0. If another value is specified, no download function is performed, and the command is terminated with a Check Condition status, with the Sense Key set to Illegal Request, with an Additional Sense Code of Illegal Field in the CDB.
- Buffer Offset specifies the offset of the memory space specified by the Buffer ID. The initiator should conform to the offset boundary requirements returned in the READ BUFFER descriptor. If the value exceeds the buffer specified, the command is terminated with a Check Condition status, with the Sense Key set to Illegal Request and an Additional Sense Code of Illegal Field In the CDB.
- Parameter List Length specifies the Parameter List Length. It must be less than the capacity of the buffer size, after adding the Buffer Offset value, on a sector boundary. A Parameter List Length of 0 indicates no data is to be transferred, and the command status is returned.
- If an invalid value is specified, the command is terminated with a Check Condition status The Sense Key is set to Illegal Request, with an Additional Sense Code of Illegal Field in the CDB.
- The MODE SPECIFIC field is ignored in this mode.
- If a download is in progress, the WRITE BUFFER command is terminated with a Check Condition status. The drive sets the Sense Key to Illegal Request, and an Additional Sense Code is set to Operation In Progress.

16.64.2 Download Microcode (Mode 00100b)

In this mode, the microcode is transferred to the control memory space of the drive. When the microcode is downloaded, it is immediately effective on the drive and operates until the next power cycle.

- The Buffer ID field is used to indicate which portion of the microcode image is being downloaded. The following Buffer IDs are supported by the target: 00h = main microprocessor code; and nnh = ID of the Vendor-Unique Reserved Area
- Any unsupported value for the Buffer ID causes the command to terminate with a Check Condition status. The drive sets the Sense Key to Illegal Request, with an Additional Sense Code of Illegal Field In the CDB.
- Buffer Offset must be 0. If an invalid value is specified, the command is terminated with a Check Condition status. The drive sets the Sense Key to Illegal Request, with an Additional Sense Code of Illegal Field In the CDB.
- Parameter List Length must be the size of the data set to be downloaded. It may also be set to 0000h in which case no code is updated and command status is returned. If an invalid value is specified, the command is terminated with a Check Condition status. And the drive sets the Sense Key to Illegal Request and an Additional Sense Code to Illegal Field In the CDB.
- This process generates a Unit Attention condition for MICROCODE HAS BEEN CHANGED for all initiators except the one that sent the WRITE BUFFER command. Upon the completion of the WRITE BUFFER command, the new microcode is immediately ready for operation.
- The MODE SPECIFIC field is ignored in this mode.

Notes:

1. The Download Microcode mode indicates that the drive accepts a command with this mode, though it is not expected a user will ever issue such a command. To use the write buffer command with this mode, a special microcode version is required from development. That version will include appropriate instructions on the function of new microcode and its effect on the drive operations after download.

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16.64.3 Download Microcode and Save (Mode 00101b) - Single Binary File

In this mode, the data is transferred to the drive to be saved into the System reserved area on the drive. This is for a functional upgrade and configuration change reflecting the user's requirements, or for a manufacturer's reason, or both. The data is stored in the media as a permanent copy. The newly downloaded code becomes effective after the drive issues and completes a self-initiated Power-on reset.

- The Buffer ID field indicates which portion of the microcode image is being downloaded. To download microcode, the buffer ID should be set to 00h. Other values are reserved for HGST development purposes only.
- The MODE SPECIFIC field is ignored in this mode.

Notes:

1. The drive supports fast updating of microcode to the drive, which is power-safe and completes in several seconds. This does not update the flash ROM.
2. New code to be downloaded to the drive is provided by development, either by customer request for an additional function, or because of a functional change by development. Note that not all possible fixes or new functions can be applied to a drive in this manner: there is a very high dependency on the level of ROM code contained within the drive. If an invalid code or a code not compatible with the ROM code is downloaded, the drive will usually reject this code and will continue normal operation. However, there is a small possibility that an invalid code will be accepted. If this occurs, the unit usually becomes inoperable and will have to be returned to the manufacturer for recovery.

16.64.4 Download Microcode and Save (Mode 00111b) - Multiple Binary Files

In this mode, the target receives a segment of the binary microcode file. The Parameter List Length (segment length) of each segment is a multiple of 4KB bytes. The total length of all segments received is equal to the total length of the binary microcode file. All segments must be sent in the proper sequential order.

- If an invalid Parameter List Length is specified, a Check Condition status is returned with Sense Key of Illegal Request and an Additional Sense Code of Invalid Field in the CDB.
- The first segment sent in this mode indicates, by default, the first segment of the binary microcode file. If a Check Condition status is returned in this mode, a Buffer ID = 00h in the subsequent Write Buffer command in this mode indicates the first segment of the binary microcode file. Otherwise the Buffer ID field is ignored.
- Buffer Offset is ignored.
- After all segments of the binary microcode file have been received, the drive behavior is the same as Download Microcode and Save (Mode 00101b) - Single Binary File.
- The MODE SPECIFIC field is ignored in this mode.

16.64.5 Write Data to Echo Buffer (Mode 01010b)

In this mode the target transfers data into the echo buffer. The echo buffer is assigned in the same manner by the target as it would be for a WRITE operation. Data is sent aligned on 4-byte boundaries.

- Upon successful completion of a WRITE BUFFER command, the data is preserved in the echo buffer unless there is an intervening command to any logical unit. In that case, the data may be changed.
- The MODE SPECIFIC field is ignored in this mode.

16.64.6 Download microcode with offsets, select activation, save, and defer activate (Mode 01101b)

In this mode, microcode is transferred to the device server using one or more WRITE BUFFER commands. Activation modes are specified in the Mode Specific field, are saved to nonvolatile storage, and considered deferred.

- The MODE SPECIFIC field defines types of code activation.
- If the PO_ACT bit (bit 7) is set, the drive will activate the code after a power-on reset. If the HR_ACT bit (bit 6) is set, the drive will activate the code after a hard reset.
    - If the VSE_ACT bit (bit 5) is set, the drive will activate the code after a vendor-specific condition is met. The deferred microcode is activated and no longer considered deferred when one of the following occurs:
        - A Power On only if the PO_ACT bit of the Mode Specific field is set in the initial WRITE BUFFER command.
        - .
        - A WRITE BUFFER command with the activate deferred microcode mode (0Fh) is processed.

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- The VSE_ACT bit for vendor-specific activation is not supported.

16.64.7 Download Microcode with Offsets, Save and Defer Activate (Mode 01110b)

In this mode, microcode is transferred to the device server using one or more WRITE BUFFER commands, saved to nonvolatile storage, and considered deferred.

The deferred microcode is activated and no longer considered deferred when one of the following occurs:

a) a power on occurs.
b) a WRITE BUFFER command with the activate deferred microcode mode (0Fh) is processed.
c) a Self Initated Reset occurs.

16.64.8 Activate Deferred Microcode Mode (Mode 01111b)

In this mode, deferred microcode that has been saved using the download microcode with offsets, save, and defer activate mode, if any, is activated and no longer considered deferred.

- The BUFFER ID, BUFFER OFFSET, and PARAMETER LIST LENGTH fields are ignored in this mode.
- The MODE SPECIFIC field is ignored in this mode.

16.64.9 Enable Expander Communications Protocol (Mode 11010b)

In this mode, the drive behavior is the same as Write Data to Echo Buffer (Mode 0101b). The MODE SPECIFIC field is ignored in this mode.

16.65 WRITE LONG (10) - (3F)

The WRITE LONG (10) command requests the drive to write one block of data transferred from the initiator. The transfer data must include User Data and 4 bytes of CRC data.

Table 16 - 207: WRITE LONG (10) - (3F)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 3Fh							
1	COR_DIS	WR_UNCOR	Reserved	Reserved				Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Byte Transfer Length							
9	Control Byte - Refer to SCSI Control Byte.							

The parameters are as follows:

- COR_DIS Correction Disabled bit: 1 = LBA is marked as a pseudo unrecovered error with correction disabled. A subsequent read to this LBA would:
  - Perform no error recovery on the block;
  - Perform no automatic reallocation of the affected logical blocks, including any automatic reallocation enabled by the Read-Write Error Recovery mode page;
  - Not consider errors on the affected logical blocks to be informational exception conditions as defined in the Information Exceptions Control mode page (see SCSI Primary Commands – 4 (SPC-4);

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- Not log errors on the affected logical blocks in the Error Counter log pages;
- On a read to the LBA, return a Check Condition status with the Sense Key set to Medium Error and the Additional Sense Code set to READ ERROR MARKED BAD BY CLIENT.

- WR_UNCOR Write Uncorrectable bit: If this value is 1, and a WRITE LONG command is received, a pseudo unrecovered error with correction enabled is created. On subsequent read commands to the LBA, the drive will:
  - Use the normal recovery procedures (that will end in a hard error);
  - Perform no automatic reallocation of the affected logical blocks, including any automatic reallocation enabled by the Read-Write Error Recovery mode page;
  - Consider errors on the affected logical blocks to be informational exception conditions as defined in the Information Exceptions Control mode page (see SCSI Primary Commands – 4 (SPC-4));
  - Log errors on the affected logical blocks in the Error Counter log pages;
  - On a read to the LBA, return a Check Condition status with the Sense Key set to Medium Error and the Additional Sense Code set to READ ERROR MARKED BAD BY CLIENT.

The error state for LBA written with the COR_DIS or WR_UNCOR bits set, will remain in effect until the LBA is rewritten by a write, write atomic, write same, format, write long without COR_DIS set, reassign, or write verify command.

- Logical Block Address specifies the logical block at which the write operation occurs.
- Byte Transfer Length must specify the exact number of bytes of data available for transfer. If a non-zero-byte transfer length does not match the available data length, the target terminates the command with a Check Condition status. The Sense Key is then set to Illegal Request, and an Additional Sense Code is set to Invalid Field in the CDB.
- The Valid and ILI bits are set to 1, and the information field is set to the difference of the requested length minus the actual length in bytes. Negative values are indicated by two's complement notation.
- Transfer length may be 0 (see the table above) or is calculated as follows:
  - Transfer Length = Logical Block Size + Protection Information Size + CRC Size

    where the Protection Information Size is either 0 (Protection Mode 0) or 8 (Protection Mode 1 or 2) and CRC Size is 4.
- The transfer data (if transfer length > 0) includes the following: [user data logical block][protection data, if any] [CRC]

Note:

1. Because the ECC bytes are not included in the Read Long data, ECC correction capability cannot be tested using Read/Write Long.

16.66 WRITE LONG (16) - (9F/11)

See WRITE LONG (10) - (3F) for a description of the fields.

Table 16 - 208: WRITE LONG (16) - (9F/11)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Operation Code (9Fh)							
1	COR_DIS	WR_UNCOR	Reserved	Service Action (11h)				
2-9	Logical Block Address							
10-11	Reserved							
12-13	Byte Transfer Length							
14	Reserved							

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15	Control

16.67 WRITE SAME (10) - (41)

The WRITE SAME (10) command instructs the target to write a single block of data transferred to the target from the initiator to a number of sequential logical blocks. This command is useful for writing large data areas without sending all the data over the SCSI bus. See the WRITE (10) command description for the definition of the WRPROTECT field.

Table 16 - 209: WRITE SAME (10) - (41)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 41h							
1	WRPROTECT			Anchor	Unmap	Obsolete		
2-5	Logical Block Address							
6	Reserved			Group Number = 0				
7-8	Number of Logical Blocks							
9	Control Byte - Refer to SCSI Control Byte							

- The Anchor bit is ignored.
- When Unmap bit is set to 1, the Write Same results in one of the following:
  - The LBA range (specified in the CDB) being anchored. The drive is resource-provisioned, so long as the data in the Data out descriptor matches what would be expected on a subsequent read. For a drive formatted with an Initialization Pattern (IP), the Data Out buffer matches the IP. For a drive initialized without an IP, the Data Out buffer contains all zeros for data. If data protection information is provided, it consists of all 0xFFs.
  - A normal WRITE SAME operation (the same Data Out buffer written to all logical blocks within the LBA range specified).
- Logical Block Address specifies the address at which the write begins.
- Number of Blocks specifies the number of contiguous blocks to be written. If 0, all the remaining blocks on the specified logical unit are written.

16.68 WRITE SAME (16) - (93)

See WRITE SAME (10) - (41) for a description of all the fields.

Table 16 - 210: WRITE SAME (16) - (93)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 93h							
1	WRPROTECT			Anchor	Unmap	Obsolete	Obsolete	NDOB
2-9	Logical Block Address							
10-13	Number of Blocks							
14	Reserved			Group Number = 0				
15	Control Byte - Refer to SCSI Control Byte							

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- NDOB (No Data Out Buffer) bit: 0 = the command is processed using the Data Out buffer. When set to 1, the target will not transfer data from the data out buffer. If the LBPRZ field is set to 000b or xx1b, the target shall process the command as if the data out buffer contained all zeros and protection information, if any, contained 0xFFs for all protection information. If the LBPRZ field is set to 010b, the target shall process the command as if the data out buffer contained user data that was set to the Initialization Pattern and protection information, if any, contained 0xFFs for all protection information.

16.69 WRITE SAME (32) - (7F/0D)

WRITE SAME (32) requests that the drive write a single block of data transferred from the initiator to the drive, for sequential logical blocks. This command is useful for writing large data areas with the same data, without sending all the data over the interface. Each logical block transferred includes user data and may include protection information, based on the WRPROTECT field and the drive format. Each logical block written includes user data; it also includes protection information if the drive is formatted to enable it.

Table 16 - 211: WRITE SAME (32) - (7F/0D)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 7Fh							
1	Control Byte - Refer to SCSI Control Byte							
2-5	Reserved							
6	Reserved			Group Number = 0				
7	Additional CDB Length = 18h							
8-9	Service Action = 000Dh							
10	WRPROTECT			Anchor	Unmap	Obsolete	Obsolete	NDOB
11	Reserved							
12-19	Logical Block Address							
20-23	Expected Initial Logical Block Reference Tag							
24-25	Expected Logical Block Application Tag							
26-27	Logical Block Application Tag Mask							
28-31	Number of Blocks							

- If the drive is formatted with type 2 protection (PROT_EN=1 and P_TYPE=001b in the READ CAPACITY (16) parameter data), this command is processed normally. Any other protection types return a Check Condition status, with Sense Key of Illegal Request and an Additional Sense Code of Invalid Command Operation Code
- Expected Initial Logical Block Reference Tag contains the value of the Logical Block Reference Tag field expected in the protection information of the first logical block accessed by the command.
- If the ATO bit is set to 1 in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a bitmask value. This value enables checking the Logical Block Application Tag field in the protection information for each logical block accessed by the command. A Logical Block Application Tag Mask bit set to 1 enables the checking of the corresponding bit of the Expected Logical Block Application Tag field, with the corresponding bit of the Logical Block Application Tag field in the protection information.
- If the ATO bit is set to 0, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

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16.70 Write Atomic (16) - (9C)

Table 16 - 212: Write Atomic (16) - (9C)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 9Ch							
1	WRPROTECT			DPO	FUA	Reserved		
2-9	Logical Block Address							
10-11	Atomic Boundary = 0							
12-13	Number of Blocks							
14	Reserved			Group Number = 0				
15	Control Byte - Refer to SCSI Control Byte							

- Refer to the Block Limits VPD page (Inquiry Data - EVPD = 1, Page Code = 03h - ASCII Information Page) for descriptions and restrictions on the fields within the Write Atomic CDB.

16.71 Write Atomic (32) - (7F/0F)

Table 16 - 213: Write Atomic (32) - 7F/0F)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Command Code = 7Fh							
1	Control Byte - Refer to SCSI Control Byte							
2-3	Reserved							
4-5	Atomic Boundary = 0							
6	Reserved			Group Number = 0				
7	Additional CDB Length = 18h							
8-9	Service Action = 000Fh							
10	WRPROTECT			DPO	FUA	Reserved	Obsolete	Reserved
11	Reserved							
12-19	Logical Block Address							
20-23	Expected Initial Logical Block Reference Tag							
24-25	Expected Logical Block Application Tag							
26-27	Logical Block Application Tag Mask							
28-31	Number of Blocks							

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- If the drive is formatted with type 2 protection (PROT_EN=1 and P_TYPE=001b in the READ CAPACITY (16) parameter data), this command is processed normally. Any other protection types return a Check Condition status, with a Sense Key of Illegal Request and an Additional Sense Code of Invalid Command Operation Code.
- For all other fields, refer to WRITE ATOMIC (16).

16.72 SCSI Status Byte

A Status Byte is sent to the initiator upon command completion. Additional sense information may also be available, depending on the contents of the Status Byte. This section describes the possible values for the Status Byte and Sense Data. The Reserved fields are set to 0.

Table 16 - 214: SCSI Status Byte. Format of the SCSI Status Byte

Bit							
7	6	5	4	3	2	1	0
Reserved		Status Code					RSVD

Status Byte		Description
00h	Good	The command successfully completed.
002	Check Condition	An error, exception, or abnormal condition has been detected. The sense data is set by the drive. The REQUEST SENSE command should be issued to determine the nature of the condition.
08h	Busy	This condition is returned when disconnect privilege is not granted while the drive is BUSY processing the other command for the other initiator. The normal initiator recovery action is to issue the command at a later time or to reissue the command and grant the disconnect privilege.
18h	Reservation Conflict	This status is returned whenever an SCSI device attempts to access the drive, but it has been reserved by another initiator.
28h	Queue Full	This status indicates that the command queue of the target is full. If a tagged command queuing feature is enabled and there is no room on the command queue, this status is returned when the initiator sends a command. For this status, the sense data is not valid.

16.73 SCSI Protocol

There are various operating conditions that prevent the target from executing a SCSI command. This section describes each of these operating conditions and their relative priority.

16.73.1 Priority of SCSI Status Byte Reporting

After establishing the I_T_L nexus or I_T_L_Q nexus, the target must first determine whether command execution is allowed. Execution is deferred until a later time if the command must be added to the command queue. Execution may also be prevented by an internal target condition that requires the reporting of a Check Condition, Queue Full, Busy, or Reservation Conflict status. There are several different internal conditions to be active at the same time. The order in which the target checks for each of these conditions determines their priority (highest priority first) as follows:

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1. Check Condition status for invalid Logical Unit Number. *See* Invalid LUN Processing.
2. Check Condition status for Incorrect initiator Connection.
3. Check Condition status for Unit Attention Condition. *See* Unit Attention Condition.
4. Busy status or Queue Full Status. *See* Command Processing During Execution of Active I/O Process.
5. Check Condition status for Deferred Error Condition.
6. Check Condition status during Startup and Format operations.
7. Reservation Conflict status. *See* Command Processing while Reserved.
8. Check Condition status for invalid command Opcode.
9. Check Condition status for invalid command descriptor block.
10. The highest priority internal condition that prevents command execution is reported by the target provided there is no bus error.
11. For all Check Conditions, the Sense Data is built by the target, provided a valid LUN address is known. Sense Data is cleared by the target upon receipt of any subsequent command to the LUN from the initiator receiving the Check Condition.

16.73.2 Invalid LUN Processing

Any value other than zero in the FCP_LUN field of the FCP_CMD IU is invalid. The target's response to an invalid LUN varies with the command, as follows:

- Inquiry: Execute the command, return the INQUIRY data that indicates unknown device type (byte 0 = 7Fh), and return Good status. All other bytes are valid. See Inquiry (12).
- Request Sense: Execute the command. Return the sense data with the Sense Key set to Illegal Request and the Additional Sense Code, with its Additional Sense Code Qualifier set to LOGICAL UNIT NOT SUPPORTED; and return Good status. See REQUEST SENSE (03).
- All Others: Do not execute the command. Return a Check Condition status, along with the auto-sense data. The Sense Key is set to Illegal Request, and the Additional Sense Code with its Additional Sense Code Qualifier set to LOGICAL UNIT NOT SUPPORTED.

In all cases, the target's response to the command for an invalid LUN does not affect the current execution of a command on the valid LUN, for this initiator or any other initiator.

16.73.3 Command Processing During Execution of Active I/O Process

When the target is not executing any I/O processes, a new I/O process may execute (unless execution is prevented by another internal target condition listed in 18.1.1; see Priority of SCSI Status Byte Reporting). If an active I/O process exists when the target receives a new command, the target determines whether:

- The command is permitted to execute.
- The command is added to the queue.
- Queue Full status is to be returned.
- Busy status is to be returned.

If an active I/O process exists when the target receives a new command, the target determines how the new command should be handled according to the following rules:

- Check Condition status is returned with Sense Key set to Logical Unit Not Ready if:
- The startup operation or a format operation is active.

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Notes: If a Unit Attention is pending when this condition exists, the Sense Key is set to Unit Attention rather than to Logical Unit Not Ready, as Unit Attention has a higher reporting priority (see Priority of SCSI Status Byte Reporting).

The command is permitted to execute if:

1. The command is a priority command. *See* Priority Commands.
2. The conditions to execute concurrently are met. *See* Concurrent I/O Process.

