Solid State Drive Specification

Ultrastar SSD800M/1000M

2.5" **Serial Attached SCSI (SAS) Solid State Drive**

Models:
HUSMH8080ASS200
HUSMH8080ASS201
HUSMH8080ASS204
HUSMH8080ASS205
HUSMH8040ASS200
HUSMH8040ASS201
HUSMH8040ASS204
HUSMH8040ASS205
HUSMH8020ASS200
HUSMH8020ASS201
HUSMH8020ASS204
HUSMH8020ASS205

HUSMM8080ASS200
HUSMM8080ASS201
HUSMM8080ASS204
HUSMM8080ASS205
HUSMM8040ASS200
HUSMM8040ASS201
HUSMM8040ASS204
HUSMM8040ASS205
HUSMM8020ASS200
HUSMM8020ASS201
HUSMM8020ASS204
HUSMM8020ASS205

HUSMR1010ASS200
HUSMR1010ASS201
HUSMR1010ASS204
HUSMR1010ASS205
HUSMR1050ASS200
HUSMR1050ASS201
HUSMR1050ASS204
HUSMR1050ASS205
HUSMR1025ASS200
HUSMR1025ASS201
HUSMR1025ASS204
HUSMR1025ASS205

Version: 1.2

08 October 2013

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1st Edition (Rev 1.2) (08 October 2013)

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1.0 General

1.1 Introduction

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

Table 1: Product ID table

Device Name	Model Name	Encryption Model	Capacity (GB)	Interface
Ultrastar SSD800MH-800	HUSMH8080ASS200	Crypto Enabled	800	2.5" SAS HE
Ultrastar SSD800MH-800	HUSMH8080ASS201	TCG Encryption	800	2.5" SAS HE
Ultrastar SSD800MH-800	HUSMH8080ASS204	Crypto Disabled	800	2.5" SAS HE
Ultrastar SSD800MH-800	HUSMH8080ASS205	TCG Encryption & FIPS Certified	800	2.5" SAS HE
Ultrastar SSD800MH-400	HUSMH8040ASS200	Crypto Enabled	400	2.5" SAS HE
Ultrastar SSD800MH-400	HUSMH8040ASS201	TCG Encryption	400	2.5" SAS HE
Ultrastar SSD800MH-400	HUSMH8040ASS204	Crypto Disabled	400	2.5" SAS HE
Ultrastar SSD800MH-400	HUSMH8040ASS205	TCG Encryption & FIPS Certified	400	2.5" SAS HE
Ultrastar SSD800MH-200	HUSMH8020ASS200	Crypto Enabled	200	2.5" SAS HE
Ultrastar SSD800MH-200	HUSMH8020ASS201	TCG Encryption	200	2.5" SAS HE
Ultrastar SSD800MH-200	HUSMH8020ASS204	Crypto Disabled	200	2.5" SAS HE
Ultrastar SSD800MH-200	HUSMH8020ASS205	TCG Encryption & FIPS Certified	200	2.5" SAS HE
Ultrastar SSD800MM-800	HUSMM8080ASS200	Crypto Enabled	800	2.5" SAS ME
Ultrastar SSD800MM-800	HUSMM8080ASS201	TCG Encryption	800	2.5" SAS ME
Ultrastar SSD800MM-800	HUSMM8080ASS204	Crypto Disabled	800	2.5" SAS ME
Ultrastar SSD800MM-800	HUSMM8080ASS205	TCG Encryption & FIPS Certified	800	2.5" SAS ME
Ultrastar SSD800MM-400	HUSMM8040ASS200	Crypto Enabled	400	2.5" SAS ME
Ultrastar SSD800MM-400	HUSMM8040ASS201	TCG Encryption	400	2.5" SAS ME
Ultrastar SSD800MM-400	HUSMM8040ASS204	Crypto Disabled	400	2.5" SAS ME
Ultrastar SSD800MM-400	HUSMM8040ASS205	TCG Encryption & FIPS Certified	400	2.5" SAS ME
Ultrastar SSD800MM-200	HUSMM8020ASS200	Crypto Enabled	200	2.5" SAS ME
Ultrastar SSD800MM-200	HUSMM8020ASS201	TCG Encryption	200	2.5" SAS ME
Ultrastar SSD800MM-200	HUSMM8020ASS204	Crypto Disabled	200	2.5" SAS ME
Ultrastar SSD800MM-200	HUSMM8020ASS205	TCG Encryption & FIPS Certified	200	2.5" SAS ME
Ultrastar SSD1000MR-1000	HUSMR1010ASS200	Crypto Enabled	1000	2.5" SAS RI
Ultrastar SSD1000MR-1000	HUSMR1010ASS201	TCG Encryption	1000	2.5" SAS RI
Ultrastar SSD1000MR-1000	HUSMR1010ASS204	Crypto Disabled	1000	2.5" SAS RI
Ultrastar SSD1000MR-1000	HUSMR1010ASS205	TCG Encryption & FIPS Certified	1000	2.5" SAS RI
Ultrastar SSD1000MR-500	HUSMR1050ASS200	Crypto Enabled	500	2.5" SAS RI
Ultrastar SSD1000MR-500	HUSMR1050ASS201	TCG Encryption	500	2.5" SAS RI
Ultrastar SSD1000MR-500	HUSMR1050ASS204	Crypto Disabled	500	2.5" SAS RI
Ultrastar SSD1000MR-500	HUSMR1050ASS205	TCG Encryption & FIPS Certified	500	2.5" SAS RI
Ultrastar SSD1000MR-250	HUSMR1025ASS200	Crypto Enabled	250	2.5" SAS RI
Ultrastar SSD1000MR-250	HUSMR1025ASS201	TCG Encryption	250	2.5" SAS RI
Ultrastar SSD1000MR-250	HUSMR1025ASS204	Crypto Disabled	250	2.5" SAS RI
Ultrastar SSD1000MR-250	HUSMR1025ASS205	TCG Encryption & FIPS Certified	250	2.5" SAS RI