The command is added to the queue if:

1. Any I/O process already exists at the target, and;
2. This is not an incorrect initiator connection.

Queue Full Status is returned if:

1. The command would otherwise be added to the queue (according to the rules described above), but all slots in the queue are full, or;
2. The command would otherwise be added to the queue (according to the rules described above), but all the available queue slots not reserved for use by another initiator are full, or;
3. A Format Unit command was previously queued but has not yet begun execution, or;
4. The target is in a Degraded Mode (see Degraded Mode), and a Start Unit command was previously queued but has not yet begun execution.

Busy status is never returned.

16.73.4 Unit Attention Condition

The target will generate a Unit Attention condition when one of the following occurs:

- The target has been reset. This includes a power-on reset or a reset caused by a Target Reset Task Management function or Reset LIP. In all of these cases, a Unit Attention condition is generated for each initiator. In addition, a process login (PRLI) causes a Unit Attention Condition Power-On Reset for that initiator with an Additional Sense Code and an Additional Sense Code Qualifier reported as Power-On Reset, Power-On Reset Occurred.
- MODE SELECT has been executed. A Unit Attention condition is generated for all initiators except the one that issued the MODE SELECT command. The Additional Sense Code and an Additional Sense Code Qualifier reported is MODE PARAMETERS CHANGED.

  A Unit Attention condition is also generated if any of the current page parameters are set by the MODE SELECT command. The target does not check to see that the old parameters are different from the new parameters. For example, suppose the initiator issues a MODE SENSE command with a page code, to report the current values. It then issues a MODE SELECT command with the same parameter list. In that case a Unit Attention condition is generated, even though the current parameters were not changed from their previous values. However, if the target detects an illegal parameter or error condition prior to modifying the current parameters, a Unit Attention condition is not generated, because the parameters were not set. The Unit Attention condition is also not generated when the MODE SELECT command parameter list does not include any pages, and only the header or header/block descriptor is present.
- FORMAT UNIT has been executed. A Unit Attention condition is generated for all initiators except the one that issued the FORMAT UNIT command. The Additional Sense Code is generated, and an Additional Sense Code Qualifier is reported as NOT READY TO READY TRANSITION, (MEDIUM MAY HAVE CHANGED). This indicates that the block descriptor parameters from the last MODE SELECT command have been used and are now considered current values.
- WRITE BUFFER/DOWNLOAD MICROCODE has been executed. A Unit Attention condition is generated for all initiators except the one that issued the WRITE BUFFER command. The Additional Sense Code is generated, and an Additional Sense Code Qualifier is reported as MICROCODE HAS BEEN CHANGED.
- Commands Cleared by Another Initiator. This Unit Attention condition is generated after an initiator sends a Clear Task Set Task Management function. The Unit Attention condition is generated for all other initiators with I/O processes that were either active or queued for the logical unit. An additional Sense Code is generated, and an Additional Sense Code Qualifier is reported as COMMANDS CLEARED BY ANOTHER INITIATOR.
- LOG SELECT with PCR bit has cleared parameters. A Unit Attention condition is generated for all initiators except the one that issued the LOG SELECT command. An additional sense sode is generated, and an Additional Sense Code Qualifier is reported as Log Select Parameters Changed.
- The registration or reservation made by a PERSISTENT RESERVED OUT command was cleared by another initiator. A Unit Attention condition is generated for the initiator that held the cleared registration or reservation. A Predictive Failure Analysis threshold has been reached, and the Method of Reporting field of mode page 1Ch is 2h.

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- The Unit Attention condition persists for each initiator until that initiator clears the condition from the logical unit, as described below. Several commands are handled as special cases during a Unit Attention condition. These cases are also discussed below.

If the target receives a command from an initiator before reporting a Check Condition status for a pending Unit Attention condition for that initiator, the target's response varies with the command as follows:

Table 16 - 215: Command Responses, before Check Condition

Command	Response
INQUIRY	Execute the command, return a Good status, and preserve the Unit Attention condition.
REPORT LUNS	Same as above.
REQUEST SENSE	Execute the command, return any pending sense data, return a Good status, and preserve the Unit Attention condition. If there is no pending sense data, the sense data associated with the highest priority Unit Attention condition is returned, and the highest priority Unit Attention condition is cleared for this initiator.
All Others	Do not execute the command, return a Check Condition status, clear the highest priority Unit Attention condition for this initiator, and return the associated sense data.

More than one Unit Attention condition may be generated for an initiator before that initiator clears the Unit Attention condition.

16.73.5 Command Processing During Startup, Format and Sanitize Operations

If the target receives a command from an initiator while the target is executing a startup, format or sanitize operation, the response of the target varies with the command as follows:

Table 16 - 218: Command Responses during Executions

Command	Response
INQUIRY	The drive sends the inquiry data and returns the appropriate status.
REQUEST SENSE	Executes the command, returns a Sense Key of NOT READY and an Additional Sense Code of LOGICAL UNIT NOT READY and a Good status.
	The return of the Additional Sense Code Qualifier depends on the type of I/O processes that are active: • For the START/STOP UNIT and the Auto-Start operations, the qualifier that is returned is LOGICAL UNIT IS IN PROCESS OF BECOMING READY. • For the FORMAT UNIT command, the qualifier returned is LOGICAL UNIT NOT READY, FORMAT IN PROGRESS. • For the SANITIZE command, the qualifier returned is LOGICAL UNIT NOT READY, SANITIZE IN PROGRESS. For these cases, the Sense Key specific bytes are set to return the progress indication.
REPORT LUNS	The drive will send REPORT LUNS data and appropriate status.
ALL OTHERS	The drive terminates the command with a Check Condition status. The Sense Data that is generated is described in REQUEST SENSE.

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16.73.6 Internal Error Condition

The Target generates an Internal Error condition for all initiators when an internally initiated operation ends with an unrecoverable error. An Internal Error condition causes Sense Data to be generated and saved for all initiators. The Error Code field of the Sense is set for a Current Error (70h) and the Sense Key is set to HARDWARE ERROR. Recovered errors are not reported.

The Internal Error condition persists for each initiator until that initiator clears the condition from the logical unit as described below. Several commands are handled as special cases during an Internal Error condition, as discussed below.

If the target receives a command from an initiator while an Internal Error condition exists for that initiator, the response of the target varies with the command as follows:

Table 16 - 218: Command Responses during Executions

Command	Response
INQUIRY	The drive executes the command with Good status and does not clear the Internal Error condition.
REPORT LUNS	The drive executes the command with Good status and does not clear the Internal Error condition.
REQUEST SENSE	The drive executes the command, returns the sense data generated by the Internal Error condition, returns Good status, and clears the Internal Error condition for that initiator.
ALL OTHERS	The drive terminates the command with a Check Condition status and clears the Internal Error condition.

16.73.6.1 Deferred Error Condition

Error Code (71h) of Sense Data indicates that a Check Condition status was returned. It results from an error or exception condition that occurred during execution of a previous command for which Good status was already returned.

The drive creates a Deferred Error condition when:

- Execution of a FORMAT UNIT command with the Immediate bit of 1 ends with an error.
- Execution of a SANITIZE command with the Immediate bit of 1 ends with an error.

16.73.7 Degraded Mode

Certain errors or conditions may impair the ability of the drive to function normally. Rather than completely fail, the drive is designed to be as responsive as possible. Also, in most cases the initiator may be used to help restore normal operation. This mode of limited operation is called Degraded Mode.

There are four degraded drive modes:

1. Degraded Mode, which could be caused by one of the following conditions:
   - Context Load was started (by the POR or Unit Start command) and the target is under Self-Configuration.
   - Context Load Failure (Disable Logical).
   - A Unit Stop command was issued after the target successfully completed the Self-Configuration.
2. Self-Configuration Failure Degraded, which can be caused by a RAM Code, Read Failure.
   - Format Command Failure Degraded. This condition occurs when a FORMAT UNIT command fails or is abnormally interrupted (Mode Page 0, Byte 5, Bit 4, FDD Controls Format Degraded Mode). The exception to this rule is that a format may fail due to insufficient reserves on the drive. If this occurs, the drive will not be put into a degraded state.
   - Sanitize Command Failure Degraded. This condition occurs when the SANITIZE command fails.

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16.73.7.1 Response to SCSI Command in Degraded Mode - Becoming Ready

Table 16 - 217: Response to SCSI Command in Degraded Mode - Becoming Ready

Command (w/Option)	Response
REQUEST SENSE	Executed. The Target may return Sense Key 02h (Not Ready) ASC/ASCQ 0401h (In Process of Becoming Ready).
INQUIRY, REPORT LUNS	Executed.
TEST UNIT READY	Executed, and a Check Condition is returned with Sense Key 02h (Not Ready) ASC/ASCQ 0401h (In Process of Becoming Ready).
START STOP UNIT (Start)	Executed. • Success: Good status is returned. Media Degraded Mode is cleared. • Context Load Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ ASCQ 4400h (Internal Target Error). • Self- Configuration Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ASCQ 4080h (Diag Fail-Bring up Fail).
Other Commands	Not Executed. Check Condition is returned with Sense Key 02h (Not Ready) ASC/ASCQ 0401h (In Process of Becoming Ready).

16.73.7.2 Response to SCSI Command in Degraded Mode - Context Load

Table 16 - 218: Response to SCSI Command in Degraded Mode - Context Load

Command (w/Option)	Response
REQUEST SENSE	Executed. The Target may return Sense Key 04h (Hardware Error) ASC/ASCQ 4400h (Internal Target Failure).
INQUIRY, REPORT LUNS	Executed.
TEST UNIT READY	Executed and Check Condition is returned with Sense Key 04h (Hardware Error) ASC/ASCQ 4400h (Internal Target Failure).
START STOP UNIT (Start)	Executed. • Success: Good status is returned. Media Degraded Mode is cleared. • Context Load Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ASCQ 4400h (Internal Target Failure). • Self-Configuration Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ASCQ 4080h (Diag Fail- Bring up Fail).
START STOP UNIT (Stop)	Executed. Good status is returned. Media Degraded Mode is *not* cleared.
WRITE BUFFER (Download and Save)	Executed. Good status is returned. Media Degraded Mode is replaced with Format Command Failure Degraded Mode.
Other Commands	Not Executed. Check Condition status is returned with Sense Key 04h (Hardware Error) ASC/ASCQ 4400h (Internal Target Failure).

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16.73.7.3 Response to SCSI Command in Degraded Mode - Drive Issued or Received Unit Stop Command

Table 16 - 2219: **Media Degraded Mode - Drive Issued/Received Unit Stop Command**

Command (w/Option)	Response
REQUEST SENSE	Executed. The Target may return Sense Key 02h (Not Ready) ASC/ASCQ 0402h (Initialize Command Required)
INQUIRY, REPORT LUNS	Executed.
TEST UNIT READY	Executed and Check Condition is returned with Sense Key 02h (Not Ready) ASC/ ASCQ 0402h (Initialize Command Required).
START STOP UNIT (Start)	Executed. • Success: Good status is returned. Media Degraded Mode is cleared. • Context Load Failure: Check Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ASCQ 4400h (Internal Target Failure). • Self-Configuration Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ASCQ 4080h (Diag Fail- Bring up Fail).
START/STOP UNIT (Stop)	Executed. Good status is returned. Media Degraded Mode is *not* cleared.
Other Commands	Not Executed. Check Condition status is returned with Sense Key 04h (Hardware Error) ASC/ASCQ 4400h (Internal Target Failure).

16.73.7.4 Self-Configuration Failure Degraded Mode

Table 16 - 220: **Self-Configuration Failure Degraded Mode**

Command (w/Option)	Response
REQUEST SENSE	Executed. The Target may return Sense Key 04h (Hardware Error) ASC/ASCQ 4080h (Diag Fail-Bring up Fail).
INQUIRY, REPORT LUNS	Executed.
TEST UNIT READY	Executed and Check Condition is returned with Sense Key 04h (Hardware Error) ASC/ ASCQ 4080h (Diag Fail-Bring up Fail).
START STOP UNIT (Start)	Executed. • Success: Good status is returned. Media Degraded Mode is cleared. • Context Load Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ASCQ 4400h (Internal Target Failure). • Self Configuration Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ASCQ 4080h (Diag Fail- Bring up Fail).
WRITE BUFFER (Download and Save)	Executed. • Success: Good status is returned. Media Degraded Mode is cleared. • Self-Configuration Failure: Check Condition with Sense Key 04h (Hardware Error) ASC/ASCQ 4080h (Diag Fail- Bring up Fail). • Sense Key 02h (Not Ready) ASC/ASCQ 4085h (Diag Fail-RAM code NOT load).
Other Commands.	Not Executed. Check Condition status is returned with Sense Key 04h (Hardware Error) ASC/ASCQ 4080h (Diag Fail- Bring up Fail).

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16.73.7.5 Format Command Failure Degraded Mode

Table 16 - 221: **Format Command Failure Degraded Mode**

Command (w/Option)	Response
REQUEST SENSE	Executed. The Target may return: • Sense Key 02h (Not Ready) ASC/ASCQ 3100h (Format Corrupted). • Sense Key 03h (Medium Error) ASC/ASCQ 3100h (Format Corrupted).
INQUIRY, REPORT LUNS	Executed.
TEST UNIT READY	Executed and Check Condition is returned with Sense Key 02h (Not Ready) ASC/ ASCQ 3100h (Format Corrupted).
FORMAT UNIT	Executed. • Success: Good status is returned. Format Degraded Mode is cleared. • Failure: Check Condition status is returned and Format Degraded Mode is NOT cleared.
WRITE BUFFER (Download and Save)	Executed. • Success: Good status is returned. Write Buffer is not cleared.
Other Commands	Not Executed. Check Condition status is returned with Sense Key 03h (Medium Error) ASC/ASCQ 3100h (Format Corrupted).

16.73.7.6 Sanitize Command Failure Degraded Mode

Table 16 - 222: **Sanitize Command Failure Degraded Mode**

Command (w/Option)	Response
REQUEST SENSE	Executed. The Target returns: Sense Key 03h (Medium Error) ASC/ASCQ 3103h (Sanitize Command Failed).
INQUIRY, REPORT LUNS	Executed.
TEST UNIT READY	Executed and Check Condition is returned with Sense Key 03h (Medium Error) ASC/ ASCQ 3103h (Sanitize Command Failed).
SANITIZE	Executed. • Success: Good status is returned. Sanitize Failed. Degraded Mode is cleared. • Failure: Check Condition status is returned and Sanitize Failed Degraded Mode is NOT cleared.
Other Commands	Not Executed. Check Condition status is returned with Sense Key 03h (Medium Error) ASC/ASCQ 3103h (Sanitize Command Failed).

16.73.7.7 Command Processing while Reserved

A logical unit is reserved after successful execution of the Reserve command. Each time a Reserve command is executed successfully, the target records the SCSI ID of the initiator that made the reservation and the SCSI ID of the initiator that is to receive the reservation. This information is needed to determine whether subsequent commands should be permitted, or if the Reservation Conflict status should be reported. The initiator that made the reservation is the one that issued the Reserve command. The initiator to receive the reservation may be either the same or a different initiator (third-party reservation).

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If the logical unit is reserved when a new command is received, the target examines the command opcode and the SCSI ID of the issuing initiator. This is done to determine whether a Reservation Conflict status should be returned based on the following rules:

- If the issuing initiator is the one that made the reservation and the one to receive the reservation, then all commands are permitted.
- If the issuing initiator is neither the one that made the reservation nor the one to receive the reservation, then:
  - A Request Sense or Inquiry command is permitted.
  - A Release command is permitted but ignored.
  - Any other command results in a Reservation Conflict status.
- If the issuing initiator is the one that made the reservation but is not the one to receive the reservation, then:
  - An Inquiry, Request Sense, Reserve, or Release command is permitted.
  - Any other command results in a Reservation Conflict status.
- If the issuing initiator is not the one that made the reservation but is the one to receive the reservation, then:
  - A Reserve command results in a Reservation Conflict status.
  - A Release command is permitted but is ignored.
  - Any other command is permitted.

If a Reservation Conflict status is not reported and the command is permitted, the target checks the next-highest priority internal condition to determine whether execution is allowed. *See* Priority of SCSI Status Byte Reporting.

16.75 Priority Commands

Certain SCSI commands always execute without returning a Busy status or Reservation Conflict status in response to the command. These commands are:

- INQUIRY
- REQUEST SENSE
- REPORT LUNS
- TEST UNIT READY

These commands are executed prior to attempting to complete the execution of any other pending command in the queue. These commands are never queued.

16.76 Command Queuing

The drive supports command queuing.

16.76.1 Queue Depth

Any initiator can queue at least one command at any time, irrespective of the actions of any other initiators in the system. A single initiator may queue up to 512 commands, if no other initiator has more than one command in the queue.

16.76.2 Queue Full Status

The drive will respond with QUEUE FULL status to a SCSI command when all queue slots are utilized. The SCSI command is not placed in the command queue under this condition.

16.76.3 Termination of I/O Processes

Normal termination of I/O processes occurs when the target returns SCSI status. I/O processes may also be terminated by the following:

- An ABORT TASK terminates the specified I/O process from the issuing initiator.
- An ABORT TASK SET or I_T NEXUS LOSS event terminates all I/O processes from the issuing initiator.
- A CLEAR TASK SET, LUN RESET or SAS OOB (hard) reset terminates all I/O processes from all initiators.

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16.76 Command Reordering

Command reordering is always enabled.

16.77 Concurrent I/O Process

Read and Write commands may execute concurrently. Priority commands may to execute concurrently with other commands. A second-priority command received while a priority command is being executed is put at the head of the command queue.

16.78 Write Cache

Write caching is always enabled. PLI circuitry ensures data integrity. Errors on write commands are reported immediately. Deferred errors do not occur on write commands.

16.79 Automatic Rewrite/Reallocate

The target supports auto reallocation for all media access commands. Auto reallocation cannot be disabled, and the ARRE setting is ignored.

16.80 Multiple initiator Support

This section describes how the target behaves in a multiple-initiator system. Up to 64 initiators may be supported at a time.

16.80.1 Sense Data

A separate sense data area is reserved for each initiator. Each area is maintained independently. This allows a command from one initiator to complete with a Check Condition status and generate Sense Data without being affected by a subsequent command from a different initiator. There is no requirement for the first initiator to send a REQUEST SENSE command to retrieve the Sense Data prior to the execution of a command from a different initiator.

16.80.2 Mode Pages

A single set of Mode pages is maintained. This includes both current and saved parameters. If a MODE SELECT command is executed that updates the current parameters, a Unit Attention condition is generated for all initiators except the one that issued the command. See Unit Attention Condition for more information.

16.81 Reset

Reset actions returns the drive to a known, initialized state. This device supports the reset sources as discussed in the following sections.

16.81.1 Reset Sources

The following reset sources are detected by the target:

Table 16 - 223: Reset Sources

Reset Name	Reset Source
Power-on Reset	Signal generated by the hardware at initial power-on
Self-initiated Reset	Software-generated reset that occurs when a catastrophic error is detected by the microcode
OOB Hard Reset	OOB Hard Reset Sequence received on the SAS interface

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LUN Reset	SSP command frame with the LUN RESET TMF flag set

16.81.2 Reset Actions

The action taken by the drive following a reset is dependent on the source of the reset.

16.73.7.8 Power-On Reset and Self-Initiated Reset

Power-On Reset and Self-Initiated Reset cause the following to be performed, in the order shown:

1. A power-up sequence
2. A startup sequence is necessary to put the drive in a ready state

These reset conditions cause the following actions:

- If the reset occurs during the power-up sequence, the power-up sequence is re-started.
- If a startup sequence has not yet completed, it is restarted. Note: The power-up sequence is not re-run, as it has already completed.
- If the reset occurs while a logical block is being written, the WRITE operation is disabled at the end of the current block. The media is not corrupted.

16.83 Diagnostics

The drive executes Power-On Diagnostics at power-on time to assure the correct operation of the drive. This is done by validating components (RAM, SPI Flash, HDC, PLI Capacitor), checking stored information in the Reserved Area and SPI Flash, and verifying fault detects circuits. The SEND DIAGNOSTIC command can be used to invoke a self-test.

16.83.1 Power-on Diagnostics

At power-on time the following tests are executed:

- Validation of SPI Flash
- RAM test for internal RAM
- Test and initialize HDC registers
- RAM test for customer RAM
- PLI self-test
- Validation of code and data from the Reserved Area

Faults detected before successful completion of Step 3 could prevent the drive from responding to a selection on the host interface. Faults detected after the successful completion of Step 3 are reported as a Check Condition status to the initiator, on the first command issued after a fault is detected (except for the INQUIRY, REPORT LUNS and REQUEST SENSE commands, which always always return a Good status.

16.83.2 Self-test via SEND DIAGNOSTIC Command

16.83.2.1 Default Self-test

The default self-test is invoked by the SlfTst bit in the SEND DIAGNOSTIC command. The response is a Good status if the test is successful, or a Check Condition status if the test fails. The following tests are performed by the default self-test (in the order defined):

1. Logical Enable Check to determine if the media is accessible logically;
2. Write, Read and Compare test. This is a drive read/write test that writes data to a predefined location in the reserved area and then reads it back and validates the content.

16.83.2.2 Short Self-tests and Extended Self-tests

Two other types of self-tests may be invoked using the Function Code field in the SEND DIAGNOSTIC command: a short self-test and an extended self-test. The tests performed in the short and extended self-tests are described later. The time required by a logical unit to complete its extended self- test is specified in the Extended Self-Test Completion Time field in the Control Mode Page. The results of a self-test can be retrieved via the LOG SENSE command for Log Page 10.

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16.83.2.3 Self-test Modes

There are two modes for short and extended self-tests: foreground and background.

- **Foreground Mode**

  When the drive receives a SEND DIAGNOSTIC command specifying a self-test to be performed in foreground mode, the drive returns status for that command after the self-test completes. While performing a self-test in foreground mode, the drive responds to all commands except INQUIRY, REPORT LUNS, and REQUEST SENSE with a Check Condition status. A Sense Key **of NOT READY and an Additional Sense Code of LOGICAL UNIT NOT READY - SELF-TEST IN PROGRESS** are also returned**.**

  If the drive is performing a self-test in the foreground mode and a test error occurs, the drive updates the self-test results log page and reports a Check Condition status, with a Sense Key of HARDWARE ERROR and an Additional Sense Code of LOGICAL UNIT FAILED SELF-TEST. The application client may obtain additional information about the failure by reading the self-test results log page.

  An application client may terminate a self-test that is being performed in the foreground mode using an ABORT TASK, ABORT TASK SET, or CLEAR TASK SET task management function. If the drive receives an ABORT TASK, ABORT TASK SET, or CLEAR TASK SET task management function while performing a self-test in the foreground mode, it will abort the self-test and update the self-test results log page.

- **Background Mode**

  When the drive receives a SEND DIAGNOSTIC command specifying a self-test to be performed in the background mode, the drive returns status for that command as soon as the command descriptor block has been validated. After returning status for the SEND DIAGNOSTIC command specifying a self- test to be performed in the background mode, the drive will initialize the self-test results log page as follows. The Function Code from the SEND DIAGNOSTIC command will be placed in the Function Code field in the log page. The self-test Results field is set to 0Fh. After the self-test results log page is initialized, the drive will begin the first self-test segment.

  While the device server is performing a self-test in the background mode, it shall terminate with a Check Condition status any SEND DIAGNOSTIC command it receives that meets one of the following criteria: The SlfTst bit is one.

  The Function Code field contains a value other than 000b or 100b.

  When terminating the SEND DIAGNOSTIC command, the Sense Key is set to NOT READY and the Additional Sense Code is set to LOGICAL UNIT NOT READY, SELF-TEST in PROGRESS. While performing a self-test in the background mode, the drive will suspend the self- test to service any other command other than SEND DIAGNOSTIC (with Function Code field set to 100b) WRITE BUFFER (with the mode set to any download microcode option), FORMAT UNIT and START UNIT STOP command. Suspension of the self-test to service the command will occur within 2 seconds. If SEND DIAGNOSTIC (with Function Code field set to 100b), WRITE BUFFER (with the mode set to any download microcode option), FORMAT UNIT or START UNIT STOP command is received, the drive will abort the self-test, update the self-test log, and service the command within two seconds after the command descriptor block has been validated.

  An application client may terminate a self-test that is being performed in the background mode by issuing a SEND DIAGNOSTIC command with the Function Code field set to 100b (Abort background self-test function).

- Elements Common to Foreground and Background Self-test Modes

  The Progress Indication field returned in response to a REQUEST SENSE command may be used by the application client at any time during execution of a self-test to poll the progress of the test. While executing a self-test unless an error has occurred, the drive will respond to a REQUEST SENSE command by returning a Sense Key of NOT READY and an Additional Sense Code of LOGICAL UNIT NOT READY - SELF-TEST IN PROGRESS with the Sense Key specific bytes set for progress indication.

  The application client may obtain information about the twenty most recently completed self-tests by reading the self- test results log page. This is the only method for an application client to obtain information about self-tests performed in the background mode. The default self-test results are not logged in the log page

- Tests Performed in the Short and Extended Self-test

  The following table defines the tests performed in the short and extended self-test. They are defined by their segment number which is also used to report Self-Test Results, in Log Sense Page 10. Note that the only difference between the Short and the Extended tests, is the sequential verify test in segment 7h. Also note that either of these tests can be run in foreground or background mode as previously described.

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Table 16 - 224: **Short and Extended Self-test Description**

Segment Number	Short Self-test	Extended Self-test	Description
1h	Drive Ready Test		Internal check to insure drive is “ready”, similar to a Test Unit Ready command.
2h	Drive Diagnostics		This test is comprised of the Default Self-Test as defined in Section Default Self-test.
-/3h		PLI Test	Drain and recharge capacitors.
3h/4h	SMART		Perform SMART testing and check results to ensure that SMART threshold criteria are not exceeded.
4h/5h	Low-Level Format Check		Check to insure that the media is currently not in the MEDIA FORMAT CORRUPTED state.
5h/6h	Reserved Area Check		Write/Read test in a predefined location in the Reserved Area of the drive.
6h/7h	Verify First 300MB Verify Last 100MB	Verify All LBAs	Sequential verify operation. Ensure that no uncorrectable errors occur within the verify range.
7h/8h	Recheck SMART		Same as segment 3h/4h.

16.83.2.4 Background Medium Scan

For a related function, see Mode Page 1Ch - Informational Exceptions Control.

16.84 Idle Time Function

The drive periodically saves data in logs and S.M.A.R.T. counters in the reserved area of the drives. The information is used by the drive to support various SCSI commands and to do failure analysis.

16.85 Command Time-out Limits

The Command Time-Out Limits are the time starting from the SCSI Arbitration phase through the SCSI Task complete message, associated with a command.

16.85.1 Format Time

A FORMAT UNIT command completes between 10 seconds and 3 minutes, depending on the drive capacity and its utilization.

16.85.2 Sanitize Time

The amount of time it takes to sanitize a drive depends on the drive capacity. Up to 6 minutes should be allowed to complete a SANITIZE command.

16.85.3 START STOP UNIT Time

A START STOP UNIT command should normally complete in under 10 seconds. However, if a prior power cycle was unsafe (i.e., a START STOP UNIT command with START=0 and IMMED=0 was not completed prior to power off), the time-to-ready (or time to complete an initial START STOP UNIT command with START=1) make take up to 20 seconds.

16.85.4 Time-out Limits for Other Commands

The default timeout for all other commands is 5 seconds.

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16.86 Recommended Initiator ERP

This section is directed toward documenting the assumptions made by the drive that the system is expected to implement. The design points for error reporting to the system assume certain system actions for the error return codes. These assumptions are:

- SCSI protocol is the first priority in reporting errors.
- The system maintains a log of all reported errors.

The error classes the system should be concerned with are Data and Non-Data errors. Data errors deal with handling data to and from the media and are identified by the Additional Sense Code contained in the Sense Data. The Additional Sense Codes for data errors are:

- 11 - Unrecovered Read Error
- 17 - Recovered Read Error

Non-data errors are not directly related to transferring data to and from the media. These errors can include data handling, if the media is not associated with the error (i.e., interface errors).

The system action assumed for each class of error is outlined here.

16.86.1 Drive Service Strategy

The drive service strategy is defined so the customer will be able to use the system as soon after a failure is detected as possible. The first priority is to replace the entire drive, to make the system operational with minimal service time. The service representative should:

- Back up all the customer data from this drive if possible.
- Replace the complete drive.
- Restore the customer data.
- Return the drive to customer service.

16.86.2 Recommendations for System Error Log

The system error log should contain information about the drive error that allow recovery actions. The system error logs should contain all the error information returned in the Sense data. At a minimum, the following information about each error occurrence should be logged:

- Valid Bit and Error Code (Sense byte 0)
- Sense Key (Sense Byte 2)
- Information Bytes (Sense bytes 3 through 6)
- Command Specific Information (Sense bytes 8 through 11)
- Additional Sense Code (Sense byte 12)
- Additional Sense Code Qualifier (Sense byte 13)
- Field Replaceable Unit (Sense byte 14)
- Sense Key Specific (Sense bytes 15, 16, and 17)
- Vendor-unique error information (Sense bytes 20 through 23)

16.86.3 Data Recovery Procedure

No action can be taken on hard or soft read errors. Block retirement occurs automatically, according to the block retirement policy of the firmware. LBAs that report a hard read error will become readable after a write. Until a write command is received for the affected LBAs, a hard error is reported on a read to the affected LBAs.

16.86.4 Non-data Error Recovery Procedure

The drive follows a logical recovery procedure for non-data errors. Options for non-data errors are limited to logging the error, retrying the failing command, or replacing the drive. These recovery procedures assume the initiator practices data backup and logs errors at the system level for interrogation by service personnel.

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16.86.4.1 Drive Busy

Drive Busy indicates the drive is busy performing an operation. This is not an error condition. Test for completion of the operation by issuing Test Unit Ready (00) (or media access) commands.

- If the TEST UNIT READY (00) (or media access) command completes with a Check Condition status, then issue a REQUEST SENSE (03).
- If the specified recovery procedure for the sense data is for a condition other than Drive Busy, follow the recovery procedure for the condition reported.
- If the specified recovery procedure for the sense data is for a Drive Busy condition, then continue re-issuing the TEST UNIT READY (00) and REQUEST SENSE (03) commands for the duration of a media access time-out or until the drive returns a Good status.
- If the drive has been busy for longer than the limit specified in Section 18.12, Command Time-out Limits, then service the drive using the service guidelines recommended in Section 18.13.1, Drive Service Strategy; otherwise, return to normal processing.
- If the TEST UNIT READY (00) (or media access) command completes with a Good status, then return to normal processing.

16.86.4.2 Unrecovered Drive Error

With an Unrecovered Drive error, retry the failing command.

- If the retry of the failing command completes with a Good status or recovered Sense Key, follow the recovery procedure in
- *Section 18.13.4.3, Recovered Drive Error*.
- If the retry of the failing command completes with hardware error sense, verify there is no outside cause (e.g., power supply) for the failure, then retry the failing command.
- If the retry of the failing command completes with a Good status, follow the recovery procedure in *Section 18.13.4.3, Recovered Drive Error*.
- If the retry of the failing command completes with Recovered sense or Hardware error sense, service the drive using the service guideline recommended in *Section 18.13.1, Drive Service Strategy*.

16.86.4.3 Recovered Drive Error

Log the Recovered Drive error as a soft error with the recovery level.

16.86.4.4 Drive Not Ready

With a Drive Not Ready error, do the following:

- Issue a START STOP UNIT (1B) command.
- Verify that the drive becomes ready within the time specified Table 9, SSD Response Time.
- If the drive fails to become ready within the specified time, service the drive using the service guidelines specified in Section 18.13.1, Drive Service Strategy.
- Retry the failing command.
- If the failing command completes with a Good status, log the error as recovered.
- If the failing command completes with a NOT READY sense, verify there is no outside cause (for example, the power supply), and then service the drive using the service guidelines specified in *Section 18.13.1, Drive Service Strategy*.

16.86.4.5 Degraded Mode

Refer to *Section 18.1.8, Degraded Mode* for the definition of the Degraded Mode state. There are four causes for entering degraded mode. In the first three cases, the Sense Key is Not Ready; in the fourth case the Sense Key is Medium Error. The causes are the following:

1. Sense Code/Qualifier of Logical Unit Not Ready, initializing command required. The media is not accessible. This may not be an error condition. Issue a START STOP UNIT (1B) command to enable media access. If the drive fails to come ready in the time specified in *Section 18.12, Command Time-Out Limits*, service the drive using the service guideline recommended in *Section 18.13.1, Drive Service Strategy*.
2. Sense Code/Qualifier of Diagnostic Failure. This is failure of a Send Diagnostic self-test, a startup sequence, or another internal target failure.
3. Failure of a send diagnostic self-test or a startup sequence.

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This failure is the result of the diagnostics that are executed during power-on or when the Send Diagnostic (1D) command is executed detecting a failure. As with the RAM code not loaded and the configuration data not loaded, the recovery is either a power cycle or issuing the SEND DIAGNOSTIC (1D) command with the self-test bit set active.

Failed SEND DIAGNOSTIC (1D)
Recovery for a failed SEND DIAGNOSTIC (1D) is achieved in one of the following ways:

- Re-executing the SEND DIAGNOSTIC (1D) command
- Power-cycling the drive

If the failure repeats, service the drive using the service guideline recommended in *Section 18.13.1, Drive Service Strategy*.

Failed Power-up Sequence
Recovery for a failed power-up sequence is achieved in one of the following ways:

- Issuing a START STOP UNIT (1B) command
- Power cycling the drive

If the failure repeats, service the drive using the service guideline recommended in *Section 18.13.1, Drive Service Strategy*.

Internal Target Failures
Recovery from an internal target failure involves either a power-cycle or successful completion of the SEND DIAGNOSTIC (1D) command. If these are attempted but failto complete successfully, service the drive using the recommended service guidelines specified in *Section 18.13.1, Drive Service Strategy*, .

Sense Code/Qualifier of Format Command Failed Format Unit (04).
Recovery from a failed FORMAT UNIT (04) command is achieved by retrying the command. If the command fails a second time, service the drive following the procedure defined in *Section 18.13.1, Drive Service Strategy*.

Sense Code/Qualifier of Sanitize Command Failed after a Sanitize (48h).
Recovery from a failed SANITIZE (48h) command is achieved by retrying the command. If the original SANITIZE (48h) was issued with AUSE=1, a second sanitize may be able to specify Service Action 1Fh (Exit Failure Mode). For this service action, the state of the media, success or not, is not guaranteed. The second attempt should select any valid sanitize Service Action.

If any of the above defined recovery procedures fail to clear the degraded mode condition, the drive should be replaced. Follow the procedure in *Section 18.13.1, Drive Service Strategy*, when replacing the drive.

16.86.4.6 Interface Protocol

For all interface protocol errors, the initiator should complete the following steps:

1. Correct the parameter that caused the Illegal Request.
2. Retry the failing command.
3. If the first retry of the failing command completes with:
   - Good status, log the error as recovered.
   - Check Condition status with Sense Data for an Illegal Request, verify there is no outside cause (for example, the power supply) for the failure.
   - Other: follow the recommendations for the error condition reported. Retry the failing command. If this retry of the failing command completes with:
     - Good status, log the error as recovered.
     - Check Condition status with Sense Data for an Illegal Request, service the drive using the service guideline recommended in *Section 18.13.1, Drive Service Strategy*.
     - Other; follow the recommendations for the error condition reported.

16.86.4.7 Aborted Command

The initiator should determine the cause from the Additional Sense Code (Byte 12).

Sense Key = B (Aborted Command) with Additional Sense Codes of 1B, 25, 43, 49, and 4E is an initiator-caused abort condition. The initiator should correct the condition that caused the abort and retry the failing command.

Sense Key = B (Aborted Command) with an Additional Sense Code of 44 or 48 is a drive-caused abort conditions. The initiator should:

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1. Retry the failing command.
2. If the retry of the failing command completes with
   - Good status, log the error as recovered.
   - Abort Command Sense, verify there is no outside cause (e.g., power supply) for the failure.
3. If an Abort Command Sense was received,
   - Retry the failing command.

     If the retry of the failing command completes with
     - o Good status, log the error as recovered; or
     - o Abort command sense, then service the drive using the service guideline recommended in *Section 18.13.1, Drive Service Strategy*.

Sense Key = B (Aborted Command) and an Additional Sense Code of 47 can be an initiator- or drive-caused abort condition. If the drive detected the SCSI bus parity error, the initiator should follow the above procedure for drive-caused abort conditions. If the *initiator* detected the SCSI bus parity error, the initiator should follow the above procedure for initiator-caused abort conditions .

16.86.4.8 Unit Attention Condition

Unit Attention Conditions are not errors. They alert the initiator that the drive had an action that may have changed an initiator controlled state in the drive. These conditions are the following:

Table 16 - 225: Unit Attention Conditions

Condition	Description
Not Ready to Ready Transition	Not ready to ready transition, unit formatted. This Unit Attention Condition will not be reported to the initiator that issued the FORMAT UNIT (04) command.
Reset	The drive was reset due to a power-on reset, LIP Reset, Target Reset or an internal reset.
Mode Parameters Changed	A MODE SELECT (15) command successfully completed. This means the mode parameters that are the current value may have changed. In any case, the command to change the parameters successfully completed. The drive does not actually compare the old current and the new current parameters to determine if the parameters changed. This Unit Attention Condition is not reported to the initiator that issued the MODE SELECT (15) command.
Microcode Has Changed	WRITE BUFFER (3B) to download microcode has successfully completed. This means the microcode that controls the drive has been changed. The code may or may not be the same as the code currently being executed. The drive does not compare old code with new code.
Commands Cleared by Another Initiator	Tagged commands cleared by a clear queue message. This means the command queue has been cleared. The Unit Attention Condition is not reported to the initiator that issued the clear queue message, but it is reported to all initiators that had commands active or queued.
Log Select Parameters Changed	A LOG SELECT (4C) command successfully completed. This means the command cleared statistical information successfully. See *FORMAT UNIT (04)*. The Unit Attention Condition is reported to all initiators except the one that issued the LOG SELECT (4C) command.
Device Identifier Changed	A SET DEVICE IDENTIFIER (A4) command successfully completed; the Set Device Identifier information field has been updated. See SET DEVICE IDENTIFIER (A4/06). A Unit Attention Condition is reported to all initiators except the one that issued the SET DEVICE IDENTIFIER (A4) command
Notify (Power Loss Expected) Received	The drive has received a Notify (Power Loss Expected) primitive. This clears any outstanding commands and reports a Unit Attention Condition to all initiators.

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16.86.4.9 Components Mismatch

The compatibility test is performed at a power cycle. The compatibility test verifies the microcode version of the electronics. When the drive detects a problem in its power-on self-tests, the most likely cause is the result of incorrect parts used during a service action. If the error reported is Sense Key/code/qualifier 4/40/80, Diagnostic failure, bring-up fail, the initiator should do the following:

- Retry the power cycle.
- Check the send diagnostic end status.
  - If a Good status, return to normal processing.
  - If a Check Condition status, issue a REQUEST SENSE (03) and follow the recommendations for the Sense Data returned, unless the Sense Data is for a component mismatch. In that case, service the drive using the service guideline recommended in *Section 18.13.1, Drive Service Strategy*.

16.86.4.10 Self-initiated Reset

The drive initiates a self-reset when the condition of the drive cannot be determined. The internal reset terminates any outstanding commands, releases any reserved initiators, and resets the firmware. The initiator can recover by

- Logging the error.
- Retrying the failing command. If the failing command completes with:
  - Good status, return to normal processing.
  - Self-Initiated Reset Sense, service the drive according the guidelines recommended in Section 18.13.1, Drive Service Strategy.
  - Other status, follow the recommendations for the error reported.

16.86.4.11 DefectListRecovery

DefectListRecovery is not an error condition. Either the initiator requested a defect list in a format (block or vendor-specific) that the drive does not support, or the requested defect list(s) exceed the maximum list length that can be returned. If the Sense Key/Code/Qualifier is:

- 1/1F/00: The requested list(s) exceeded the maximum length that can be supported. Use the READ DEFECT DATA (12) opcode to retrieve the defect data.
- 1/1C/01 or 1/1C/02: The requested defect list is not in the format that the drive supports. The requested defect list is returned in the vendor-unique format. This is the default format. There is no initiator action required for this condition.

16.86.4.12 Miscompare Recovery

A miscompare can occur on a VERIFY (2F) command or a WRITE AND VERIFY (2E) command with the Byte Check (BytChk) bit active. Recovery for a miscompare error is different for the two commands.

For a VERIFY (2F) command, the initiator should do the following:

- Verify that the data sent to the drive is the correct data for the byte-by-byte compare.
- Read the data from the media with a Read (08) or Read (28) command and verify that the data from the media is the expected data for the byte-by-byte compare.
- If all the data is correct, this indicates that the data may have been read from the media incorrectly, without an error being detected. Service the drive using the procedure specified in Section 18.13.1, Drive Service Strategy.
- If all data is not correct, this indicates that the data on the media is not the data the initiator expected. Rewrite the correct data to the media.

For a WRITE AND VERIFY (2E) command, the drive uses the same data in the data buffer to write and then read and compare. A miscompare error on the WRITE AND VERIFY (2E) command indicates the drive cannot reliably write or read the media. Service the drive using the procedures specified in *Section 18.13.1, Drive Service Strategy*.

16.86.4.13 Microcode Error

The microcode from the interface is validated before the device operates using that microcode. If the validation fails, the command is rejected with no impact to the drive. If the validation passes but some other error occurs, the drive enters degraded mode.

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If the initiator attempted to load microcode using the WRITE BUFFER (3B) command, then retry the command. If WRITE BUFFER (3B) completes with:

- Good status, return to normal processing.
- Check Condition status, service the drive using the service guidelines recommended in *Section 18.13.1, Drive Service Strategy*.