HE = High Endurance (25 Drive Write per Day)

ME = Mainstream Endurance (10 Drive Write per Day)

RI = Read Intensive (2 Drive Write per Day)

Note:

(1) Drive Write per Day spec is based on Lifetime Petabytes for 4KB Random Write 4KB aligned.

(2) The specifications in this document are subject to change without notice.
For technical and ordering information, please visit our website at http://www.hgst.com.

1.2 Glossary

Word	**Meaning**
BMS	Background Media Scan
Kb	Kilobit = 1000 bits
Mb	Megabit = 1,000,000 bits
GB	Gigabyte = 1,000,000,000 bytes
SSD	Solid State Drive
MB	Megabyte = 1,000,000 bytes
KB	Kilobyte = 1000 bytes
SAS	Serial Attached SCSI
SFF	Small Form Factor
SMART	Self-Monitoring and Reporting Technology

1.3 Caution

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

1.4 Document Conventions

1.4.1 Byte Ordering Conventions

In this specification, 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 2: Byte Ordering Conventions

Byte	Bit							
	7	6	5	4	3	2	1	0
	Defect List Header							
0	1 byte Field							
1	Bit 7	Bits 6-4 of byte 1			Bits 3-0 of byte 1			
2-3	MSB 2 byte field LSB							
4-7	MSB 3 or more byte field LSB							

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 code should avoid dependencies on Reserved fields.

All fields marked 'Obsolete' or 'Ignored' will not be processed/examined by the drive. It is recommended that these be treated as Reserved fields.

2.0 Outline of the Drive

- Storage capacities of 800GB, 400GB, and 200GB
- 6 Gbps and 12 Gbps SAS-3 interface
- Supports Dual-ported operations
- Supports full duplex operations
- Variable sector size (512B, 520B, 528B, 4096B, 4160B and 4224B)
- Tagged Command Queuing support
- Automatic read/write data transfer
- 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)
- Sanitize (Block Erase, Crypto Erase)
- UnMap
- Fast Format
- High Endurance, Mainstream Endurance and Read Intensive models

3.0 Solid State Drive

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:

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

4.0 Drive Characteristics

4.1 Formatted Capacity

Table 3: Formatted Capacities are listed in blocks.

Description	Label Capacity	Encryption Model	Default Capacity	Soft Capacity
HUSMH8080ASS200	800	Crypto Enabled	1,562,824,368 (5D26CEB0h)	2344225968 (8BBA0CB0h)
HUSMH8080ASS201	800	TCG Encryption	1,562,824,368 (5D26CEB0h)	2344225968 (8BBA0CB0h)
HUSMH8080ASS204	800	Crypto Disabled	1,562,824,368 (5D26CEB0h)	2344225968 (8BBA0CB0h)
HUSMH8080ASS205	800	TCG Encryption & FIPS Certified	1,562,824,368 (5D26CEB0h)	2344225968 (8BBA0CB0h)
HUSMH8040ASS200	400	Crypto Enabled	781,422,768 (2E9390B0h)	1172123568 (45DD2FB0h)
HUSMH8040ASS201	400	TCG Encryption	781,422,768 (2E9390B0h)	1172123568 (45DD2FB0h)
HUSMH8040ASS204	400	Crypto Disabled	781,422,768 (2E9390B0h)	1172123568 (45DD2FB0h)
HUSMH8040ASS205	400	TCG Encryption & FIPS Certified	781,422,768 (2E9390B0h)	1172123568 (45DD2FB0h))
HUSMH8020ASS200	200	Crypto Enabled	390,721,968 (1749F1B0h)	586072368 (22EEC130h)
HUSMH8020ASS201	200	TCG Encryption	390,721,968 (1749F1B0h)	586072368 (22EEC130h)
HUSMH8020ASS204	200	Crypto Disabled	390,721,968 (1749F1B0h)	586072368 (22EEC130h)
HUSMH8020ASS205	200	TCG Encryption & FIPS Certified	390,721,968 (1749F1B0h)	586072368 (22EEC130h)
HUSMM8080ASS200	800	Crypto Enabled	1,562,824,368 (5D26CEB0h)	1,953,525,168 (74706DB0h)
HUSMM8080ASS201	800	TCG Encryption	1,562,824,368 (5D26CEB0h)	1,953,525,168 (74706DB0h)
HUSMM8080ASS204	800	Crypto Disabled	1,562,824,368 (5D26CEB0h)	1,953,525,168 (74706DB0h)
HUSMM8080ASS205	800	TCG Encryption & FIPS Certified	1,562,824,368 (5D26CEB0h)	1,953,525,168 (74706DB0h)
HUSMM8040ASS200	400	Crypto Enabled	781,422,768 (2E9390B0h)	976,773,168 (3A386030h)
HUSMM8040ASS201	400	TCG Encryption	781,422,768 (2E9390B0h)	976,773,168 (3A386030h)
HUSMM8040ASS204	400	Crypto Disabled	781,422,768 (2E9390B0h)	976,773,168 (3A386030h)
HUSMM8040ASS205	400	TCG Encryption & FIPS Certified	781,422,768 (2E9390B0h)	976,773,168 (3A386030h)
HUSMM8020ASS200	200	Crypto Enabled	390,721,968 (1749F1B0h)	488,397,168 (1D1C5970h)