If the checksum error occurred during normal processing, the initiator may attempt to load microcode before deciding to service the drive using the service guidelines recommended in *Section 18.13.1, Drive Service Strategy*.

To load new microcode, the initiator should issue a WRITE BUFFER (3B) command with the download and save option. If the command completes with Good status, return to normal processing. Otherwise, retry the failing command. If the task completes with:

- Good status, continue normal processing.
- Check Condition status for a check sum error, service the drive using the service guidelines recommended in Section 18.13.1, Drive Service Strategy.
- Check Condition status for any other error, follow the recommendations for the returned sense data.

16.86.4.14 Predictive Failure Analysis

The drive performs error log analysis and will alert the initiator of a potential failure. The initiator should determine if this device is the only one attached with error activity. If so, service the drive using the procedures specified in *Section 18.13.1, Drive Service Strategy*.

Notes:

1. Service for this drive can be deferred. The longer service is deferred, the more probable a failure can occur that will require immediate service.
2. If the drive continues to experience error activity, the drive is probably not at fault. Locate and service the outside source causing error activity on this drive.

16.87 Logical Block Provisioning

Each LBA on the drive is either mapped or unmapped. For LBAs that are mapped, there is a known relationship between the LBA and any physical blocks that contain user data and protection information. For LBAs that are unmapped, the relationship between the LBA and a physical block is not defined. The drive uses a physical block size based on 4KB. The LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field in the READ CAPACITY (16) parameter data is 3 for the 512, 520, and 528 block sizes. This value will be 0 for 4KB-based block sizes.

The drive is always considered to be resource-provisioned; all unmapped LBAs are considered anchored. The drive provides LBA mapping resources sufficient to contain all logical blocks for the reported capacity. All LBAs are accessible at all times. The initial condition of every LBA on the drive is anchored.

For more information, refer to Section 4.7 of the latest SBC-3 standard.

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17.0 SCSI Sense Data

17.1 SCSI Sense Data Format Introduction

Sense data is returned with a Check Condition status, as parameter data in response to the REQUSET SENSE command. The sense data returned by the drive can be in fixed or descriptor format.

17.1.1 Sense Data Format

The format of sense data returned as a CHECK_CONDITION_STATUS is based on the value D_SENSE bit in the Control mode page (see Mode Page 0Ah - Control Mode Page Parameters). The REQUEST_SENSE command may be used to request either the fixed format sense data or the descriptor format sense data (see REQUEST SENSE (03).

17.1.2 Sense Data Length

The ength of the sense data returned as part of CHECK_CONDITION status is determined by the sense data format:

- The length of fixed format sense data is always 32 bytes.
- The length of descriptor format sense data depends on the number of descriptors available to report.

For the REQUEST SENSE command, the length of the sense data is the number of bytes in the command's Allocation Length or the sense data length described above, whichever is less.

17.1.3 Sense Data Response Code

The first byte of all sense data contains the RESPONSE CODE field that indications the error type and format of the sense data. Table 257 "Sense data response codes" shows the RESPONSE CODE values which may be returned by the drive.

Table 17 - 1: Sense Data Response Code

Response Code	Error Type	Sense Data Format
70h	Current	Fixed
71h	Deferred	Fixed
72h	Current	Descriptor
73h	Deferred	Descriptor

- Current Error indicates an error for the current command.
- Deferred Error indicates that the error is for a previous command that has already returned a Good status. Such commands are associated with the immediate bit or write caching. The FORMAT UNIT (04h) command, for example, may return a deferred error.

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17.2 Fixed Format Sense Data

The format of the sense data returned by the drive, in response to the REQUEST SENSE command, is described below.

Table 17 - 2: Format of Sense Data

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Valid	Response Code (70h or 71h)						
1	Reserved							
2	0		ILI	0	Sense Key			
3-6	Information Bytes							
7	Additional Sense Length							
8-11	Command-Specific Information							
12	Additional Sense Code							
13	Additional Sense Code Qualifier							
14	FRU = 0							
15	SKSV	Sense Key Specific Bits						
16-17	Sense Key Specific Bytes							
18-19	Reserved							
20-23	Vendor-Unique Error Information							
24-29	Vendor-Unique Physical Error Record Information							
30-31	Reserved							

17.2.1 Valid (Bit 7 of Byte 0)

Table 17 - 3: Valid (Bit 7 of Byte 0)

0	The Information Bytes (byte 3 through 6) are not defined.
1	The Information Bytes (byte 3 through 6) contain a valid logical block address.

17.2.2 Response Code (Bit 6 - 0 of Byte 0)

Table 17 - 4: Error Code (Bit 6 - 0 of Byte 0)

70h	Current Error. This indicates an error for the current command.
71h	Deferred Error. This indicates that the error is for a previous command that has already returned a Good status. Such commands are associated with the IMMED bit. The FORMAT UNIT (04h) command, for example, may return a deferred error.

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17.2.3 ILI: Incorrect Length Indicator (Bit 5 of Byte 2)

The ILI bit is only valid for the READ LONG (3Eh) and WRITE LONG (3Fh) commands. If the ILI and Valid bits are set to one, this indicates the requested logical block length does not match the logical block length of the data on the medium. The Information field contains residual information about the error. An ILI bit set to 0 indicates there is no incorrect length condition.

Table 17 - 5: ILI (Bit 5 of Byte 2)

Valid	ILI	READ LONG (3Eh)/ WRITE LONG (3Fh)	Description
X	0	X	No incorrect length condition
1	1	Yes	The requested logical block length does not match the logical block length of the data on the drive.

17.2.4 Sense Key (Bit 3 - 0 of Byte 2)

The Sense Key provides generic categories in which error and exception conditions can be reported. Initiators would typically use Sense Keys for high-level error recovery procedures.

Table 17 - 6: Sense Key

Sense Key	Category	Description
0h	No Sense	There is no Sense Key information to report for the logical unit.
1h	Recovered Error	The last command completed successfully, with some recovery action performed by the drive. More detailed information is available in the Additional Sense Code and an Additional Sense Code Qualifier.
2h	Not Ready	The logical unit addressed cannot be addressed. More detailed information is available in the Additional Sense Code and an Additional Sense Code Qualifier.
3h	Medium Error	The command terminated with an unrecoverable error condition caused by a flaw in the media or an error in the recorded data. More detailed information is contained in the Additional Sense Code and an Additional Sense Code Qualifier.
4h	Hardware Error	The drive detected an unrecoverable hardware error while performing a command or during a diagnostic test. More detailed information is contained in the Additional Sense Code and an Additional Sense Code Qualifier.
5h	Illegal Request	There was an illegal parameter in the command descriptor block or additional parameter supplied as data. If an invalid parameter is found in the CDB, the command is terminated without altering the medium. If an invalid parameter is found in parameters supplied as data, the drive might have altered the medium.
6h	Unit Attention	The drive entered the Unit Attention Condition (see Unit Attention Condition).
7h-Ah	Not Implemented	– – –
Bh	Aborted Command	The drive aborted the command.
Ch	Reserved	– – –
Dh	Not Implemented	– – –
Eh	Miscompare	– – –

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Fh	Completed	– – –

17.2.5 Information Bytes (Bytes 3 through 6)

This field is valid only when Valid Bit is 1.

- ILI = 0: This field contains the unsigned LBA associated with the Sense Key. The LBA reported will be within the LBA range of the command as defined in the CDB.
- ILI = 1: This field contains the difference (residue) of the requested length in bytes. Negative values are indicated by two's complement notation.

Table 17 - 7: Information Bytes (3-6)

Valid	ILI	Description
0	x	0x00000000 - (not used/invalid)
1	0	LBA
1	1	Residue of the requested length in bytes

17.2.6 Additional Sense Length (Byte 7)

Indicates the remaining number of bytes in the sense data. (It is always set to 18h.)

17.2.7 Command-Specific Information (Byte 8 through 11)

Table 17 - 8: Command-Specific Information (Bytes 8-11)

	Bit							
Byte	7	6	5	4	3	2	1	0
8	Descriptor Type							
9	Additional Length							
10	Valid	Reserved						
11	Reserved							

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17.2.8 Additional Sense Code/Qualifier (Bytes 12 and 13)

The following table presents the descriptions of Sense Key / Sense Code / Qualifier combinations.

Table 17 - 9: **Additional Sense Code/Qualifier (Bytes 12 and 13)**

Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
Sense Key (0x0) = No Sense				
0x0	0x00	0x00		No additional sense information.
0x0	0x0B	0x01		Temperature Warning Indicator
			0x1A02	SMART Warning: Measured temperature exceeded warning threshold (default 75°C configurable) (MRIE = 5 or 6).
0x0	0x0B	0x03		Background Self-Test Failure Warning
			0x1A03	SMART Warning: Background Self-Test completed in Error (MRIE = 5 or 6).
0x0	0x0B	0x04		Background Pre-Scan Failure Warning
			0x1A04	SMART Warning: Background Pre-scan completed with Hard Error (MRIE = 5 or 6).
0x0	0x0B	0x05		Background Media Scan Failure Warning
			0x1A05	SMART Warning: Background Media Scan completed with Hard Error (MRIE = 5 or 6).
0x0	0x0B	0x06		Background NAND Wear Indicator Warning
			0x1A06	SMART Warning: Number of NAND Erases on any Band exceeded Maximum Threshold (MRIE = 5 or 6).
0x0	0x5D	0x22		Predictive Failure Analysis Temperature Threshold Exceeded
			0x1A22	SMART Pre-failure: Measured temperature exceeded 75°C (MRIE = 5 or 6).
0x0	0x5D	0x28		Predictive Failure Analysis Capacitor Error
			0x1A28	SMART Pre-failure: PLI Capacitor Self-Test Failed due to capacitor charge or discharge thresholds exceeded (MRIE = 5 or 6).
0x0	0x5D	0x53		Predictive Failure Analysis Remaining Reserve 1
			0x1A53	SMART Pre-failure: Number of reserve erase blocks drops within 1% of the Remaining Reserve 2 Threshold (MRIE = 5 or 6).
0x0	0x5D	0x54		Predictive Failure Analysis Remaining Reserve 2
			0x1A54	SMART Pre-failure: Number of reserve erase blocks that drops below the threshold where XOR Parity Protection is no longer enabled (MRIE = 5 or 6).
0x0	0x5D	0x55		Predictive Failure Analysis NAND Channel Failure

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			0x1A55	SMART Pre-failure: NAND Channel failure (MRIE = 5 or 6).
Error				
SCSI Sense Information			**HGST**	
Key	**Code**	**Qualifier**	**UEC**	**Description**
0x0	0x5D	0x56		Predictive Failure Analysis TCG Wear Indicator
			0x1A56	SMART Pre-failure: TCG Wear failure (MRIE = 5 or 6).
0x0	0x5D	0x57		Predictive Failure Analysis XOR Depletion Indicator
			0x1A57	SMART Pre-failure: XOR Depletion failure (MRIE = 5 or 6).
0x0	0x5D	0x73		Predictive Failure Analysis NAND Wear Failure
			0x1A73	SMART Pre-failure: NAND wear failure (MRIE = 5 or 6)
0x0	0x5D	0xFF		Predictive Failure Analysis SMART Test Failure
			0x1AFF	SMART Warning: SMART test trip (MRIE = 5 or 6).
Sense Key (0x1) = Recovered Error				
0x1	0x0B	0x01		Temperature Warning Indicator
			0x2A02	SMART Warning: Measured temperature exceeded 75°C (MRIE = 3 or 4).
0x1	0x0B	0x03		Background Self=Test Failure Warning
			0x2A03	SMART Warning: Background Self-Test completed in Error (MRIE = 3 or 4).
0x1	0x0B	0x04		Background Pre-Scan Failure Warning
			0x2A04	SMART Warning: Background Prescan completed with Hard Error (MRIE = 3 or 4).
0x1	0x0B	0x05		Background Media Scan Failure Warning
			0x2A05	SMART Warning: Background Media Scan completed with Hard Error (MRIE = 3 or 4).
0x1	0x0B	0x06		Background NAND Wear Indicator Warning
			0x2A06	SMART Warning: Number of NAND Erases on any Band exceeded Maximum Threshold (MRIE = 3 or 4).
0x1	0x17	0x01		Recovered Data with Retries
			0x172A	NAND ECC Error was corrected with XOR Rebuild.
			0x172C	NAND Error was corrected with HW ECC.
			0x172F	NAND ECC Error was corrected with MRR.
0x1	0x1C	0x00		Defect List Not Found
			0x1746	Defect List format not supported.
0x1	0x1C	0x01		Primary Defect List Not Found

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
			0x1747	Primary Defect List not found.
0x1	0x1C	0x02		Grown Defect List Not Found
			0x1748	Grown Defect List not found.
0x1	0x1F	0x00		Partial Defect List Transferred
			0x1749	Defect List exceeds the Allocation Length for READ DEFECT DATA command (partial list transferred).
0x1	0x44	0x00		Recovered Internal Target Failure
			0xF123	Power transition to sleep mode requested at inappropriate time.
			0x1201	Sense K/C/Q does not exist for an error that is being reported.
			0x1202	Sense K/C/Q does not exist for an error that is being reported.
0x1	0x5D	0x01		Predictive Failure Analysis Media Error Threshold Exceeded
			0x2A80	Self-test exceeded recovered error threshold.
			0x2A81	Self-test exceeded unrecovered error threshold.
0x1	0x5D	0x22		Predictive Failure Analysis Temperature Threshold Exceeded
			0x2A22	SMART Pre-failure: Measured temperature exceeded Temperature Threshold (MRIE = 3 or 4).
0x1	0x5D	0x28		Predictive Failure Analysis Capacitor Error
			0x2A28	SMART Pre-failure: PLI Capacitor Self-Test Failed due to Capacitor charge or discharge thresholds exceeded (MRIE = 3 or 4).
0x1	0x5D	0x53		Predictive Failure Analysis Remaining Reserve 1
			0x2A53	SMART Pre-failure: Number of reserve erase blocks drops within 1% of the Remaining Reserve 2 Threshold (MRIE = 3 or 4).
0x1	0x5D	0x54		Predictive Failure Analysis Remaining Reserve 2
			0x2A54	SMART Pre-failure: Number of reserve erase blocks that drops below the threshold where XOR Parity Protection is no longer enabled (MRIE 3 or 4).
0x1	0x5D	0x55		Predictive Failure Analysis NAND Channel Failure
			0x2A55	SMART Pre-failure: NAND Channel failure (MRIE = 3 or 4).
0x1	0x5D	0x56		Predictive Failure Analysis TCG Wear Indicator
			0x2A56	SMART Pre-failure: TCG Wear failure (MRIE = 3 or 4).
0x1	0x5D	0x57		Predictive Failure Analysis XOR Depletion Indicator
			0x2A57	SMART Pre-failure: XOR Depletion failure (MRIE = 3 or 4).

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
0x1	0x5D	0x73		Predictive Failure Analysis NAND Wear Failure
			0x2A73	SMART Pre-failure: General wear failure (MRIE = 3 or 4).
0x1	0x5D	0xFF		Predictive Failure Analysis SMART Test Failure
			0x2AFF	SMART Warning: SMART Test Trip (MRIE = 3 or 4).
Sense Key (0x2) = Not Ready				
0x2	0x04	0x00		Logical Unit Not Ready
			0xF501	LUN is in not ready state.
0x2	0x04	0x01		Logical Unit In The Process of Becoming Ready
			0xF502	LUN is in process of becoming ready.
0x2	0x04	0x02		Logical Unit Not Ready, Initialization Command Required
			0xF124	Invalid operating state transition detected.
			0xF503	LUN is not ready and waiting for initializing command.
0x2	0x04	0x04		Logical Unit Not Ready, Format In Progress
			0xF504	LUN is not ready due to format in progress.
0x2	0x04	0x09		Logical Unit Not Ready, Self-Test In Progress
			0xF505	LUN is not ready due to Self-Test in progress.
0x2	0x04	0x0D		Logical Unit Not Ready, Structure Check Required
			0xF508	LUN is not ready due to session not open.
0x2	0x04	0x11		Logical Unit Not Ready, Notify (Enable Spin-up) Required
			0xF553	SAS drive not ready due to waiting for Notify to complete reserved area boot.
0x2	0x04	0x1B		Logical Unit Not Ready, Sanitize In Progress
			0xF50B	LUN is not ready due to sanitize in progress.
0x2	0x04	0xF0		Logical Unit Not Ready, Customer Mismatch
			0xF133	Customer mismatch detected during load of a reserved area file.
0x2	0x31	0x01		Logical Unit Not Ready, Format Command Failed
			0xF507	LUN is in a format degraded state due to previous format failure or change definition request.
Sense Key (0x3) = Medium Error				
0x3	0x11	0x00		Unrecovered Read Error

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
			0xF72D	NAND ECC Error was uncorrectable.
			0xF72E	NAND ECC Error was uncorrectable (detected by NAND processor).
0x3	0x11	0x14		Read Error, LBA Marked Bad by Application Client
			0xF7CA	Sector marked bad by application client with correction disabled.
			0xF7CC	Sector marked bad by application client with correction enabled.
			0xF7CD	Sector marked bad by application client by corrupting data and/or CRC.
0x3	0x31	0x00		Medium Format Corrupted
			0xF701	Drive is in a format degraded state
0x3	0x31	0x01		Unable to Format Medium
			0xF740	Too many defects to support the capacity.
0x3	0x31	0x03		Sanitize Command Failed
			0xF50C	Sanitize command failed.
0x3	0x5D	0x01		Predictive Failure Analysis Media Error Threshold Exceeded
			0xFA81	Self-Test exceeded the Self-Test Unrecovered Error Threshold.
Sense Key (0x4) = Hardware Error				
0x4	0x3E	0x03		Logical Unit Failed Self-Test
			0xF75D	Media self-test failed due to error,
0x4	0x3E	0x04		Logical Unit Failed to Update Self-Test Log
			0xF762	DRAM Self-Test Failed due to Hard Error
0x4	0x40	0x80		Diagnostic Failure
			0xF101	FW Function Argument Validation Check Failed
			0xF102	Error accessing a file in the drive reserved area.
			0xF103	Unexpected Version ID found in a drive reserved area file.
			0xF104	Incorrect checksum calculated on a drive reserved area file.
			0xF105	Unexpected header on a drive reserved area file.
			0xF106	Accessed an uninitialized file in drive reserved area.
			0xF107	Incorrect size specified during request for a reserved area file.
			0xF108	Incorrect offset specified during request for a reserved area file.

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
			0xF111	Error occurred while loading Flash or Disk Code.
			0xF11D	Code from Reserved Area does not match Flash Code.
			0xF125	An invalid Reserved Area File was detected during Code Download Request.
			0xF12B	Invalid Model detected during load attempt of a reserved area file.
			0xF12E	Unable to write/read Directory Table to Reserved Area.
			0xF12F	Unable to write/read File Allocation Table to Reserved Area.
			0xF131	Timeout during write of one word to flash.
			0xF139	Error detected during an attempt to resize reserved area files during a code download.
			0xF13C	Error detected during test of reserved DRAM.
			0xF147	Security AES verification failure.
			0xF148	Security RSA verification failure.
			0xF149	Security DRGB verification failure.
			0xF14A	Security SHA256 verification failure.
0x4	0x42	0x00	0xF144	PLI Capacitor charge time exceeds 500ms.
0x4	0x40	0xA0		Diagnostic Failure
			0xF11B	POST CRC Test Failed
			0xF11C	POST XOR Test Failed
			0xF11E	POST Register Access Test Failed
			0xF136	Failure detected during POST Test of End-End Protection HW.
0x4	0x44	0x00		Internal Target Failure
0x4	0x44	0xF2	0xF208	Insufficient NAND exists for the desired customer capacity.
0x4	0x44	0xF2	0xF209	Mismatch between customer block size and NAND block size on system boot.
0x4	0x44	0xF2	0xF20A	Unable to locate Saved Mode Parameters during system boot.
0x4	0x44	0xF4	0xF402	Overflow Error reported from HW Data Path.
0x4	0x44	0xF4	0xF403	Overflow Error reported from HW Data Path.
0x4	0x44	0xF4	0xF404	Overflow Error reported from HW Data Path.
0x4	0x44	0xF4	0xF405	Overflow Error reported from HW Data Path.

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
0x4	0x44	0x81	0xF601	NAND Processor failed to complete boot.
0x4	0x44	0x82	0xF602	NAND Processor failed to load FW from NAND.
0x4	0x44	0x83	0xF603	NAND Processor failed to service a request within desired timeout.
0x4	0x44	0x84	0xF604	NAND Processor failed to load host interface FW from NAND.
0x4	0x44	0x85	0xF605	NAND Processor failed to service a request due to error or abort.
0x4	0x44	0x87	0xF607	NAND Processor detected fatal error condition and asserted.
0x4	0x44	0x88	0xF608	NAND Processor failed to service Identify Request following initial boot.
0x4	0x44	0x8E	0xF60E	NAND Processor failed to complete FCONFIG Update.
0x4	0x44	0x8F	0xF60F	NAND Processor provided FCONFIG Data that did not contain the desired token.
0x4	0x44	0x95	0xF615	NAND Processor failed XOR self-test.
0x4	0x44	0xA2	0xF622	NAND Processor failed to find good context.
0x4	0x44	0xA3	0xF623	NAND Processor detected fatal error condition and asserted.
0x4	0x44	0xA4	0xF624	NAND Processor failed to find defect map.
0x4	0x44	0xA8	0xF628	NAND Processor failed to find NAND Log Information.
0x4	0x44	0xB0	0xF630	NAND Processor generic boot error.
0x4	0x44	0x00	0xFCxx	Drive failed to read file xx from Flash or Reserved Area.
0x4	0x44	0xB1		Internal Target Failure
			0xF631	NAND Processor logically disabled.
0x4	0x5D	0x01		Predictive Failure Analysis Command Timeout Error Threshold Exceeded.
			0xFA82	Self-Test exceeded the Self-Test Command Timeout Error Threshold.
0x4	0x81	0x00		Vendor-unique, Internal Logic Error
			0xF56F	Insufficient DRAM available to pull drive logs.
Sense Key (0x5) = Illegal Request				
0x5	0x15	0x00		Phy Test Function In Progress
			0xF50D	Illegal Phy Test Request
0x5	0x1A	0x00		Parameter List Length Error
			0xF820	SCSI Command failed to execute due to Parameter List Length Error.

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
0x5	0x20	0x00		Invalid Command Operation Code
			0xF821	SCSI Command failed to execute due to Illegal Operation Code.
0x5	0x21	0x00		Logical Block Address Out of Range
			0xF822	SCSI Command failed to execute due to LBA Range Error.
0x5	0x24	0x00		Invalid Field in CDB
			0xF823	SCSI Command failed to execute due to Invalid Field Setting in the CDB.
0x5	0x25	0x00		Logical Unit Not Supported
			0xF824	SCSI Command failed to execute due to Invalid LUN specified in SCSI Command Frame.
0x5	0x26	0x00		Invalid Field in Parameter List
			0xF825	SCSI Command failed to execute due to Invalid Field Setting in Parameter List.
			0xF826	SCSI Command failed to execute due to Unsupported Log Page Selected.
0x5	0x26	0x02		Parameter Value Invalid
			0xF120	Single binary download is not compatible with existing code on drive.
			0xF126	A checksum error was calculated for a chunk of a single binary download file.
			0xF127	Invalid length or chunk size detected during single binary code download.
			0xF130	Customer version of single binary download is not compatible with existing code on drive.
			0xF13D	RSA signature verification failure on download file
0x5	0x26	0x04		Invalid Release of Persistent Reservation
			0xF828	SCSI Command failed to perform Release due to Persistent Reservation.
0x5	0x2A	0x03		Reservations Preempted
			0xF536	Reservation Conflict detected.
0x5	0x2C	0x00		Command Sequence Error
			0xF511	Command sequence error.
0x5	0x49	0x00		Invalid Message Error
			0xF512	Illegal ACA Task Attribute sent due to no outstanding ACA Condition.

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
0x5	0x55	0x03		TCG Certificate Data Error
			0xF81E	Insufficient memory allocation by the drive for the TCG Certificate Data requested by the host.
0x5	0x55	0x04		Insufficient Reservation Resources
			0xF567	Insufficient resources to process Registration Request
Sense Key (0x6) = Unit Attention				
0x6	0x0B	0x01		Temperature Warning Indicator
			0x3A02	SMART Warning: Measured temperature exceeded 75 °C (MRIE = 2).
0x6	0x0B	0x03		Background Self-Test Failure Warning
			0x3A03	SMART Warning: Background Self-Test completed in Error (MRIE = 2)
0x6	0x0B	0x04		Background Pre-Scan Failure Warning
			0x3A04	SMART Warning: Background Prescan completed with Hard Error (MRIE = 2).
0x6	0x0B	0x05		Background Media Scan Failure Warning
			0x3A05	SMART Warning: Background Media Scan completed with Hard Error (MRIE = 2).
0x6	0x0B	0x06		Background NAND Wear Indicator Warning
			0x3A06	SMART Warning: Number of NAND Erases on any Band exceeded Maximum Threshold (MRIE = 2).
0x6	0x28	0x00		Not Ready to Ready Change, Medium May Have Changed
			0xF514	Unit Attention marking transition from Not Ready to Ready State during Format.
0x6	0x29	0x01		Power On Occurred
			0xF516	Unit Attention for POR.
0x6	0x29	0x02		SCSI Bus Reset Occurred
			0xF517	Unit Attention for Hard Reset.
0x6	0x29	0x03		Bus Device Reset Function Occurred
			0xF518	Unit Attention for Soft Reset.
0x6	0x29	0x04		Device Internal Reset
			0xF519	Unit Attention for Self-initiated Reset.
0x6	0x29	0x07		I_T Nexus Loss Occurred

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
			0xF554	Unit Attention for SAS I_T Nexus Loss.
0x6	0x2A	0x01		Mode Parameters Changed
			0xF51C	Unit Attention for Mode Parameters Change
0x6	0x2A	0x02		Log Parameters Changed
			0xF51D	Unit Attention for Log Parameters Change
0x6	0x2A	0x03		Reservations Preempted
			0xF51E	Unit Attention for Reservation Clear
0x6	0x2A	0x04		Reservations Released
			0xF51F	Unit Attention for Reservation Release
0x6	0x2A	0x05		Registrations Preempted
			0xF520	Unit Attention for Registration Clear
0x6	0x2F	0x00		Commands Cleared by Another initiator
			0xF521	Unit Attention for Commands Aborted by another initiator.
0x6	0x2F	0x01		Commands Cleared by Power Loss Notification
			0xF573	Unit Attention for SAS Expected Power Failure Notify
0x6	0x3F	0x01		Microcode Has Been Changed
			0xF522	Unit Attention for Microcode Change
0x6	0x3F	0x03		Inquiry Data Has Changed
			0xF523	Unit Attention for Inquiry Parameters Change
0x6	0x3F	0x05		Device Identifier Changed
			0xF537	Unit Attention for Device Identifier Change
0x6	0x5D	0x22		Predictive Failure Analysis Temperature Threshold Exceeded
			0x3A22	SMART Pre-failure: Measured temperature exceeded Temperature Threshold (MRIE = 2).
0x6	0x5D	0x28		Predictive Failure Analysis Capacitor Error
			0x3A28	SMART Pre-failure: PLI Capacitor Self-Test Failed due to Capacitor charge or discharge thresholds exceeded (MRIE = 2).
0x6	0x5D	0x53		Predictive Failure Analysis Remaining Reserve 1
			0x3A53	SMART Pre-failure: Number of reserve erase blocks drops within 1% of the Remaining Reserve 2 Threshold (MRIE = 2).

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
0x6	0x5D	0x54		Predictive Failure Analysis Remaining Reserve 2
			0x3A54	SMART Pre-failure: Number of reserve erase blocks that drops below the threshold where XOR Parity Protection is no longer enabled (MRIE = 2).
0x6	0x5D	0x55		Predictive Failure Analysis NAND Channel Failure
			0x3A55	SMART Pre-failure: NAND Channel failure (MRIE = 2).
0x6	0x5D	0x56		Predictive Failure Analysis TCG Wear Indicator
			0x3A56	SMART Pre-failure: TCG Wear failure (MRIE = 2).
0x6	0x5D	0x57		Predictive Failure Analysis XOR Depletion Indicator
			0x3A57	SMART Pre-failure: XOR Depletion failure (MRIE = 2).
0x6	0x5D	0x73		Predictive Failure Analysis NAND Wear Failure
			0x3A73	SMART Pre-failure: General wear failure (MRIE = 2).
0x6	0x5D	0xFF		Predictive Failure Analysis SMART Test Failure
			0x3AFF	SMART Warning: SMART Test Trip (MRIE = 2)
Sense Key (0x7) = Data Protect				
0x7	0x20	0x02		Access Denied, No Access Rights
			0xF509	Data Protect - Access Denied (Locked by Self-Test)
			0xF827	Data Protect - Access Denied
			0xF82A	Zero Key
Sense Key (0x9) = Vendor Specific				
0x9	0xED	0x00		Vendor-unique, Error During Eye Data Measurement
			0xF50E	Error detected during Data Eye Measurement.
Sense Key (0xB) = Aborted Command				
0xB	0x0E	0x01		Information Unit Too Short
			0xF561	SAS Data-out Transfer aborted due to invalid frame length.
0xB	0x10	0x00		ID CRC or ECC Error
			0xF417	HW Data-out Transfer aborted due to CRC Error.
			0xF52F	HW Data-out Transfer aborted due to internal CRC Error
0xB	0x10	0x01		Logical Block Guard Check Failed
			0xF414	HW Data-out Transfer aborted due to T10 Guard Band Check Error.

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
			0xF424	HW Data-in Transfer aborted due to T10 Guard Band Check Error.
			0xF529	HW Data-in Transfer aborted due to T10 Guard Band Check Error.
			0xF538	Verify with BYTECHK = 1 with Guard Field Compare Error.
			0xF568	HW Data-in Transfer aborted due to T10 Guard Band Check Error
0xB	0x10	0x02		Logical Block Application Tag Check Failed
			0xF415	HW Data-out Transfer aborted due to T10 Application Tag Check Error.
			0xF423	HW Data-in Transfer aborted due to T10 Application Tag Check Error.
			0xF52A	HW Data-in Transfer aborted due to T10 Application Tag Check Error.
			0xF539	Verify with BYTECHK = 1 with Application Tag Compare Error.
			0xF569	Data-in Transfer aborted due to T10 Application Tag Check Error.
0xB	0x10	0x03		Logical Block Reference Tag Check Failed
			0xF416	HW Data-out Transfer aborted due to T10 Reference Tag Check Error.
			0xF422	HW Data-in Transfer aborted due to T10 Reference Tag Check Error.
			0xF52B	HW Data-in Transfer aborted due to T10 Reference Tag Check Error.
			0xF53A	Verify with BYTECHK = 1 with Reference Tag Compare Error.
0xB	0x10	0x03	0xF56A	Data-in Transfer aborted due to T10 Reference Tag Check Error.
0xB	0x11	0x00		Unrecovered Read Error
			0xF729	HW Data-in Transfer aborted due to internal error while handling media error.
0xB	0x3F	0x0F		Echo Buffer Overwritten
			0xF544	DRAM Read Echo Buffer was overwritten.
0xB	0x44	0x00		Internal Target Failure
			0x0406	HW Data Transfer aborted due to error.
			0xF410	HW Data-out Transfer aborted due to error.
			0xF411	HW Data-out Transfer aborted due to DRAM ECC Error.
			0xF412	HW Data-out Transfer aborted due to Data Path CRC Error.
			0xF413	HW Data-out Transfer aborted due to Data Path LBA Mismatch.
			0xF418	HW Data-out Transfer aborted due to transfer error.
			0xF419	HW Data-out Transfer aborted due to transfer timeout.

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
			0xF420	HW Data-in Transfer aborted due to error.
			0xF425	HW Data-in Transfer aborted due to Data Path LBA Error.
			0xF426	HW Data-in Transfer aborted due to transfer error.
			0xF427	HW Data-in Transfer aborted due to transfer timeout.
			0xF429	HW Data transfer aborted due to read error.
			0xF42A	HW Data transfer aborted due to read transfer length error.
			0xF52C	HW Data-out or Data-in Transfer aborted due to Data Path CRC Error.
			0xF52D	HW Data-in Transfer aborted due to internal CRC error
			0xF52E	HW Data-out or Data-in Transfer aborted due to internal target failure.
			0xF54A	HW Data-out or Data-in Transfer aborted due to Transfer Ready Burst Length Mismatch.
			0xF54B	HW Data-out or Data-in Transfer aborted due to Data Length Mismatch,
			0xF56B	Data Transfer aborted due to DRAM LBA ECC Error.
			0xF56C	Data Transfer aborted due to Uncorrectable DRAM ECC Error.
			0xF570	Data Transfer aborted due to Data Path CRC Error.
			0xF57B	Data Transfer aborted due to LBA CRC Error.
			0xF731	Access Denied - Write initialization required as read data is associated with Invalid Management Key.
			0xF75C	Overall Command Timeout exceeded.
0xB	0x47	0x01		Data Phase CRC Error Detected
			0xF54E	Data-out Transfer aborted due to Data Frame CRC Error.
0xB	0x4B	0x00		Data Phase Error
			0xF53E	Data Phase error during a Data-out Transfer.
0xB	0x4B	0x02		Too Much Write Data
			0xF560	SAS Data-out Transfer aborted due to Transfer Ready Burst Length Mismatch.
0xB	0x4B	0x03		ACK/NAK Timeout
			0xF551	SAS Data-in Transfer failed for timeout waiting for ACK or NAK.
0xB	0x4B	0x04		NAK Received
			0xF550	SAS Data-in Transfer received a NAK on Data Frame.

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Error				
SCSI Sense Information			HGST	
Key	Code	Qualifier	UEC	Description
0xB	0x4B	0x05		Data Offset Error
			0xF552	Data-out Transfer failed due to incorrect relative offset value in data frame header.
0xB	0x4B	0x06		initiator Response Timeout
			0xF555	Data-out Transfer aborted due to timeout from host in sending data frames.
			0xF556	Data-out Transfer aborted due to initiator response timeout.
0xB	0x4F	0x00		Command Aborted Due to Link Initialization
			0xF53F	Command was aborted due to link initialization.
Sense Key (0xE) = Miscompare				
0xE	0x1D	0x00		Miscompare During Verify Operation
			0xF535	Miscompare detected during Verify or Write & Verify with Byte Check

17.2.9 FRU: Field Replaceable Unit (Byte 14)

The FRU (Field Replaceable Unit) field value will always be zero.

17.2.10 Sense Key Specific (Bytes 15 through 17)

The definition of this field is determined by the value of the Sense Key field.

Sense Key Specific - Illegal Request (Sense Key = 5h)
An error field pointer is returned.

Table 17 - 10: **Field Pointer Bytes**

	Bit							
Byte	7	6	5	4	3	2	1	0
15	SKSV	C/D	Reserved		BPV	Bit Pointer		
16-17	Field Pointer							

- SKSV - Sense Key Specific Valid: 0 = Sense-key-specific field is not valid; 1 = Sense-key-specific field is valid.
- C/D - Command Data: 0 = Illegal parameter in the data parameters sent by the initiator during the Data Out phase; 1 = Illegal parameter in the command descriptor block.
- BPV - Bit Pointer Valid: 0 = Bit pointer field is not valid; 1 = Bit pointer field is significant.
- Bit Pointer – Indicates which bit of the byte number reported in Field Pointer is the bit in error. When a multiple bit field is in error, the pointer points to the most significant bit of the field.
- Field Pointer – Indicates which bytes of the command descriptor block or of the parameter data were in error. Bytes are numbered starting from zero, as shown in the tables describing the commands and parameters. When a multiple byte field id is in error, the pointer points to the most significant byte of that field.

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17.2.10.1 Sense Key Specific - Recovered (Sense Key = 1h) or Medium (Sense Key = 3h) or Hardware (Sense Key = 4h)

- Hardware (Sense Key = 4h) or Medium Error (Sense Key = 3h)
- Number of Bits in Error is reported.

Table 17 - 11: **Number of Bits in Error**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
15	SKSV	Reserved						
16	Reserved							
17	Number of Bits in Error							

- SKSV - Sense Key Specific Valid: 0 = Number of Bits in Error is not valid; 1 = Number of Bits in Error is valid.
- Number of Bits in Error represents the number of bits in error and/or last recovery step attempted, with the following ranges:
- 1-64: Recovered error, number represents the number of bits in error divided by 8 (maximum of 64) in the data block corrected by LDPC.
- 65: Recovered error, data was unrecoverable with LDPC; however, MRR (moving read reference) recovery was successful.
- 66: Recovered error, data was unrecoverable with LDPC or MRR; however the data was recovered via XOR rebuild of the data stripe.
- 67: Unrecoverable (hard) error, multiple blocks on the data stripe were unable to be recovered via LDPC or MRR.

17.2.10.2 Sense Key Specific - Not Ready (Sense key = 2h)

These fields are defined for the Format unit (04h) command with the Immediate bit set to one and the Send Diagnostic (1Dh) command with Background self-test function. Progress Indication is returned.

Table 17 - 12: **Progress Indication**

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
15	SKSV	Reserved						
16-17		Progress Indication						

- SKSV - Sense Key Specific Valid: 0 = Progress Indication is not valid; 1 = Progress Indication is valid.
- Progress Indication indicates a percentage complete where the returned value is the numerator and 10000h is the denominator.

17.2.11 Reserved (Bytes 18 through 19)

These bytes are filled with zeros.

17.2.12 Vendor-Unique Error Information (Bytes 20 through 23)

This field returns information about the error. It contains a unique code that describes where the error was detected and which piece of hardware or microcode detected the error depending on current operation.

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17.2.13 Physical Error Record (Bytes 24 thru 29)

- ILI = 1 - This field contains zeros.
- ILI = 0 - These bytes contain the physical location of the error.
  - o If the physical location has no relevance for the error, bytes 24 through 29 will all be set to 0FFFFFFFFFFFh for Valid = 0 and ILI = 0.
  - o This Physical Error Record field is valid for Sense Key 1, 3, and 4 only.

17.2.13 Reserved (Bytes30 through 31)

These bytes are filled with zeros.

17.2.14 Unit Error Codes (UEC) List

The following table lists the Unit Error Codes (UEC) and associated descriptions. The Unit Error Codes are returned by the target in Sense Data Bytes 20-21.

Table 17 - 13: Unit Error Codes

UEC	Description
0x1201	Sense K/C/Q does not exist for an error that is being reported.
0x1202	Sense K/C/Q does not exist for an error that is being reported.
0x172A	NAND ECC Error was corrected with XOR Rebuild.
0x172C	NAND Error was corrected with HW ECC.
0x172F	NAND ECC Error was corrected with MRR.
0x1746	Defect List format not supported.
0x1747	Primary Defect List not found.
0x1748	Grown Defect List not found.
0x1749	Defect List exceeds the Allocation Length for Read Defect Data command (partial list transferred).
0x1A02	SMART Warning: Measured temperature exceeded warning threshold (default 70° C configurable) (MRIE = 5 or 6).
0x1A03	SMART Warning: Background Self-Test completed in Error (MRIE = 5 or 6).
0x1A04	SMART Warning: Background Prescan completed with Hard Error (MRIE = 5 or 6).
0x1A05	SMART Warning: Background Media Scan completed with Hard Error (MRIE = 5 or 6).
0x1A06	SMART Warning: Number of NAND Erases on any Band exceeded Maximum Threshold (MRIE = 5 or 6).
0x1A22	SMART Pre-failure: Measured temperature exceeded 70°C (MRIE = 5 or 6).
0x1A28	SMART Pre-failure: PLI Capacitor Self-Test Failed due to capacitor charge or discharge thresholds exceeded (MRIE = 5 or 6).
0x1A53	SMART Pre-failure: Number of reserve erase blocks drops within 1% of the Remaining Reserve 2 Threshold (MRIE = 5 or 6).
0x1A54	SMART Pre-failure: Number of reserve erase blocks that drops below the threshold where XOR Parity Protection is no longer enabled (MRIE = 5 or 6).
0x1A55	SMART Pre-failure: NAND Channel failure (MRIE = 5 or 6).
0x1A56	SMART Pre-failure: TCQ Wear failure (MRIE = 5 or 6).