HUSMM8020ASS201	200	TCG Encryption	390,721,968 (1749F1B0h)	488,397,168 (1D1C5970h)
HUSMM8020ASS204	200	Crypto Disabled	390,721,968 (1749F1B0h)	488,397,168 (1D1C5970h)
HUSMM8020ASS205	200	TCG Encryption & FIPS Certified	390,721,968 (1749F1B0h)	488,397,168 (1D1C5970h)
HUSMR1010ASS200	1000	Crypto Enabled	1,953,525,168 (74706DB0h)	1,953,525,168 (74706DB0h)
HUSMR1010ASS201	1000	TCG Encryption	1,953,525,168 (74706DB0h)	1,953,525,168 (74706DB0h)
HUSMR1010ASS204	1000	Crypto Disabled	1,953,525,168 (74706DB0h)	1,953,525,168 (74706DB0h)
HUSMR1010ASS205	1000	TCG Encryption & FIPS Certified	1,953,525,168 (74706DB0h)	1,953,525,168 (74706DB0h)
HUSMR1050ASS200	500	Crypto Enabled	976,773,168 (3A386030h)	976,773,168 (3A386030h)
HUSMR1050ASS201	500	TCG Encryption	976,773,168 (3A386030h)	976,773,168 (3A386030h)
HUSMR1050ASS204	500	Crypto Disabled	976,773,168 (3A386030h)	976,773,168 (3A386030h)
HUSMR1050ASS205	500	TCG Encryption & FIPS Certified	976,773,168 (3A386030h)	976,773,168 (3A386030h)
HUSMR1025ASS200	250	Crypto Enabled	488,397,168 (1D1C5970h)	488,397,168 (1D1C5970h)
HUSMR1025ASS201	250	TCG Encryption	488,397,168 (1D1C5970h)	488,397,168 (1D1C5970h)
HUSMR1025ASS204	250	Crypto Disabled	488,397,168 (1D1C5970h)	488,397,168 (1D1C5970h)
HUSMR1025ASS205	250	TCG Encryption & FIPS Certified	488,397,168 (1D1C5970h)	488,397,168 (1D1C5970h)

Default Capacity refers to what a drive will format to using 0xFFFFFFFF for requested number of blocks in a mode select block descriptor.
Soft Capacity allows a user to trade off drive endurance for capacity, by requesting the desired number of blocks up to the limit listed above in a mode select block descriptor.
Soft Capacity is configured to be the default on the read intensive drive models ("HUSMR10...").
Refer to section 16.10.1.2 Block Descriptor and section 16.4 FORMAT UNIT for details.

4.2 Data Sheet

Table 4: Data Sheet

Host Interface Transfer Rate	6.0Gbps and 12.0 Gbps SAS
Flash Media	25 nm Multi Level Cell NAND
SDRAM size	512 MB (200GB Drive) 1024MB (400GB Drive) 2048MB (800GB Drive)

4.3 Inquiry Information

4.3.1 Product ID

Product ID in Section 16.4.2, “Inquiry Data - EVPD = 0, Page Code = 00h - Standard Inquiry Data Page” on page 85, is as follows:

Table 5: Product ID in Inquiry CommandWorld Wide ID - Block Assignment

Description	Label Capacity	Encryption Model	Endurance Level
HUSMH8080ASS200	800	Crypto Enabled	HE
HUSMH8080ASS201	800	TCG Encryption	HE
HUSMH8080ASS204	800	Crypto Disabled	HE
HUSMH8080ASS205	800	TCG Encryption & FIPS Certified	HE
HUSMH8040ASS200	400	Crypto Enabled	HE
HUSMH8040ASS201	400	TCG Encryption	HE
HUSMH8040ASS204	400	Crypto Disabled	HE
HUSMH8040ASS205	400	TCG Encryption & FIPS Certified	HE
HUSMH8020ASS200	200	Crypto Enabled	HE
HUSMH8020ASS201	200	TCG Encryption	HE
HUSMH8020ASS204	200	Crypto Disabled	HE
HUSMH8020ASS205	200	TCG Encryption & FIPS Certified	HE
HUSMM8080ASS200	800	Crypto Enabled	ME
HUSMM8080ASS201	800	TCG Encryption	ME
HUSMM8080ASS204	800	Crypto Disabled	ME
HUSMM8080ASS205	800	TCG Encryption & FIPS Certified	ME
HUSMM8040ASS200	400	Crypto Enabled	ME
HUSMM8040ASS201	400	TCG Encryption	ME
HUSMM8040ASS204	400	Crypto Disabled	ME
HUSMM8040ASS205	400	TCG Encryption & FIPS Certified	ME
HUSMM8020ASS200	200	Crypto Enabled	ME
HUSMM8020ASS201	200	TCG Encryption	ME
HUSMM8020ASS204	200	Crypto Disabled	ME
HUSMM8020ASS205	200	TCG Encryption & FIPS Certified	ME
HUSMR1010ASS200	1000	Crypto Enabled	RI
HUSMR1010ASS201	1000	TCG Encryption	RI
HUSMR1010ASS204	1000	Crypto Disabled	RI
HUSMR1010ASS205	1000	TCG Encryption & FIPS Certified	RI
HUSMR1050ASS200	500	Crypto Enabled	RI
HUSMR1050ASS201	500	TCG Encryption	RI
HUSMR1050ASS204	500	Crypto Disabled	RI
HUSMR1050ASS205	500	TCG Encryption & FIPS Certified	RI
HUSMR1025ASS200	250	Crypto Enabled	RI
HUSMR1025ASS201	250	TCG Encryption	RI
HUSMR1025ASS204	250	Crypto Disabled	RI
HUSMR1025ASS205	250	TCG Encryption & FIPS Certified	RI

Block Assignment of World Wide ID is as follows:

Table 6: Block assignment of World Wide ID in INQUIRY Command

Manufacturing Site	Product	Block Assignment
China	HUSMH8080ASS201	001h(1)
	HUSMH8040ASS201	001h(1)
	HUSMH8020ASS201	001h(1)
	HUSMM8080ASS201	001h(1)
	HUSMM8040ASS201	001h(1)
	HUSMM8020ASS201	001h(1)
	HUSMR1010ASS201	001h(1)
	HUSMR1050ASS201	001h(1)
	HUSMR1025ASS201	001h(1)

Note (1) - Additional block assignment will be issued as needed based on 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)

Note: All the above parameters contribute to drive performance. There are other parameters that contribute to the performance of the actual system. This specification tries to define the bare drive characteristics, not system throughput, which depends on the system and the application.

4.4.1 Drive ready time

Table 7: Drive ready time

Model	
800/400/200 (GB)	<10 seconds to Data Ops, <1 second to Interface Response

4.4.2 SSD Command Overhead

Table 8: SSD Command Overhead

Model	
800/400/200 (GB)	45 usec

4.4.3 SSD Response Time

Table 9: SSD Response time

Model	Typical (Sec)	Max (Sec)
800/400/200 (GB)	100 Micro Second	20 Milli Second

4.4.4 Data transfer speeds (Drive can sustain performance up to these values)

Table 10: 12Gbps Single Port 9W mode

	ME			HE		
	200G	**400G**	**800G**	**200G**	**400G**	**800G**
Access Type	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**
Sequential Write 64KB, aligned, QD=32	457	629	566	536	591	562
Sequential Read 64KB, aligned, QD=32	1001	1001	998	1001	1001	1001
	IOPs	**IOPs**	**IOPs**	**IOPs**	**IOPs**	**IOPs**
Random Write, 4KB, aligned, QD = 1	21760	22240	22030	23220	22860	23450
Random Write, 4KB, aligned, QD = 4	42740	53710	54950	60180	64200	64960
Random Write, 4KB, aligned, QD = 32	42840	67630	58260	67660	94010	90180
Random 70% Read / 30% Write, 4KB, aligned, QD = 1	10120	10380	10720	10510	10630	10930
Random 70% Read / 30% Write, 4KB, aligned, QD = 4	25720	30210	33830	29230	32880	34990
Random 70% Read / 30% Write, 4KB, aligned, QD = 32	75270	94220	103610	94250	109030	114030
Random 70% Read / 30% Write, 4KB, aligned, QD = 64	86960	105010	108460	102960	114430	117830
Random Read, 4KB, aligned, QD = 1	9400	9260	9370	9420	9340	9400
Random Read, 4KB, aligned, QD = 4	35100	35000	35080	35190	34890	34410
Random Read, 4KB, aligned, QD = 32	134630	136540	137710	137510	138070	138140
Random Write, 8KB, aligned, QD = 1	15520	16570	16490	17270	17570	17620
Random Write, 8KB, aligned, QD = 4	21600	32940	29170	35430	43440	43230
Random Write, 8KB, aligned, QD = 32	21550	33880	29120	34200	46990	44970
Random 70% Read / 30% Write, 8KB, aligned, QD = 1	7880	8270	8530	8240	8560	8690
Random 70% Read / 30% Write, 8KB, aligned, QD = 4	18640	22340	25030	21610	24900	26560
Random 70% Read / 30% Write, 8KB, aligned, QD = 32	45910	59590	65040	57830	69660	72470
Random 70% Read / 30% Write, 8KB, aligned, QD = 64	48810	64440	66170	60120	71040	73290
Random Read, 8KB, aligned, QD = 1	7840	7800	7960	7910	7830	7940
Random Read, 8KB, aligned, QD = 4	28040	28810	29150	28740	29220	29290
Random Read, 8KB, aligned, QD = 32	106740	107820	108240	108230	107900	107980
Random Write, 64KB, aligned, QD = 1	2700	4230	3690	4500	5830	5530
Random Write, 64KB, aligned, QD = 4	2690	4240	3670	4300	5870	5630
Random Write, 64KB, aligned, QD = 32	2680	4240	3650	4300	5880	5640
Random 70% Read / 30% Write, 64KB, aligned, QD = 1	2620	3050	3460	3040	3530	3730
Random 70% Read / 30% Write, 64KB, aligned, QD = 4	4790	6220	7440	6360	7880	8340
Random 70% Read / 30% Write, 64KB, aligned, QD = 32	5330	6940	8190	7550	9480	10090
Random Read, 64KB, aligned, QD = 1	4430	4340	4440	4380	4440	4490
Random Read, 64KB, aligned, QD = 4	11100	11160	11680	11330	11590	11670
Random Read, 64KB, aligned, QD = 32	15150	15370	15800	15750	15940	15950