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UEC	Description
0x1A57	SMART Pre-failure: XOR Depletion failure (MRIE = 5 or 6).
0x1A73	SMART Pre-failure: General wear failure (MRIE = 5 or 6).
0x1A85	SMART Self Test exceeded recovered error count threshold.
0x1AFB	SMART Die retirement started.
0x1AFC	SMART Die retirement completed.
0x1AFF	SMART Warning: SMART test trip (MRIE = 5 or 6).
0x2A02	SMART Warning: Measured temperature exceeded 70 degree C (MRIE = 3 or 4).
0x2A03	SMART Warning: Background Self-Test completed in Error (MRIE = 3 or 4).
0x2A04	SMART Warning: Background Prescan completed with Hard Error (MRIE = 3 or 4).
0x2A05	SMART Warning: Background Media Scan completed with Hard Error (MRIE = 3 or 4)
0x2A06	SMART Warning: Number of NAND Erases on any Band exceeded Maximum Threshold (MRIE = 3 or 4).
0x2A22	SMART Pre-failure: Measured temperature exceeded Temperature Threshold (MRIE = 3 or 4).
0x2A28	SMART Pre-failure: PLI Capacitor Self-Test Failed due to Capacitor charge or discharge thresholds exceeded (MRIE = 3 or 4).
0x2A53	SMART Pre-failure: Number of reserve erase blocks drops within 1% of the Remaining Reserve 2 Threshold (MRIE = 3 or 4).
0x2A54	SMART Pre-failure: Number of reserve erase blocks that drops below the threshold where XOR Parity Protection is no longer enabled (MRIE 3 or 4).
0x2A55	SMART Pre-failure: NAND Channel failure (MRIE = 3 or 4).
0x2A02	SMART Warning: Measured temperature exceeded 70 degree C (MRIE = 3 or 4).
0x2A56	SMART Pre-failure: TCQ Wear failure (MRIE = 3 or 4).
0x2A57	SMART Pre-failure: XOR Depletion failure (MRIE = 3 or 4).
0x2A73	SMART Pre-failure: General wear failure (MRIE = 3 or 4).
0x2A80	Self-test exceeded recovered error threshold.
0x2AFF	SMART Warning: SMART Test Trip (MRIE = 3 or 4).
0x3A02	SMART Warning: Measured temperature exceeded 70°C (MRIE = 2).
0x3A03	SMART Warning: Background Self-Test completed in Error (MRIE = 2).
0x3A04	SMART Warning: Background Prescan completed with Hard Error (MRIE = 2).
0x3A05	SMART Warning: Background Media Scan completed with Hard Error (MRIE = 2).
0x3A06	SMART Warning: Number of NAND Erases on any Band exceeded Maximum Threshold (MRIE = 2).
0x3A22	SMART Pre-failure: Measured temperature exceeded Temperature Threshold (MRIE = 2).
0x3A28	SMART Pre-failure: PLI Capacitor Self-Test Failed due to Capacitor charge or discharge thresholds exceeded (MRIE = 2)
0x3A53	SMART Pre-failure: Number of reserve erase blocks drops within 1% of the Remaining Reserve 2 Threshold (MRIE = 2)
0x3A54	SMART Pre-failure: Number of reserve erase blocks that drops below the threshold where XOR Parity Protection is no longer enabled. (MRIE = 2)

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UEC	Description
0x3A55	SMART Pre-failure: NAND Channel failure (MRIE = 2).
0x3A56	SMART Pre-failure: TCQ Wear failure (MRIE = 2).
0x3A57	SMART Pre-failure: XOR Depletion failure (MRIE = 2).
0x3A73	SMART Pre-failure: General wear failure (MRIE = 2).
0x3AFF	SMART Warning: SMART Test Trip (MRIE = 2).
0x4A85	SMART Self Test command timeout and exceeded error count.
0xF101	FW Function Argument Validation Check Failed.
0xF102	Error finding and location a file in the drive reserved area.
0xF103	Unexpected Version ID found in a drive reserved area file.
0xF104	Incorrect checksum calculated on a drive reserved area file.
0xF105	Unexpected header on a drive reserved area file.
0xF106	Reserved area – Uninitialized file.
0xF111	Error occurred while loading Flash or Disk Code.
0xF11B	BATS2 CRC Test Failed.
0xF11C	BATS2 XOR Test Failed.
0xF11E	Register access error.
0xF120	Single binary download is not compatible with existing code on drive.
0xF121	Request segment allocation error.
0xF124	Invalid operating state transition detected.
0xF125	An invalid Reserved Area File was detected during Code Download Request.
0xF126	A checksum error was calculated for a chunk of a single binary download file.
0xF127	Invalid length or chunk size detected during single binary code download.
0xF128	DRAM test in progress.
0xF129	DRAM test complete.
0xF12A	DRAM test failed.
0xF133	Customer mismatch detected during load of a reserved area file.
0xF13C	Error detected during test of reserved DRAM.
0xF13D	RSA signature verification failure on download file.
0xF144	PLI Capacitor charge time exceeds 500ms.
0xF147	Security AES verification failure.
0xF148	Security RSA verification failure.
0xF149	Security DRGB verification failure.

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UEC	Description
0xF14A	Security SHA256 verification failure.
0xF14B	Security HMAC verification failure.
0xF14C	Security hardware AES verification failure
0xF14D	Security hardware SHA256 verification failure.
0xF150	Random number generator self-test failed.
0xF151	Random number generator entropy source self-test failed.
0xF152	Random number generator entropy source large window self-test failed.
0xF153	Random number generator entropy source small window self-test failed.
0xF154	Random number generator entropy source repetition self-test failed.
0xF208	Insufficient NAND exists for the desire customer capacity.
0xF402	Overflow Error reported from HW Data Path.
0xF403	Overflow Error reported from HW Data Path.
0xF404	Overflow Error reported from HW Data Path.
0xF405	Overflow Error reported from HW Data Path.
0xF406	HW Data Transfer aborted due to error.
0xF407	HW FIFO address valid overflow.
0xF408	HW FIFO address available overflow.
0xF409	HW SRAM parity error.
0xF410	HW Data-out Transfer aborted due to error.
0xF411	HW Data-out Transfer aborted due to DRAM ECC Error.
0xF412	HW Data-out Transfer aborted due to Data Path CRC Error.
0xF413	HW Data-out Transfer aborted due to Data Path LBA Mismatch.
0xF414	HW Data-out Transfer aborted due to T10 Guard Band Check Error.
0xF415	HW Data-out Transfer aborted due to T10 Application Tag Check Error.
0xF416	HW Data-out Transfer aborted due to T10 Reference Tag Check Error.
0xF417	HW Data-out Transfer aborted due to CRC Error.
0xF41A	HW Data-out Transfer aborted due to segment register error.
0xF41B	HW Data-out Transfer aborted due to TBUF write error.
0xF41C	HW Data-out Transfer aborted due to TLL read error.
0xF41D	HW Data-out Transfer aborted due to TLL parity error.
0xF420	HW Data-in Transfer aborted due to error.
0xF421	HW Data-in Transfer aborted due to CRC Error.

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UEC	Description
0xF422	HW Data-in Transfer aborted due to T10 Reference Tag Check Error.
0xF423	HW Data-in Transfer aborted due to T10 Application Tag Check Error.
0xF424	HW Data-in Transfer aborted due to T10 Guard Band Check Error.
0xF425	HW Data-in Transfer aborted due to Data Path LBA Error.
0xF428	HW Data transfer aborted due to write error.
0xF429	HW Data transfer aborted due to read error.
0xF42B	HW Data transfer aborted due to TBuf read error.
0xF42C	HW Data transfer aborted due to TLL read error.
0xF42D	HW Data transfer aborted due to TLL parity error.
0xF42E	HW Data transfer aborted due to Token LBA error
0xF430	HW Write data transfer aborted due to Data Descriptor having an invalid icmd index.
0xF431	HW Write data transfer aborted due to Data Descriptor having an invalid stripe bit.
0xF432	HW Write data transfer aborted due to Data Descriptor having an invalid next pointer.
0xF433	HW Write data transfer aborted due to Data Descriptor having an SRAM parity error.
0xF434	HW Write data transfer aborted due to head pointer SRAM parity error.
0xF440	HW Read data transfer aborted due to Data Descriptor having an invalid icmd index.
0xF441	HW Read data transfer aborted due to Data Descriptor having an invalid stripe bit.
0xF442	HW Read data transfer aborted due to Data Descriptor having an invalid next pointer.
0xF443	HW Read data transfer aborted due to Data Descriptor having an SRAM parity error.
0xF444	HW Read data transfer aborted due to head pointer SRAM parity error.
0xF501	LUN is in not ready state.
0xF502	LUN is in process of becoming ready.
0xF503	LUN is not ready and waiting for initializing command.
0xF504	LUN is not ready due to format in progress.
0xF505	LUN is not ready due to Self-Test in progress.
0xF507	LUN is in a format degraded state due to previous format failure or change definition request.
0xF508	LUN is not ready due to session not open.
0xF509	A band is locked during Self-test.
0xF50A	Secure Erase Failed.
0xF50B	LUN is not ready due to in progress.
0xF50C	Sanitize command failed.
0xF50D	Illegal Phy Test Request.

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UEC	Description
0xF50E	Error detected during Data Eye Measurement.
0xF511	Command sequence error.
0xF512	Illegal ACA Task Attribute sent due to no outstanding ACA Condition.
0xF514	Unit Attention marking transition from Not Ready to Ready State during Format.
0xF516	Unit Attention for POR.
0xF517	Unit Attention for Hard Reset.
0xF518	Unit Attention for Soft Reset.
0xF519	Unit Attention for Self-initiated Reset.
0xF51C	Unit Attention for Mode Parameters Change.
0xF51D	Unit Attention for Log Parameters Change.
0xF51E	Unit Attention for Reservation Clear.
0xF51F	Unit Attention for Reservation Release.
0xF520	Unit Attention for Registration Clear.
0xF521	Unit Attention for Commands Aborted by another initiator.
0xF522	Unit Attention for Microcode Change.
0xF523	Unit Attention for Inquiry Parameters Change.
0xF524	Unit Attention for Capacity Data Change.
0xF525	Unit Attention for TimeStamp change.
0xF529	HW Data-in Transfer aborted due to T10 Guard Band Check Error.
0xF52A	HW Data-in Transfer aborted due to T10 Application Tag Check Error.
0xF52B	HW Data-in Transfer aborted due to T10 Reference Tag Check Error.
0xF52C	HW Data-out or Data-in Transfer aborted due to Data Path CRC Error.
0xF52D	HW Data-in Transfer aborted due to internal CRC Error.
0xF52E	HW Data-out or Data-in Transfer aborted due to internal target failure.
0xF52F	HW Data-out Transfer aborted due to internal CRC Error.
0xF534	HW Data Transfer aborted due to overlapped commands attempted.
0xF535	Miscompare detected during Verify or Write & Verify with Byte Check.
0xF536	Reservation Conflict detected.
0xF537	Unit Attention for Device Identifier Change.
0xF538	HW Data Transfer aborted due to byte check miscompare on guard field.
0xF539	HW Data Transfer aborted due to byte check miscompare on app tag field.
0xF53A	HW Data Transfer aborted due to byte check miscompare on ref tag field

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UEC	Description
0xF53E	Data Phase error during a Data-out Transfer.
0xF53F	Command was aborted due to link initialization.
0xF541	HW Transfer aborted due to WriteSame timeout.
0xF544	DRAM Read Echo Buffer was overwritten.
0xF54A	HW Data-out or Data-in Transfer aborted due to Transfer Ready Burst Length Mismatch.
0xF54B	HW Data-out or Data-in Transfer aborted due to Data Length Mismatch.
0xF54E	Data-out Transfer aborted due to Data Frame CRC Error.
0xF550	SAS Data-in Transfer received a NAK on Data Frame.
0xF551	SAS Data-in Transfer failed for timeout waiting for ACK or NAK.
0xF552	Data-out Transfer failed due to incorrect relative offset value in data frame header.
0xF553	SAS Drive not ready due to waiting for Notify to complete reserved area boot.
0xF554	Unit Attention for SAS I_T Nexus Loss.
0xF555	Data-out Transfer aborted due to timeout from host in sending data frames.
0xF556	Data-out Transfer aborted due to initiator response timeout.
0xF560	SAS Data-out Transfer aborted due to Transfer Ready Burst Length Mismatch.
0xF561	SAS Data-out Transfer aborted due to invalid frame length.
0xF565	Data Transfer aborted due to OC hang caused by a DRAM error.
0xF566	Data Transfer aborted due to OC wait for FIFO empty hang.
0xF567	Insufficient resources to process Registration Request.
0xF568	HW Data-in Transfer aborted due to T10 Guard Band Check Error.
0xF569	Data-in Transfer aborted due to T10 Application Tag Check Error.
0xF56A	Data-in Transfer aborted due to T10 Reference Tag Check Error.
0xF56B	Data Transfer aborted due to DRAM LBA ECC Error.
0xF56C	Data Transfer aborted due to Uncorrectable DRAM ECC Error.
0xF56E	Data Size Mismatch detected during read of reserved area contents.
0xF56F	Insufficient DRAM available to pull drive logs.
0xF570	Data Transfer aborted due to Data Path CRC Error.
0xF573	Unit Attention for SAS Expected Power Failure Notify.
0xF57B	Data Transfer aborted due to LBA CRC Error.
0xF57D	Data Transfer aborted due to break received.
0xF601	NAND Processor failed to complete boot.
0xF602	NAND Processor failed to load FW from NAND.

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UEC	Description
0xF603	NAND Processor failed to service a request within desired timeout.
0xF604	NAND Processor failed to load host interface FW from NAND.
0xF605	NAND Processor failed to service a request due to error or abort.
0xF607	NAND Processor detected fatal error condition and asserted
0xF608	NAND Processor failed to service Identify Request following initial boot.
0xF60D	NAND Processor failed to copy Bootloader to scratch SRAM.
0xF60F	NAND Processor provided FCONFIG Data that did not contain the desired token.
0xF615	NAND Processor failed XOR self-test.
0xF622	NAND Processor failed to find good context.
0xF623	NAND Processor detected fatal error condition and asserted.
0xF624	NAND Processor failed to find defect map.
0xF627	NAND Processor is in read-only mode.
0xF628	NAND Processor failed to find NAND Log Information.
0xF630	NAND Processor generic boot error.
0xF631	NAND Processor logically disabled.
0xF701	Drive is in a format degraded state.
0xF729	HW Data-in Transfer aborted due to internal error while handling media error.
0xF72D	NAND ECC Error was uncorrectable.
0xF72E	NAND ECC Error detected by background NAND operation was uncorrectable.
0xF731	Access Denied - Write initialization required as read data is associated with Invalid Management Key.
0xF740	Too many defects to support the capacity.
0xF75C	Overall Command Timeout exceeded.
0xF75D	Media Self-Test Failed due to Error.
0xF762	DRAM Self-Test Failed due to Hard Error.
0xF7CA	Sector marked bad by application client with correction disabled.
0xF7CC	Sector marked bad by application client with correction enabled.
0xF7CD	Sector marked bad by application client by corrupting Data and/or CRC.
0xF815	Command internally aborted .
0xF81E	SCSI Command failed to execute due not enough free cache sections.
0xF81F	SCSI Command operation in progress.
0xF820	SCSI Command failed to execute due to Parameter List Length Error.
0xF821	SCSI Command failed to execute due to Illegal Operation Code.

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UEC	Description
0xF822	SCSI Command failed to execute due to LBA Range Error.
0xF823	SCSI Command failed to execute due to Invalid Field Setting in the CDB.
0xF824	SCSI Command failed to execute due to Invalid LUN specified in SCSI Command Frame.
0xF825	SCSI Command failed to execute due to Invalid Field Setting in Parameter List.
0xF826	SCSI Command failed to execute due to Unsupported Log Page Selected.
0xF827	SCSI Command access denied.
0xF828	SCSI Command failed to perform Release due to Persistent Reservation.
0xF829	SCSI Command zero key detected
0xFA81	Self-Test exceeded the Self-test Unrecovered Error Threshold.
0xFA82	Self-Test exceeded the Self-test Command Timeout Error Threshold.
0xFA85	Self-Test exceeded unrecoverable error count threshold.
0xFCxx	Drive failed to read file xx from Flash or Reserved Area

17.3 Descriptor Format Sense Data Format

This section describes the Descriptor format of the sense data returned by the drive, in response to the REQUEST SENSE command.

Table 17 - 10: Descriptor Format of Sense Data

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Reserved	Response Code (72h or 73h)						
1	Reserved				Sense Key			
2	Additional Sense Code							
3	Additional Sense Code Qualifier							
4	SDAT_OVFL	reserved						
5-6	reserved							
7	Additional Sense Length							
8-n	Sense Data Descriptor(s)							

17.3.1 Additional Fields

Fields not described here match fields in the Fixed Sense Format Data and can be found in Fixed Format Sense Data.

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17.3.2 Response Code (Bits 6-0 of Byte 0)

- 72h Current Error. This indicates an error for the current command.
- 73h Deferred Error. This indicates that the error is for a previous command that has already returned a Good status. Such commands are associated with the IMMED bit. The FORMAT UNIT (04h) command is an example of a command that may return a deferred error.

17.3.3 SDAT_VFL: Sense Data Over Flow (Bit 7 of Byte 4)

- The sense data has not been truncated to ensure the sense data length is less than or equal to the maximum length specified in the Control Extension mode page.
- The sense data has been truncated to ensure the sense data length is less than or equal to the maximum length specified in the Control Extension mode page.

17.3.4 Sense Data Descriptor(s) (Bytes 8-n)

Sense Data Descriptor(s) provide specific sense information.

Table 17 - 10: Sense Data Descriptors

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Descriptor Type							
1	Additional Length							
2-n	Sense Data Descriptor Specific							

Table 17 - 11: Descriptor Type (Byte 0)

Code	Description
00h	Information
01h	Command-specific
02h	Sense Key-specific
03h	Field Replaceable Unit (FRU)
05h	Block Command
80h	Vendor-specific – Unit Error Code (UEC)
81h	Vendor-specific – Physical error record

17.2.13.1 Additional Length (Byte 1)

Additional Length indicates the bytes of data to follow in the Sense Data Descriptor Specific data.

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17.3.5.1 Sense Data Descriptor Specific (Bytes 2-n)

Table 17 - 12: **Information Sense Data Descriptor (00h)**

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Descriptor Type (00h)							
1	Additional Length (0Ah)							
2	Valid=1	Reserved						
3	Reserved							
4-11	Information							

Table 17 - 13: **Command Specific Sense Data Descriptor (01h)**

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Descriptor Type (01h)							
1	Additional Length (0Ah)							
2-3	Reserved							
4-11	Command Specific Information							

Table 17 - 14: **Sense Key Specific Sense Data Descriptor (02h)**

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Descriptor Type (02h)							
1	Additional Length (06h)							
2-3	Reserved							
4	SKSV=1	Information						
5								
6								
7	Reserved							

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Table 17 - 15: **Field Replaceable Unit (FRU) Sense Data Descriptor (03h)**

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Descriptor Type (03h)							
1	Additional Length (02h)							
2	Reserved							
3	Field Replaceable Unit Code							

Table 17 - 16: **Block Commands Sense Data Descriptor (05h)**

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Descriptor Type (05h)							
1	Additional Length (02h)							
2	Reserved							
3	Reserved			ILI	Reserved			

Table 17 - 17: **Vendor Specific – Unit Error Code (UEC) Sense Data Descriptor (80h)**

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Descriptor Type (80h)							
1	Additional Length (02h)							
2-3	Unit Error Code (see Unit Error Codes and Unit Error Codes (UEC) List)							

Table 17 - 18: **Vendor Specific – Physical error record Sense Data Descriptor (81h)**

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Descriptor Type (81h)							
1	Additional Length (06h)							
2-3	Die Number							
4-5	Erase Block Number							
6	Sector Offset							
7	Page Number							

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18.0 Security Firmware and Hardware

This chapter provides information for HGST Self Encrypting Drives (SEDs). The reader will need familiarity with the referenced specifications and industry standards.

18.1 Referenced Specifications and Standards

18.1.1 TCG Specifications

This section references three separate Trusted Computing Group (TCG) specifications, which are available on the TCG website (http://www.trustedcomputinggroup.org/).

- TCG Storage Core Specification, Version 2.00, Revision 1.00 (2009). TCG Core is the general specification for trusted computing storage devices.
- TCG Storage Interface Interactions Specification (SIIS), Version 1.02, (2011). This specifies the interaction between the SSD and the SCSI/ATA protocols.
- TCG Enterprise Security Subsystem Class (SSC): Enterprise, Version 1.00, rev 3.00 (2011)
    - A Security Subsystem Class defines minimum acceptable Core Specification capabilities of a storage device in a specific class (in this case, enterprise).
    - Storage devices in specific classes may have a subset of the capabilities that are defined in the core specification.
- TCG Opal SSC, Version 2.00 Final Revision 1.00 (2012)

18.1.2 National Institute of Standards and Technology (NIST)

This section references the following NIST publications, available on the NIST website (https://csrc.nist.gov/projects/cryptographic-module-validation-program/validated-modules/search).