Table 11: 12Gbps Dual Port 9W mode

	ME			HE		
	200G	**400G**	**800G**	**200G**	**400G**	**800G**
Access Type	Mbps	Mbps	Mbps	Mbps	Mbps	Mbps
Sequential Write 64KB, aligned, QD=32	453	631	567	535	591	562
Sequential Read 64KB, aligned, QD=32	1073	1095	1302	1202	1267	1278
	IOPs	**IOPs**	**IOPs**	**IOPs**	**IOPs**	**IOPs**
Random Write, 4KB, aligned, QD = 1	34050	37170	37150	39820	40510	40770
Random Write, 4KB, aligned, QD = 4	43240	65170	58320	70260	88930	88070
Random Write, 4KB, aligned, QD = 32	42870	66920	58230	66960	94050	89930
Random 70% Read / 30% Write, 4KB, aligned, QD = 1	16650	18240	19500	18310	19410	19920
Random 70% Read / 30% Write, 4KB, aligned, QD = 4	40110	48640	55140	46710	54730	58230
Random 70% Read / 30% Write, 4KB, aligned, QD = 32	86960	104960	108970	103240	114710	118980
Random 70% Read / 30% Write, 4KB, aligned, QD = 64	86860	104420	107570	102720	114080	117670
Random Read, 4KB, aligned, QD = 1	17180	17550	18470	18480	18210	17720
Random Read, 4KB, aligned, QD = 4	63550	64930	65330	64750	65260	65670
Random Read, 4KB, aligned, QD = 32	148010	148830	148700	148760	149390	149620
Random Write, 8KB, aligned, QD = 1	20960	26400	26620	28640	30660	30510
Random Write, 8KB, aligned, QD = 4	21470	33930	29140	34360	46950	45100
Random Write, 8KB, aligned, QD = 32	21510	33750	29120	34030	46990	44990
Random 70% Read / 30% Write, 8KB, aligned, QD = 1	12460	13850	15300	14370	15480	15390
Random 70% Read / 30% Write, 8KB, aligned, QD = 4	27140	34420	39050	33140	39610	42280
Random 70% Read / 30% Write, 8KB, aligned, QD = 32	48700	64820	66430	60640	72410	74890
Random 70% Read / 30% Write, 8KB, aligned, QD = 64	48690	64450	66360	60360	72060	74490
Random Read, 8KB, aligned, QD = 1	14870	14870	15540	15350	15290	15160
Random Read, 8KB, aligned, QD = 4	51350	51830	52990	52460	53260	53290
Random Read, 8KB, aligned, QD = 32	115360	118520	116190	121560	122630	120910
Random Write, 64KB, aligned, QD = 1	2680	4230	3680	4310	5880	5510
Random Write, 64KB, aligned, QD = 4	2680	4230	3670	4290	5880	5650
Random Write, 64KB, aligned, QD = 32	2680	4230	3650	4290	5880	5660
Random 70% Read / 30% Write, 64KB, aligned, QD = 1	3650	4520	5180	4440	5340	5840
Random 70% Read / 30% Write, 64KB, aligned, QD = 4	5460	7160	8460	7710	9800	10420
Random 70% Read / 30% Write, 64KB, aligned, QD = 32	5440	7150	8420	7690	9780	10410
Random Read, 64KB, aligned, QD = 1	7160	7150	6980	6820	6910	7380
Random Read, 64KB, aligned, QD = 4	15170	15530	17120	16420	17140	17240
Random Read, 64KB, aligned, QD = 32	15560	15950	17820	17050	17980	18050

Table 12: 12Gbps Single Port 11W mode

	ME			HE		
	200G	**400G**	**800G**	**200G**	**400G**	**800G**
Access Type	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**
Sequential Write 64KB, aligned, QD=32	458	706	776	539	776	717
Sequential Read 64KB, aligned, QD=32	999	1001	998	1000	1001	997
	IOPs	**IOPs**	**IOPs**	**IOPs**	**IOPs**	**IOPs**
Random Write, 4KB, aligned, QD = 1	21680	22150	22130	23180	22910	23250
Random Write, 4KB, aligned, QD = 4	42790	54190	54460	60010	64250	64110
Random Write, 4KB, aligned, QD = 32	42890	67590	69050	67720	99860	97750
Random 70% Read / 30% Write, 4KB, aligned, QD = 1	10130	10400	10720	10530	10660	10860
Random 70% Read / 30% Write, 4KB, aligned, QD = 4	25730	30520	33320	29240	33080	34660
Random 70% Read / 30% Write, 4KB, aligned, QD = 32	75290	94300	103300	94300	109010	113880
Random 70% Read / 30% Write, 4KB, aligned, QD = 64	86960	105040	108950	103040	114530	117740
Random Read, 4KB, aligned, QD = 1	9400	9350	9360	9400	9320	9380
Random Read, 4KB, aligned, QD = 4	35130	34730	34520	34600	35020	35100
Random Read, 4KB, aligned, QD = 32	135110	136460	137720	137560	137530	138270
Random Write, 8KB, aligned, QD = 1	15490	16500	16560	17320	17570	17720
Random Write, 8KB, aligned, QD = 4	21670	33240	34090	35380	43460	43080
Random Write, 8KB, aligned, QD = 32	21570	33900	37190	34220	52020	52430
Random 70% Read / 30% Write, 8KB, aligned, QD = 1	7890	8260	8640	8230	8580	8840
Random 70% Read / 30% Write, 8KB, aligned, QD = 4	18840	22430	24840	21550	24790	26130
Random 70% Read / 30% Write, 8KB, aligned, QD = 32	45960	59550	65600	57920	69770	73020
Random 70% Read / 30% Write, 8KB, aligned, QD = 64	48840	64410	67380	60150	71080	73870
Random Read, 8KB, aligned, QD = 1	7870	7840	7930	7820	7800	7900
Random Read, 8KB, aligned, QD = 4	29100	29040	29320	29170	29010	29000
Random Read, 8KB, aligned, QD = 32	106740	107830	107520	108230	108320	108230
Random Write, 64KB, aligned, QD = 1	2700	4230	4580	4510	5840	5890
Random Write, 64KB, aligned, QD = 4	2690	4240	4820	4300	6750	6930
Random Write, 64KB, aligned, QD = 32	2690	4240	4810	4300	6750	6930
Random 70% Read / 30% Write, 64KB, aligned, QD = 1	2620	3070	3430	3040	3510	3710
Random 70% Read / 30% Write, 64KB, aligned, QD = 4	4830	6220	7370	6350	7950	8470
Random 70% Read / 30% Write, 64KB, aligned, QD = 32	5340	6950	8190	7540	9480	10000
Random Read, 64KB, aligned, QD = 1	4430	4380	4430	4380	4440	4480
Random Read, 64KB, aligned, QD = 4	11120	11170	11560	11230	11710	11760
Random Read, 64KB, aligned, QD = 32	15180	15350	15870	15770	15890	15950

Table 13: 12Gbps Dual Port 11W mode

	ME			HE		
	200G	400G	800G	200G	400G	800G
Access Type	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**
Sequential Write 64KB, aligned, QD=32	456	456	703	774	539	775
Sequential Read 64KB, aligned, QD=32	1074	1074	1086	1311	1189	1264
	IOPs	**IOPs**	**IOPs**	**IOPs**	**IOPs**	**IOPs**
Random Write, 4KB, aligned, QD = 1	34040	34040	37530	37400	39770	40500
Random Write, 4KB, aligned, QD = 4	43280	43280	65150	67000	70350	88780
Random Write, 4KB, aligned, QD = 32	42890	42890	67070	68940	67090	97260
Random 70% Read / 30% Write, 4KB, aligned, QD = 1	16660	16660	18570	19780	17980	19440
Random 70% Read / 30% Write, 4KB, aligned, QD = 4	40220	40220	48840	55030	46460	54620
Random 70% Read / 30% Write, 4KB, aligned, QD = 32	86960	86960	104990	108590	103270	114710
Random 70% Read / 30% Write, 4KB, aligned, QD = 64	86890	86890	104500	107820	102860	114180
Random Read, 4KB, aligned, QD = 1	17210	17210	18350	18490	17700	18210
Random Read, 4KB, aligned, QD = 4	63840	63840	64810	65110	64620	65020
Random Read, 4KB, aligned, QD = 32	148320	148320	148890	148570	148860	149200
Random Write, 8KB, aligned, QD = 1	21030	21030	26600	26660	28330	30590
Random Write, 8KB, aligned, QD = 4	21510	21510	33980	37230	34410	54110
Random Write, 8KB, aligned, QD = 32	21550	21550	33760	37180	34100	51680
Random 70% Read / 30% Write, 8KB, aligned, QD = 1	12420	12420	14270	15340	14010	15480
Random 70% Read / 30% Write, 8KB, aligned, QD = 4	27080	27080	34440	39330	32850	39810
Random 70% Read / 30% Write, 8KB, aligned, QD = 32	48750	48750	64750	67520	60580	72440
Random 70% Read / 30% Write, 8KB, aligned, QD = 64	48690	48690	64470	67360	60540	72080
Random Read, 8KB, aligned, QD = 1	14880	14880	15240	15530	15150	15320
Random Read, 8KB, aligned, QD = 4	50980	50980	51910	52550	52500	53060
Random Read, 8KB, aligned, QD = 32	115420	115420	118520	117160	121540	123040
Random Write, 64KB, aligned, QD = 1	2680	2680	4240	4810	4310	6890
Random Write, 64KB, aligned, QD = 4	2680	2680	4230	4830	4290	6730
Random Write, 64KB, aligned, QD = 32	2680	2680	4230	4810	4290	6740
Random 70% Read / 30% Write, 64KB, aligned, QD = 1	3640	3640	4490	5180	4500	5350
Random 70% Read / 30% Write, 64KB, aligned, QD = 4	5470	5470	7180	8450	7720	9790
Random 70% Read / 30% Write, 64KB, aligned, QD = 32	5460	5460	7160	8430	7700	9770
Random Read, 64KB, aligned, QD = 1	7170	7170	6870	6980	7140	6910
Random Read, 64KB, aligned, QD = 4	15150	15150	15460	17030	16400	17150
Random Read, 64KB, aligned, QD = 32	15530	15530	15940	17910	17020	17970