- [AES] Advanced Encryption Standard, FIPS PUB 197, NIST, 2001, November
- [DSS] Digital Signature Standard, FIPS PUB 186-4, NIST, 2013, July
- [FIPS140] Security Requirements for Cryptographic Modules, FIPS PUB 140-2, NIST, 2002 December
- [HMAC] The Keyed-Hash Message Authentication Code, FIPS PUB 198-1, 2008 July
- [SHA] Secure Hash Standard (SHS), FIPS PUB 180-4, NIST, 2015 August
- [SP800-38E] Recommendation for Block Cipher Modes of Operation: The XTS-AES Mode for Confidentiality on Storage Devices, SP800-38E, NIST, 2010 January
- [SP800-38F] Recommendation for Block Cipher Modes of Operation: Methods for Key Wrapping, NIST, 2012 December
- [SP800-57] Recommendation for Key Management – Part I General (Revision 4), NIST, 2016 January
- [SP800-88] Guidelines for Media Sanitization (Revision 1), 2014 December
- [SP800-90A] Recommendation for Random Number Generation Using Deterministic Random Bit Generators (Revision 1), NIST, 2015 June
- [SP800-90B] Draft Recommendation for the Entropy Sources Used for Random Bit Generators (Second Draft), NIST, 2016 January.
- [SP800-131A] Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths (Revision 1), NIST, 2015 November
- [SP800-132] Recommendation for Password-Based Key Derivation, NIST, 2010 December

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18.1.3 INCITS Standards

SCSI Primary Commands-4 (SPC-4), Revision 15: http://www.t10.org/

18.1.4 Department of Defense

- DoD 5220.22-M, "National Industrial Security Program Operating Manual", 2/28/2006: http://www.dtic.mil/whs/directives/corres/pdf/522022m.pdf
- DoD 5220.22-M Supplement 1, “National Industrial Security Program Operating Manual Supplement”, 02/1995: http://www.dtic.mil/whs/directives/corres/pdf/522022MSup1.pdf

18.2 TCG Enterprise Implementation Exceptions

The following list declares exceptions to the TCG Enterprise specification:

- The ‘Locking SP’ K_AES_256 table is implemented with only the UID and MODE columns.
- Only one active session is permitted at a time. If a new session is requested when a session is already active, the drive answers the host with SP_BUSY, instead of NO_SESSIONS_AVAILABLE.
- TCG Enterprise states: “The TPer SHALL implement the ParamCheck Longitudinal Redundancy Check (LRC) for Get and Set method calls on a PIN value". If the LRC check is erroneously applied to a value other than a PIN, it is ignored; therefore, no error is generated.
- CRC checking is disabled in all cases; the SED returns data to the host. If the user successfully authenticates, unencrypted data is returned to the host. If the user is unable to authenticate, encrypted data is returned to the host.

18.3 Encryption Algorithms

18.3.1 Advanced Encryption Standard (AES)

The hardware AES encryption implementation configured in ECB mode uses a 256-bit key. AES keys are generated internally and are never accessible externally. AES encryption is performed over T10 end-to-end data protection fields, so the fields are encrypted along with customer data.

18.3.2 ‘Level 0 Discovery’ Vendor Specific Data

This section refers to section 10.2.14 of the TCG Enterprise document (see the Specifications section of this document). This vendor-specific section is documented below.

Table 18 - 1: Persistent Reserve In (5E)

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
16	Version (Set to 0)							
17	Vendor Specific State Information							
18	Reserved							
19	RSVD	MB_s	0	0	Diag_s	Dload_s	Locking_s	FDE_s
20	Reserved							
21	RSVD	MB_e	0	0	Diag_s	Dload_e	Locking_e	FDE_e
22	0	0	0	0	0	0	0	inFIPS

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23-47	Reserved

- FDE_s: Full disk encryption is supported (equivalent to Media Encryption in Locking Feature Descriptor Enterprise SSC.
- FDE_e: Full disk encryption is enabled on one or more bands.
- Locking_s: LBA band locking is supported; the locking object exists in the locking SP of the device (equivalent to Locking Enabled in Locking Feature Descriptor Enterprise SSC 10.2.14).
- Locking_e: The locking object for a band has either ReadLocked or WriteLocked attribute set (equivalent to Locked in Locking Feature Descriptor Enterprise SSC 10.2.14).
- Dload_s: Support for Admin SP Firmware download port
- Dload_e: Firmware download port via Admin SP is locked.
- Diag_s: Support for Admin SP vendor-specific Diagnostic port
- Diag_e: Diagnostics port via Admin SP is locked.
- MB_s: Multiple encrypting bands are supported.
- MB_e: Multiple encrypting bands are enabled. This bit is set to 1 if more than one band exists, in addition to the global band, and is defined with at least one LBA.
- inFIPS: This bit is set when FIPS mode has been configured.

18.3.3 Deterministic Random Bit Generation (DRBG)

The firmware DRBG implementation utilizes a Non-Deterministic Random Bit Generator (NDRBG) as an entropy source. Thirty-two physically isolated ring oscillators make up the entropy source. The DRBG implementation complies with the SP800-90A block cipher mechanism (CTR_DRBG).

18.3.4 Key Erasure and Generation

All keys and Critical Security Parameters are protected and confined inside the drive. The TCG Core specification requires that keys and other security parameters always have an associated value throughout the lifecycle of the SED. The following procedure is used to change keys:

1. Overwrite wrapped key material.
2. Generate a new key with the DRBG.
3. Wrap the key.
4. Store the newly wrapped key.

18.3.5 Key Wrap

The NIST SP800-38F key wrap algorithm is used to encrypt a key with another key (KEK= Key Encryption Key). For any band *i*, the KEK_i is derived from PIN_i and $salt_i$ using the NIST 800-132 algorithm. The KEK_i is then used to wrap an encryption key for a band.

18.4 TCG Enterprise Tables

Two copies of TCG tables and data structures are stored in a reserved area of the SED; one is used as a primary copy and the other as a backup copy. The backup copy is used in the event the primary copy becomes corrupted. Each time a write is executed to any TCG table, both the primary and backup copies of the tables are updated and saved. In the event of a corrupted copy, the good copy is always used to restore the corrupted copy to the correct state. If both copies of the tables become corrupted during operation, the tables will be automatically reinitialized to default values. This causes a key mismatch error when a read is attempted.

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The default values in the TCG tables created at the time of manufacturing are per the TCG SSC specification. The following tables contain VU (Vendor-Unique) entries, which are set at manufacturing time:

- 'Admin SP' C_PIN table
- 'Locking C'_PIN table
- 'Locking SP' K_AES_256 table
- 'Locking SP' Locking Access Control table
- 'Locking SP' LockingInfo table
- 'Locking SP' Locking table
- DataStore Table

The VU entries for these tables are specified below. Explanation of default values is given for non-VU entries that require it.

18.4.1 'Admin SP' C_PIN and 'Locking SP' C_PIN Tables

Per TCG SSC specification, the PIN is set to the MSID at manufacturing time. HGST has specified the MSID to be the serial number of the drive, concatenated 4x. TryLimit is set to 0, meaning that there is no limit. Tries is set 0, meaning that there have been no fail attempts. Persistence is set to 0, meaning the "Tries" value does not persist through power cycles (the "Tries" value is reset to 0 after successful attempt or a power cycle).

Table 18 - 2: HGST Default Values for 'Admin SP' C_PIN and 'Locking SP' C_PIN

PIN	TryLimit	Tries	Persistence
SID	0	0	0
MSID	0	0	0
..	..	..	..
PSID	0	0	0

18.4.2 'Locking SP' K_AES_256 Table

The K_AES_256 table has 4 rows, one row for each band that can be allocated by the user. The first row is for the "global range", also known as Band 0. This table was implemented without the Name, CommonName, and Key columns.

Table 18 - 3: GST Implementation of K_AES_256 Table

UID (8 Byte Hex)	MODE
00 00 08 06 00 00 00 01	23
00 00 08 06 00 00 00 02	23
..	..
00 00 08 06 00 00 00 04	23

The mode is specified in the TCG Enterprise SSC as a "Vendor-Unique" (VU) entry. HGST initializes it in manufacturing to mode=23 (media encryption mode, per TCG specification) for all four entries.

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18.4.3 'Locking SP' Access Control Table

The TCG Enterprise defines the values for Row Number and UID as "Vendor-unique" (VU). HGST has defined them to be the row number in the table, with a range of 0-459. The range is calculated using the following formula:
number_of_rows = (#SupportedBands * 7) +12, where #SupportedBands = 16 (the implementation supports 16 bands).

The number 7 comes from the fact that each band has 7 UID/method combinations, and the number 12 comes from the following 12 methods that must be included in the table:

1. ThisSP / Authenticate
2. AuthorityTable/Next
3. Anybody Authority Object/ Get
4. BandMasters Authority Object/ Get
5. EraseMaster Auth. Object / Get
6. C_PIN table / Next
7. EraseMaster C_PIN Object/ Set
8. LockingInfo Table / Get
9. Locking Table / Next
10. DataStore / Get
11. DataStore / Set
12. ThisSP / Random

Table 18 - 4: HGST Implementation of 'Locking SP' AccessControl Table

Row Number	UID	.
0	0	.
1	1	.
.	.	.
39	39	.

18.4.4 'Locking SP' LockingInfo Table

As specified in the TCG Enterprise, this table has only 1 row. The "Vendor-unique" entries are specified in the table below. Encryption Support is initialized to EncryptionSupport = 23 (media encryption mode) at manufacturing time.

Table 18 - 5: HGST Implementation of 'Locking Info' Table

.	NAME	Version	.	Encrypt Support	MaxRanges	MaxReEncryption	KeysAvailableCfg
.	0	0	.	23	4	0	0

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18.4.5 'Locking SP' Locking Table

The "Vendor-Unique" (VU) values for this table are shown below.

Table 18 - 6: **HGST Implementation of 'Locking SP' Locking Table**

.	NextKey	ReEncrypt State	ReEncrypt Request	AdvKey Mode	VerfMode	ContOn Reset	LastReEncrypt LBA	LastRe EncStat	General Status
	00 00 00 00h	0	0	0	0	0	0	0	0
.	.	.	.	.	.	.	.	.	.
.	00 00 00 00 00 00 00 03h	0	0	0	0	0	0	0	0

Note:

1. In the ActiveKey column, the Enterprise SCC allows for byte 3 to be defined as either 05 or 06. The HGST implementation uses 06.

18.4.6 DataStore Table

TCG Enterprise requires SEDs to contain a DataStore table. The DataStore table provides 1024 bytes of non-volatile storage for host access and modification. TCG allows authenticated BandMaster authorities to write to the DataStore table. TCG Enterprise specifies that the Anybody authority may read information from the DataStore table.

Notes:

1. BandMasters should not save sensitive data to the DataStore table, because any connecting entity is permitted to read the data via the unauthenticated Anybody authority.

18.5 Firmware Download and Signing

HGST firmware signature verification provides a mechanism for secure firmware updates. Firmware is downloaded to the SED through the host interface, and the signature is verified using a public key, before it is stored or allowed to execute. Signature verification is implemented with FIPS 186--4 [DSS], with RSA2048 and SHA256.

Issuing a firmware download to the SED results in an implicit close of all open sessions. Failure to verify the firmware image returns a Check Condition ststus with KCQ 5/26/9a (FRU 0).

18.6 Ports Feature

The ports capability is an HGST feature that is not a requirement under TCG Enterprise SSC. To use the ports capabilities on SEDs, the operator must authenticate successfully. Then the state of any of the ports can be changed at any time during an active session to either the locked or unlocked state. These ports are defined in the table below.

This feature uses TCG structures and tables. The additional Ports Table has been implemented, and entries have been added to the 'Admin SP' ACE table and the 'Admin SP' AccessControl Table. The Ports Table and the modified TCG tables are shown below.

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Table 18 - 7: **Port Definitions**

Port Name	Description
Firmware Download	The download port for encrypted drives is initially unlocked, and LockOnReset is Null. Code can be downloaded onto the drive after the signature is verified. If the signature cannot be verified, the firmware cannot be downloaded to the drive. The user can change the state of the firmware download port only after authentication.
Diagnostics	This port has two valid states: locked and unlocked. The port allows HGST access to modify any TCG table or key. The SID and the Maker authorities must be authenticated to open this port. The purpose of this port is to aid HGST in debugging the drive.

Table 18 - 8: **'Admin SP' Ports Table**

UID	Name	LockOnReset	PortLocked
00 01 00 02 00 01 00 02	Firmware_Dload_Port	Null	FALSE
00 01 00 02 00 01 00 01	Diagnostic_Port	PowerCycle	TRUE

Table 18 - 9: **Modified 'Admin SP' ACE Table**

UID	Name	Cmnd Name	Boolean Expression	Row Start	Row End	Column Start	Column End
00 00 00 08 00 00 00 01	Anybody	""	00 00 00 09 00 00 00 01	Null	Null	""	""
00 00 00 08 00 00 00 03	Makers	""	00 00 00 09 00 00 00 03	Null	Null	""	""
00 00 00 08 00 00 02 01	SID	""	00 00 00 09 00 00 00 06	Null	Null	""	""
00 00 00 08 00 00 8C 03	SID_SetSelf	""	00 00 00 09 00 00 00 06	Null	Null	"PIN"	"PIN"
00 00 00 08 00 00 8C 04	MSID_Get	""	00 00 00 09 00 00 00 01	Null	Null	"PIN"	"PIN"
00 00 00 08 00 00 8C 05	SID_Set Makers	""	00 00 00 09 00 00 00 06	Null	Null	"Enabled"	"Enabled"
00 00 00 08 00 00 8C 06	SID_Makers_ SetDiag SetDiag	""	00 00 00 09 00 00 00 06 and 00 00 00 09 00 00 00 03	Null	Null	"PortLocked"	"PortLocked"
00 00 00 08 00 00 8C 07	SID_Makers_ SetDiag SetDiag	""	00 00 00 09 00 00 00 06 and 00 00 00 09 00 00 00 03	Null	Null	"PortLocked"	"PortLocked"
00 00 00 08 00 00 8C 08	SID_GetPort	""	00 00 00 09 00 00 00 06	Null	Null	"PortLocked"	"PortLocked"
00 00 00 08 00 00 8C 09	SID_GetPort	""	00 00 00 09 00 00 00 06	Null	Null	"LockOnReset"	"PortLocked"

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Table 18 - 10: **Modified 'Admin SP' AccessControl Table**

Row	UID	Invoking ID	MethodID	Common Name	ACL	Log	Add ACE ACL	Remove ACE ACL	MethodID
VU	VU	00 00 00 00 00 00 00 01 (ThisSP)	00 00 00 06 00 00 00 0C (Authenticate)	Anybody Authenticate AdminSP	00 00 00 08 00 00 00 01 (Anybody)	None	Null	Null	00 00 00 06 00 00 00 0C (Authenticate)
VU	VU	00 00 00 09 00 00 00 00 (Authority Table)	00 00 00 06 00 00 00 08 (Next)	Makers-Next-Authority table	00 00 00 08 00 00 00 03 (Makers)	None	Null	Null	00 00 00 08 00 00 00 03 (Makers)
VU	VU	00 00 00 09 00 00 00 01 (Anbody Authority Object)	00 00 00 06 00 00 00 06 (Get)	Anybody-Get-Anbody Authority Object	00 00 00 08 00 00 00 01 (Anybody)	None	Null	Null	00 00 00 08 00 00 00 01 (Anybody)
VU	VU	00 00 00 09 00 00 00 03 (Makers Authority Object)	00 00 00 06 00 00 00 06 (Get)	Anybody-Get-Anbody Authority Object	00 00 00 08 00 00 00 03 (Makers)	None	Null	Null	00 00 00 08 00 00 00 03 (Makers)
VU	VU	00 00 00 09 00 00 00 06 (SID Authority Ibject)	00 00 00 06 00 00 00 06 (Get)	SID-Get-SID Authority Object	00 00 00 08 00 00 02 01 (SID)	None	Null	Null	00 00 00 08 00 00 02 01 (SID)
VU	VU	00 00 00 0B 00 00 00 00 (C_PIN Table)	00 00 00 06 00 00 00 08 (Next)	Makers-Next-C_PIN Table	00 00 00 08 00 00 00 02 (Makers)	None	Null	Null	00 00 00 08 00 00 00 02 (Makers)
VU	VU	00 00 00 0B 00 00 00 01 (SID C_PIN Object)	00 00 00 06 00 00 00 07 (Set)	SID_SetSelf-Set-SID_C_PIN Object	00 00 00 08 00 00 8C 03 (SID_SetSelf)	None	Null	Null	00 00 00 08 00 00 02 01 (SID)
VU	VU	00 00 00 0B 00 00 84 02 (MSID C_PIN Object)	00 00 00 06 00 00 00 06 (Get)	MSID_Get-Get-MSID C_PIN Object	00 00 00 08 00 00 8C 04 (MSID_Get)	None	Null	Null	00 00 00 08 00 00 02 01 (SID)
VU	VU	00 00 00 09 00 00 00 03 (Makers Authority Object)	00 00 00 06 00 00 00 07 (Set)	SID_SetMakers - Set-Makers Authority Object	00 00 00 08 00 00 8C 05 (SID_SetMakers)	None	Nul	Nul	00 00 00 08 00 00 02 01 (SID)
VU	VU	00 00 00 00 00 00 00 01 (ThisSP)	00 00 00 06 00 00 06 01 (Random)	Anybody Random	00 00 00 08 00 00 00 01 (Anybody)	None	Nul	Nul	00 00 00 08 00 00 00 01 (Anybody)
VU	VU	00 01 00 02 00 01 00 02	00 00 00 06 00 00 00 07	SID_Set_Dload	SID_SetPort	None	Nul	Nul	00 00 00 08 00 00 02 01 (SID)
VU	VU	00 01 00 02 00 01 00 02	00 00 00 06 00 00 00 06	SID_GetDload	SID_GetPort	None	Nul	Nul	00 00 00 08 00 00 02 01 (SID)
VU	VU	00 01 00 02 00 01 00 01	00 00 00 06 00 00 00 07	SID_Makers _SetDiag	SID_Makers _SetDiag	None	Nul	Nul	00 00 00 08 00 00 02 01 (SID)
VU	VU	00 01 00 02 00 01 00 02	00 00 00 06 00 00 00 06	SID_Makers _SetDiag	SID_Makers _SetDiag	None	Nul	Nul	00 00 00 08 00 00 02 01 (SID)

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Row	UID	Invoking ID	MethodID	Common Name	ACL	Log	Add ACE ACL	Remove ACE ACL	MethodID
				GET Makers ENABLED (by anybody authority): TBD					
				TBD: Get “TryLimit” and Persistence?					

Notes:

1. The last two lines of the table are the additional entries required to implement the firmware download port.

18.7 MSID (Manufacturer’s Security Identifier)

The MSID is created for each drive at manufacturing time. The MSID is the serial number concatenated four times to create a 32-byte PIN. For example, if the serial number of a drive is ‘abcd1234’, the MSID would then be set to ‘abcd1234abcd1234abcd1234abcd1234’. The TCG Revert method restores PINs to the MSID.

HGST serial numbers are unique and are generated according to the following general rules:

- Maximum length of the serial number is eight (8) characters.
- Serial numbers do not contain the characters “I” or “O”.

18.8 Logging

HGST logging functions do not record any sensitive data such as customer plain text data, passwords, encryption keys, or wrapping keys.

18.9 Number of Sessions

The HGST implementation supports one active session at a time. If there is a currently active session, and a new session is requested, the drive responds to the the host with SP_BUSY. This addresses the following two scenarios:

- An SP is in session, and an attempt is made to start a second session with the same SP.
- An SP is in session, and an attempt is made to start a second session with a different SP.

18.10 Number of Bands

The HGST implementation supports a maximum of 16 bands (not including the global Band-0).

18.11 Number of COMIDs

The HGST Enterprise SSC implementation supports two COMIDs, the minimum requirement in the Enterprise SSC specification. There can be only one COMID in use at any time.

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18.12 Locked and Unlocked Behavior

18.12.1 T10 SCSI Commands

The table below describes how basic T10 SCSI commands behave on SEDs in the locked and unlocked states.