Table 14: 6Gbps Single Port 9W mode

Access Type	ME			HE		
	200G	400G	800G	200G	400G	800G
	Mbps	Mbps	Mbps	Mbps	Mbps	Mbps
Sequential Write 64KB, aligned, QD=32	442	489	503	485	501	504
Sequential Read 64KB, aligned, QD=32	537	537	537	537	537	536
	IOPs	IOPs	IOPs	IOPs	IOPs	IOPs
Random Write, 4KB, aligned, QD = 1	17710	18070	17940	18700	18540	18500
Random Write, 4KB, aligned, QD = 4	40420	47850	47570	51550	54490	53790
Random Write, 4KB, aligned, QD = 32	42670	65490	58270	69700	73010	73930
Random 70% Read / 30% Write, 4KB, aligned, QD = 1	9150	9340	9520	9720	9560	9870
Random 70% Read / 30% Write, 4KB, aligned, QD = 4	24930	28160	31020	27340	30480	31980
Random 70% Read / 30% Write, 4KB, aligned, QD = 32	68790	81410	85610	81330	88320	90070
Random 70% Read / 30% Write, 4KB, aligned, QD = 64	80850	90170	92340	88530	92620	93810
Random Read, 4KB, aligned, QD = 1	8740	8520	8740	8520	8500	8520
Random Read, 4KB, aligned, QD = 4	32310	32320	32540	32490	32490	32420
Random Read, 4KB, aligned, QD = 32	110760	110640	110630	110720	110610	110510
Random Write, 8KB, aligned, QD = 1	12960	13610	13680	14190	14280	14260
Random Write, 8KB, aligned, QD = 4	21470	30650	29170	32790	36670	36420
Random Write, 8KB, aligned, QD = 32	21390	33750	29160	33830	44950	45120
Random 70% Read / 30% Write, 8KB, aligned, QD = 1	7110	7410	7750	7630	7670	8060
Random 70% Read / 30% Write, 8KB, aligned, QD = 4	18070	21030	23250	20550	23190	24320
Random 70% Read / 30% Write, 8KB, aligned, QD = 32	42670	50670	53680	49110	53550	54620
Random 70% Read / 30% Write, 8KB, aligned, QD = 64	46990	53800	55040	51930	54840	55330
Random Read, 8KB, aligned, QD = 1	7270	7110	7320	7100	7080	7110
Random Read, 8KB, aligned, QD = 4	26450	26480	26760	26500	26750	26850
Random Read, 8KB, aligned, QD = 32	61910	61880	61910	61890	61860	61850
Random Write, 64KB, aligned, QD = 1	2690	3720	3680	3920	4540	4540
Random Write, 64KB, aligned, QD = 4	2690	4170	3680	4280	5880	5590
Random Write, 64KB, aligned, QD = 32	2680	4170	3640	4280	5880	5630
Random 70% Read / 30% Write, 64KB, aligned, QD = 1	2360	2690	2980	2740	3020	3260
Random 70% Read / 30% Write, 64KB, aligned, QD = 4	4440	5470	6310	5490	6520	6820
Random 70% Read / 30% Write, 64KB, aligned, QD = 32	4950	6110	7060	6560	7550	7800
Random Read, 64KB, aligned, QD = 1	3750	3610	3820	3570	3600	3660
Random Read, 64KB, aligned, QD = 4	8560	8540	8550	8550	8580	8520
Random Read, 64KB, aligned, QD = 32	8570	8590	8590	8590	8590	8590

Table 15: 6Gbps Dual Port 9W mode

	ME			HE		
	200G	**400G**	**800G**	**200G**	**400G**	**800G**
Access Type	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**
Sequential Write 64KB, aligned, QD=32	451	631	568	528	592	563
Sequential Read 64KB, aligned, QD=32	1004	1009	1057	1058	1046	1042
	IOPs	**IOPs**	**IOPs**	**IOPs**	**IOPs**	**IOPs**
Random Write, 4KB, aligned, QD = 1	30700	32450	32640	34250	34520	34720
Random Write, 4KB, aligned, QD = 4	42850	64230	58280	69340	82390	82800
Random Write, 4KB, aligned, QD = 32	42500	67450	58280	66330	94020	90190
Random 70% Read / 30% Write, 4KB, aligned, QD = 1	16110	17000	18300	16950	17740	18430
Random 70% Read / 30% Write, 4KB, aligned, QD = 4	38770	46990	52110	44410	51680	55020
Random 70% Read / 30% Write, 4KB, aligned, QD = 32	86430	104940	108690	102140	113950	118290
Random 70% Read / 30% Write, 4KB, aligned, QD = 64	86270	104300	107400	101510	113230	116900
Random Read, 4KB, aligned, QD = 1	16760	16940	16870	16970	16750	17040
Random Read, 4KB, aligned, QD = 4	59820	59340	61210	60410	60880	60960
Random Read, 4KB, aligned, QD = 32	148120	148530	149280	148550	148910	149250
Random Write, 8KB, aligned, QD = 1	19850	23470	23710	24920	26200	26430
Random Write, 8KB, aligned, QD = 4	21320	34170	29140	34260	46950	44990
Random Write, 8KB, aligned, QD = 32	21330	33910	29220	33710	46950	44940
Random 70% Read / 30% Write, 8KB, aligned, QD = 1	12160	13340	14040	13340	13930	14770
Random 70% Read / 30% Write, 8KB, aligned, QD = 4	26240	33110	37250	31490	37990	39900
Random 70% Read / 30% Write, 8KB, aligned, QD = 32	48420	64590	66040	59670	71250	74190
Random 70% Read / 30% Write, 8KB, aligned, QD = 64	48320	64190	66050	59490	70890	73810
Random Read, 8KB, aligned, QD = 1	13960	14010	14070	14050	14020	14130
Random Read, 8KB, aligned, QD = 4	47980	48550	49130	48430	49130	49300
Random Read, 8KB, aligned, QD = 32	114510	117440	115640	120780	120440	120160
Random Write, 64KB, aligned, QD = 1	2660	4240	3680	4290	5870	5520
Random Write, 64KB, aligned, QD = 4	2660	4230	3670	4250	5870	5630
Random Write, 64KB, aligned, QD = 32	2660	4230	3640	4250	5870	5640
Random 70% Read / 30% Write, 64KB, aligned, QD = 1	3370	4120	4770	4050	4850	5040
Random 70% Read / 30% Write, 64KB, aligned, QD = 4	5320	6960	8190	7410	9290	9920
Random 70% Read / 30% Write, 64KB, aligned, QD = 32	5280	6900	8090	7360	9190	9760
Random Read, 64KB, aligned, QD = 1	5900	5710	5950	5710	5760	5840
Random Read, 64KB, aligned, QD = 4	14180	14470	15540	15010	15380	15390
Random Read, 64KB, aligned, QD = 32	14980	15340	16520	15970	16460	16390