Notes:

1. In the table below, “Locked” means one or more TCG Bands are locked. “Unlocked” means all the TCG Bands are unlocked.

Table 18 - 11: T10 SCSI Commands Behavior Table

Command	Unlocked[1]	Locked[2]
FORMAT UNIT (04)	OEM	The command cannot be executed when locked; it must be first unlocked with the MSID or password.
INQUIRY (12)	OEM	OEM
LOG SELECT (4C)	OEM	OEM
LOG SENSE (4D)	OEM	OEM has no access to customer data; some log information will be available.
MODE SELECT (15)	OEM	OEM
MODE SELECT (55)	OEM	OEM
MODE SENSE (1A)	OEM	OEM
MODE SENSE (5A)	OEM	OEM
PERSISTENT RESERVE IN (5E)	OEM	OEM
PERSISTENT RESERVE IN (5F)	OEM	OEM
PRE-FETCH (34)	OEM	MSID only; limits DRAM accessibility. This is a READ function.
READ (6) - (08)	OEM	Ent_A authorized only.
READ (10) - (28)	OEM	Ent_A authorized only.
READ (12) - (A8)	OEM	Ent_A authorized only.
READ (16) - (88)	OEM	Ent_A authorized only.
READ (32) (7F/09)	OEM	Ent_A authorized only.
READ BUFFER (3C)	OEM	OEM. Cannot snapshot sensitive data from DRAM.
READ CAPACITY (10) (25)	OEM	OEM
READ CAPACITY (16) (9E/10)	OEM	OEM
READ DEFECT DATA (37)	OEM	OEM
READ DEFECT DATA (B7)	OEM	OEM
READ LONG (16) (9E/11)	OEM	Ent_A authorized only.
READ LONG (3E)	OEM	Ent_A authorized only.
REASSIGN BLOCKS (07)	OEM	OEM

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Command	Unlocked[1]	Locked[2]
RECEIVE DIAGNOSTICS RESULTS (1C)	OEM	OEM
RELEASE (17)	OEM	OEM
RELEASE (57)	OEM	OEM
REPORT DEVICE IDENTIFIER (A3/05)	OEM	OEM
REPORT LUNS (A0)	OEM	OEM
REPORT SUPPORTED OPERATION CODES (A3/0C)	OEM	OEM
REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS (A3/0D)	OEM	OEM
REQUEST SENSE (03)	OEM	OEM
RESERVE (16)	OEM	OEM
RESERVE (56)	OEM	OEM
REZERO UNIT (01)	OEM	OEM
RELEASE (17)	OEM	OEM
RELEASE (57)	OEM	OEM
REPORT DEVICE IDENTIFIER (A3/05)	OEM	OEM
REPORT LUNS (A0)	OEM	OEM
REPORT SUPPORTED OPERATION CODES (A3/0C)	OEM	OEM
REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS (A3/0D)	OEM	OEM
REQUEST SENSE (03)	OEM	OEM
RESERVE (16)	OEM	OEM
RESERVE (56)	OEM	OEM
REZERO UNIT (01)	OEM	OEM
SANITIZE (48)	OEM	OEM
SECURITY PROTOCOL IN (A2)	TBD	TBD
SECURITY PROTOCOL OUT (B5)	TBD	TBD
SEEK (6) (0B)	OEM	OEM
SEEK (10) (2B)	OEM	OEM
SEND DIAGNOSTIC (1D)	OEM	Customer Specific.
SET DEVICE IDENTIFIER (A4/06)	OEM	OEM
START STOP UNIT (1B)	OEM	OEM
SYNCHRONIZE CACHE (10) (35)	OEM	OEM
SYNCHRONIZE CACHE (16) (91)	OEM	OEM

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Command	Unlocked[1]	Locked[2]
TEST UNIT READY (00)	OEM	OEM
UNMAP (42)	OEM	OEM
VERIFY (2F)	OEM	Access to customer data, but does not return data back to customer. CRC checking is ignored, but ECC is enabled and executable on locked LBAs.
VERIFY (12) (AF)	OEM	Access to customer data, but does not return data back to customer. CRC checking is ignored but ECC is enabled and executable on locked LBAs.
VERIFY (16) (8F)	OEM	Access to customer data, but does not return data back to customer. CRC checking is ignored, but ECC is enabled and executable on locked LBAs.
VERIFY (32) (7F/0A)	OEM	Access to customer data, but does not return data back to customer. CRC checking is ignored, but ECC is enabled and executable on locked LBAs.
WRITE (6) (0A)	OEM	Ent_A authorized only.
WRITE (10) (2A)	OEM	Ent_A authorized only.
WRITE (12) (AA)	OEM	Ent_A authorized only.
WRITE (16) (8A)	OEM	Ent_A authorized only.
WRITE (32) (7F/0B)	OEM	Ent_A authorized only.
WRITE AND VERIFY (10) (2E)	OEM	Ent_A authorized only.
WRITE AND VERIFY (12) (AE)	OEM	Ent_A authorized only.
WRITE AND VERIFY (16) (8E)	OEM	Ent_A authorized only.
WRITE AND VERIFY (32) (7F/0C)	OEM	Ent_A authorized only.
WRITE BUFFER (3B)(T10)	OEM	OEM (Write DRAM onto drive media.)
WRITE BUFFER (3B) (FW Downloads)	FW Signed/ Downloaded	OEM. FW is signed and downloaded; otherwise, the WRITE BUFFER command only writes to the buffer.
WRITE LONG (10) (3F)	OEM	Per TCG and T10 specification. Ent_A authorized only.
WRITE LONG (16) (9F/11)	OEM	Per TCG and T10 specification. Ent_A authorized only.
WRITE SAME (41)	OEM	Ent_A authorized only.
WRITE SAME (16) (93)	OEM	Ent_A authorized only.
WRITE SAME (32) (7F/0D)	OEM	Ent_A authorized only.
SECURITY_IN	OEM	Per TCG spec. Contains TCG payload.
SECURITY_OUT	OEM	Per TCG spec. Contains TCG payload.

1. * Locked means when one or more TCG Bands are locked.
2. * Unlocked means when all the TCG Bands are unlocked.

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18.12.2TCG Enterprise Commands

The following table describes the behavior of required TCG Enterprise commands on encryption drives in the locked and unlocked states. The TCG Enterprise requires the implementation of the Base, Admin, Locking, and Crypto Templates

Note:

1. In the below table, “Locked” means one or more TCG Bands are locked. “Unlocked” means all the TCG Bands are unlocked.

Table 18 - 12: TCG Enterprise SSC Commands Behavior

Command	Description	Unlocked[1]	Locked[2]
Session Management	There are two types of sessions: Read-Only and Read-Write The SSC requires that Read-Write sessions are supported; Read-Only sessions are not allowed. The host always initiates the session(s). See the “Write” parameter in the StartSession method description, TCG Core 5.2.3.1 and the SSC requirement in SSC 6.2.1.2.		
Properties	Returns the session properties to the host.	N/A	N/A
StartSession	Starts a session.	N/A	N/A
SyncSession	Responds to a say session successfully started.	N/A	N/A
CloseSession	Closes (ends) a session.	N/A	N/A
Discovery	Allows the host to discover a TCG drive, its properties, and table values.		
Level 0	Discovery request sent by host as an IF-RCV command; Security Protocol = 0x01, COMID = 0x0001	N/A	N/A
Level 1	Request basic TPER capabilities via properties using host messaging.	Uses the Properties method.	Uses the Properties method.
Level 2	TCG methods retrieve table cell values.	See Methods below.	See Methods below.
Cryptographic Template			
Random	This is the only required method in the crypto template for SSC. It is a random number generator in software.	N/A – Not related to bands/data on drive. Authentication required.	N/A – Not related to bands/data on drive. Authentication required.
Base Template	Mandatory		
Set	Sets a value in a table.	N/A – Not related to bands/data on drive. Authentication required.	N/A – Not related to bands/data on drive. Authentication required.
Get	Gets (reads) a value in a table.	N/A – Not related to drive authentication.	N/A – Not related to drive authentication.

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Command	Description	Unlocked[1]	Locked[2]
ParamCheck LRC	TPer implements *param* check LRC (a longitudinal Redundancy Check) on Get/Set method calls on PIN value.	N/A	N/A
Next	Iterates over all the rows of a table. Method requires user to specify "where" (row in table) and a "count". If where not specified, 1st row in table is used. For count not specified, default is number of last row in table. Returns 0 or more row number/ uidref pairs currently in use in table, per parameters specified.	N/A – Not related to bands/data on drive. Authentication required.	N/A – Not related to bands/data on drive. Authentication required.
Authenticate	Authenticate an authority within a session (the session must have successfully begun).	Must be authorized.	Must be authorized.
GetACL	Returns contents of access controls association with ACL stored in the Method Table. The result is a list of UIDREFS to ACE objects.	N/A – Not related to bands/data on drive. Authentication required.	N/A – Not related to bands/data on drive. Authentication required.
Locking Template	Mandatory		
Erase	Performs a cryptographic erase of user data in a specified LBA range and resets the access control (locking) of the LBA range. Once a Band has been erased, the LBAs must be written before being read. An error is returned if an attempt is made to read an LBA before it is written.	Can Erase if authorized.	Can Erase if authorized.

Notes:

1. "Locked" means one or more TCG Bands are locked.
2. "Unlocked" means all the TCG Bands are unlocked.

18.13 Revert Method

The manufacturer has extended TCG Enterprise to include the TCG Opal Revert Method. Revert enables the customer, as required by organizational policy, to overwrite existing TCG settings and restore the default values that were written during manufacturing.
Revert introduces a new TCG authority, PSID, to the Admin SP. The PSID is hashed during the manufacturing process, and the digest is stored in a reserved area of the drive. The PSID is also printed, in plaintext, on the external label of the drive. The PSID PIN cannot be accessed nor changed using the drive interface. *See RevertSP Method.*

The Revert procedure is as follows:

1. Start a Session on the Admin SP.
2. Authenticate to PSID authority.
3. Execute the Revert Method.

Notes:

1. Revert execution may require up to 30 seconds to complete.
2. Revert execution that encounters an error does not close the session.
3. Reset of the drive during Revert causes the subsequent power-up sequence to be extended until Revert completes.
4. A successful completion of Revert automatically ends the session.

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Table 18 - 13: **Revert Method – PSID Authority Added to Admin SP Authority Table**

UID	Name	Common Name	IsClass	Class	Enabled	Operation	Credential
00 00 00 09 00 01 FF 01	PSID	PhysicalDriveOwner	F	Null	T	Password	C_PIN_PSID

Table 18 - 14: **Revert Method – PSID Addition to Admin SP C_PIN Table**

UID	Name	Common Name	PIN	CharSet	TryLimit	Tries	Persistence
00 00 00 0B 00 01 FF 01	C_PIN_PSID	PhysicalDriveOwner	VU	Null	VU	VU	FALSE

Table 18 - 15: **Revert Method – Additions to Admin SP Access Control Table**

InvokingID	MethodID	ACL	GetACLACL
AdminSPObj 00 00 02 05 00 00 00 01	Revert 00 00 00 06 00 00 02 02	ACE_SP_SID_ACE_SP_PSID 00 00 00 08 00 01 00 E0	ACE_Anybody 00 00 00 08 00 00 00 01
PSID 00 00 00 09 00 01 FF 01	Get 00 00 00 06 00 00 00 06	Anybody 00 00 00 08 00 00 00 01	Anybody 00 00 00 08 00 00 00 01
PSID 00 00 00 09 00 01 FF 01	Set 00 00 00 06 00 00 00 07	ACE_Makers_Set_Enabled 00 00 00 08 0003 00 01	Anybody 00 00 00 08 00 00 00 01
C_PIN_PSID 00 00 00 0B 00 01 FF 01	Get 00 00 00 06 00 00 00 06	ACE_C_PIN_Get_PSID_NoPIN_UID 00 00 00 80 00 01 00 E1	Anybody 00 00 00 08 00 00 00 01

18.14 RevertSP Method

The manufacturer also supports the TCG Opal RevertSP Method to overwrite existing TCG settings and restore the default values that were written during manufacturing. *See Revert Method.*

The RevertSP procedure works as follows:

1. Start a Session on the Admin SP.
2. Authenticate to PSID authority.
3. Invoke the “ThisSP.RevertSP” Method.

Notes:

1. RevertSP execution may require up to 30 seconds to complete.
2. RevertSP execution that encounters an error does not close the session.
3. A reset of the drive during RevertSP causes the subsequent power-up sequence to be extended until RevertSP completes.
4. A successful completion of RevertSP automatically ends the session.

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Table 18 - 16: RevertSP Method – PSID Authority Added to Admin SP Authority Table

UID	Name	Common Name	IsClass	Class	Enabled	Operation	Credential
00 00 00 09 00 01 FF 01	PSID	PhysicalDriveOwner	F	Null	T	Password	C_PIN_PSID

Table 18 - 17: RevertSP Method – PSID Addition to Admin SP C_PIN Table

UID	Name	Common Name	PIN	CharSet	TryLimit	Tries	Persistence
00 00 00 0B 00 01 FF 01	C_PIN_PSID	PhysicalDriveOwner	VU	Null	VU	VU	FALSE

Table 18 - 18: RevertSP Method – Additions to Admin SP Access Control Table

InvokingID	MethodID	ACL	GetACLACL
ThisSP 00 00 00 00 00 00 00 01	RevertSP 00 00 00 06 00 00 00 11	ACE_SP_SID_ACE_SP_PSID 00 00 00 08 00 01 00 E0	ACE_Anybody 00 00 00 08 00 00 00 01

18.15 Error Codes

All error codes are compliant with the TCG Core specification and SIIF, except for these:

1. The maximum sessions allowed at any time is one.
2. When a session is active and a new session is requested, the drive answers the host with SP_BUSY, rather than of NO_SESSIONS_AVAILABLE.

18.16 Customer-specific Requirements

This manual does not cover customer-specific requirements. Customer-specific requirements are submitted by the customer to HGST in the form of a customer-specification document.

18.17 FIPS140 Cryptographic Officer Instructions

Instructions to the Cryptographic Officer of FIPS140 models are of paramount importance for the correct deployment and operation of the drive. The Cryptographic Officer is a trusted operator in the delivery and operation of the drive. *Cryptographic Officers shall faithfully execute these instructions or intended security policies can fail.*

The Security Policy may be downloaded from the NIST/CMVP website. The FIPS140 model numbers, firmware versions and hardware versions are also posted: http://csrc.nist.gov/groups/STM/cmvp/documents/140-1/140val-all.htm

18.17.1 Physical Security

Verify that the drive has not been tampered with by inspecting the tamper evidence labels as described in the Security Policy.

18.17.2 Certified Models, Hardware Versions and Firmware Versions

The INQUIRY (12) command can be used to read the model number and the firmware version from the device. The user should verify that these have been certified by comparing against the values published in the Security Policy or on the CMVP website Module Validation Lists.

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18.17.3 Cryptographic Module Acceptance and Provisioning

Initialize cryptographic services by executing the following TCG methods:

1. StartSession and SyncSession using the 'AdminSP'.
2. Get 'MSID'.
3. Authenticate 'SID with MSID'; FAILURE indicates the Cryptographic Module has been tampered with.
4. Set 'SID PIN' to your organizational value.
5. Set 'Makers.Enabled = FALSE' (required to enter FIPS mode).
6. Set 'Firmware_Dload_Port.PortLocked = TRUE'
7. Set 'Firmware_Dload_Port.LockOnReset = PowerCycle'
8. EndSession.
9. StartSession and SyncSession on the 'LockingSP'.
10. Authenticate 'EraseMaster with MSID'; FAILURE indicates the Cryptographic Module has been tampered with.
11. Set 'EraseMaster PIN' to a new value.
12. Erase Band0.
13. Authenticate 'BandMaster0 with MSID'; FAILURE indicates the Cryptographic Module has been tampered with.
14. Set 'BandMaster0 PIN' to a new value.
15. Repeat Steps [12-14] for each Band required by the organizational policy.
16. EndSession.
17. OPTIONAL: Reset the SED.

18.17.4 Zeroization of the Cryptographic Module

The TCG Revert method overwrites all security parameters to factory defaults:

1. StartSession and SyncSession on 'AdminSP'.
2. Authenticate 'PSID'.
3. Execute the TCG Revert or Revert SP method.
4. EndSession.
5. OPTIONAL: Reset the drive.

18.17.5 Security Protocol Parameters

18.17.5.1 Security Protocol Information Description

The security protocol information security protocol (i.e., the SECURITY PROTOCOL field set to 00h in a SECURITY PROTOCOL IN command) returns security protocol related information. A SECURITY PROTOCOL IN command with the Security Protocol field set to 00h is not associated with a previous SECURITY PROTOCOL OUT command and is processed without regard for whether a SECURITY PROTOCOL OUT command has been processed. If the SECURITY PROTOCOL IN command is supported, a Security Protocol field of 00h is supported as defined in the SCSI Specification.

18.17.5.2 CDB Description

If the Security Protocol field is set to 00h in a SECURITY PROTOCOL IN command, its contents in the Security Protocol Specific field will be those defined in the following table.

Table 18 - 19: Security Protocol Specific Field for SECURITY PROTOCOL IN Protocol 00h

Code	Description	Support	Reference
0000h	Supported Security Protocol List	Mandatory	SPC-4 7.7.1.3
0001h	Certificate Data	Mandatory	SPC-4 7.7.1.4

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0002h	Security Compliance Information	Optional	SPC-4 7.7.1.5
All others.	Reserved	– – –	– – –

Notes:

1. The remaining CDB fields for the SECURITY PROTOCOL IN command must meet the requirements as stated in the SCSI Specification.
2. Each time a SECURITY PROTOCOL IN command with the Security Protocol field set to 00h is received, the device server transfers data as defined in this specification, starting with Byte 0.

18.17.5.3 Certificate Data Description

A certificate is either an X.505 Public Key Certificate or an X.509 Attribute Certificate, depending upon the capabilities of the logical unit. If the Security Protocol field is set to 00h, and the Security Protocol Specific field is set to 0001h in a SECURITY PROTOCOL IN command, then the parameter data has the format described in the following table.

Table 18 - 20: Certificate Data SECURITY PROTOCOL IN Parameter Data

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0		Reserved						
1								
2	(MSB)	Certificate Length (m-3)						
3								(LSB)
4		Certificate						
. . .								
m								
m+1		Pad Bytes (if any)						
. . .								
n								

Notes:

1. The Certificate Length field indicates the total length, in bytes, of the certificate or certificates that follow. The length may include more than one certificate.
2. If the device server does not have a certificate to transfer, the Certificate Length field is set to 0000h.
3. The contents of the certificate field are defined in the following *Public Key Certificate Description* and *Attribute Certification Description* sections in this manual.
4. The total data length conforms to the Allocation Length field requirements. Pad Bytes may be appended to equal this length. Pad Bytes have a value of 00h.

18.17.5.4 Public Key Certificate Description

RFC 5280 defines the certificate syntax for certificates, consistent with the X.509v3 Public Key Certificate Specification.

18.17.5.5 Attribute Certificate Description

RFC 3281 defines the certificate syntax for certificates, consistent with the X.509v2 Attribute Certificate Specification.

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18.17.6 Security Compliance Information Description

The security compliance information parameter data contains information about security standards that apply to the target device. If the Security Protocol field is set to 00h and the Security Protocol Specific field is set to 0002h in a SECURITY PROTOCOL command, then the parameter data has the format shown in the following table.

Table 18 - 21: Security Compliance Information SECURITY PROTOCOL IN Parameter Data

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	(MSB)	Security Compliance Information Length (m-3)						
. . .								
3								(LSB)
Compliance Descriptors								
4		Compliance Descriptor [First]						
. . .								
		. . .						
		Compliance Descriptor [Last]						
. . .								
n								
m+1		Pad Bytes (if any)						
. . .								
n								

Notes:

1. The Security Compliance Information Length field indicates the total length in bytes of the compliance descriptors that follow.
2. Each compliance descriptor contains information about a security standard that applies to the target device. The compliance descriptors may be returned in any order.
3. The total data length conforms to the Allocation Length field requirements. Pad Bytes may be appended to equal this length. Pad Bytes have a value of 00h.

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18.17.7 Compliance Descriptor Overview

The format of a compliance descriptor, in the security compliance information SECURITY PROTOCOL IN parameter data, is shown in the following table.

Table 18 - 22: Compliance Descriptor Format

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	(MSB)	Compliance Descriptor Type						
1								(LSB)
2		Reserved						
3								
4	(MSB)	Compliance Descriptor Length (n-3)						
. . .								
7								(LSB)
8		Descriptor Specific Information						
. . .								
n								

Notes:

1. The Compliance Descriptor Type field (see the following table) indicates the format of the descriptor-specific information. The security compliance information SECURITY PROTOCOL IN parameter data may contain more than one compliance descriptor with the same value in the Compliance Descriptor Type field.

Table 18 - 23: Compliance Descriptor Type Field

Code	Description	Related Standards	Reference
0001h	Security requirements for cryptographic modules.	FIPS 140-2 FIPS 140-3	SPC-4 7.7.1.5.3
All others.	Reserved	– – –	– – –

2. The compliance Descriptor Length field indicates the number of bytes that follow in the compliance descriptor.
3. The contents of the descriptor-specific information depend on the value in the Compliance Descriptor type field.

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18.17.8 FIPS 140 Compliance Descriptor

The FIPS 140 Compliance Descriptor contains information that may be used to locate a FIPS 140 Certificate associated with the target device. The target device may or may not be operating in the mode as specified by that certificate.

Table 18 - 24: FIPS 140 Compliance Descriptor

	Bit							
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	(MSB)	Compliance Descriptor Type (0001h)						
1								(LSB)
2		Reserved						
3								
4	(MSB)	Compliance Descriptor Length (0000 0208h)						
. . .								
7								(LSB)
8	Related Standard (32h; FIPS 140-2)							
9	Overall Security Level							
10		Reserved						
. . .								
15								
16	(MSB)	Compliance Descriptor Hardware Version						
. . .								
143								(LSB)
144	(MSB)	Compliance Descriptor Version						
. . .								
271								(LSB)
272	(MSB)	Compliance Descriptor Module Name						
. . .								
527								(LSB)

Notes:

1. The Compliance Descriptor Type field and Compliance Descriptor Length field are defined in the previous sections of this manual. They are set as shown in the table above, for the FIPS 140 Compliance Descriptor.
2. The Related Standard field is an ASCII data field that indicates the related standard described by this compliance descriptor.
3. The Overall Security Level field is an ASCII data field that indicates the FIPS 140 overall security level reported by NIST or CSEC.
4. The Compliance Descriptor Hardware Version field is null-terminated, null-padded data that indicates the version number of the hardware in the module, as reported by NIST or CSEC.

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5. The Compliance Descriptor Version field is null-terminated, null-padded data that indicates the version number of the firmware or software in the module, as reported by NIST or CSEC. The value in the field is not related to the Product Revision Level field of standard INQUIRY data.
6. The Compliance Descriptor Module Name is null-terminated, null-padded data that indicates the name or identifier of the cryptographic module, as reported by NIST or CSEC.

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