Table 16: 6Gbps Single Port 11W mode

	ME			HE		
	200G	**400G**	**800G**	**200G**	**400G**	**800G**
Access Type	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**
Sequential Write 64KB, aligned, QD=32	443	489	502	485	501	502
Sequential Read 64KB, aligned, QD=32	537	537	537	537	537	537
	IOPs	**IOPs**	**IOPs**	**IOPs**	**IOPs**	**IOPs**
Random Write, 4KB, aligned, QD = 1	17700	18040	17940	18690	18540	18510
Random Write, 4KB, aligned, QD = 4	40520	47650	47760	51600	53890	53980
Random Write, 4KB, aligned, QD = 32	42700	65480	69680	69670	72930	73960
Random 70% Read / 30% Write, 4KB, aligned, QD = 1	9460	9340	9840	9450	9570	9590
Random 70% Read / 30% Write, 4KB, aligned, QD = 4	24910	28410	31180	27380	30510	31960
Random 70% Read / 30% Write, 4KB, aligned, QD = 32	68820	81370	85580	81290	88320	90060
Random 70% Read / 30% Write, 4KB, aligned, QD = 64	80800	90160	92330	88540	92580	93830
Random Read, 4KB, aligned, QD = 1	8520	8730	8530	8530	8500	8710
Random Read, 4KB, aligned, QD = 4	32430	32260	32580	32420	32460	32540
Random Read, 4KB, aligned, QD = 32	110760	110740	110770	110700	110550	110520
Random Write, 8KB, aligned, QD = 1	12930	13600	13660	14190	14270	14220
Random Write, 8KB, aligned, QD = 4	21500	30240	31160	32780	36730	36520
Random Write, 8KB, aligned, QD = 32	21410	33590	36140	33860	44930	45310
Random 70% Read / 30% Write, 8KB, aligned, QD = 1	7320	7400	7870	7390	7670	7740
Random 70% Read / 30% Write, 8KB, aligned, QD = 4	18040	21120	23200	20440	23270	24210
Random 70% Read / 30% Write, 8KB, aligned, QD = 32	42710	50670	53820	49080	53570	54600
Random 70% Read / 30% Write, 8KB, aligned, QD = 64	46990	53800	55110	51940	54830	55370
Random Read, 8KB, aligned, QD = 1	7120	7270	7150	7090	7090	7260
Random Read, 8KB, aligned, QD = 4	26470	26500	26830	26480	26720	26730
Random Read, 8KB, aligned, QD = 32	61910	61820	61910	61880	61840	61880
Random Write, 64KB, aligned, QD = 1	2700	3700	3940	3930	4540	4550
Random Write, 64KB, aligned, QD = 4	2690	4170	4800	4280	6690	6840
Random Write, 64KB, aligned, QD = 32	2690	4180	4810	4280	6600	6700
Random 70% Read / 30% Write, 64KB, aligned, QD = 1	2420	2690	3100	2670	3020	3150
Random 70% Read / 30% Write, 64KB, aligned, QD = 4	4440	5470	6320	5510	6520	6830
Random 70% Read / 30% Write, 64KB, aligned, QD = 32	4960	6090	7030	6550	7550	7810
Random Read, 64KB, aligned, QD = 1	3620	3750	3630	3520	3600	3910
Random Read, 64KB, aligned, QD = 4	8580	8560	8580	8570	8580	8550
Random Read, 64KB, aligned, QD = 32	8570	8580	8570	8580	8590	8590

Table 17: 6Gbps Dual Port 11W mode

	ME			HE		
	200G	**400G**	**800G**	**200G**	**400G**	**800G**
Access Type	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**	**Mbps**
Sequential Write 64KB, aligned, QD=32	453	702	774	529	766	714
Sequential Read 64KB, aligned, QD=32	1009	1024	1061	1051	1039	1041
	IOPs	**IOPs**	**IOPs**	**IOPs**	**IOPs**	**IOPs**
Random Write, 4KB, aligned, QD = 1	30750	32580	32460	34320	34540	34830
Random Write, 4KB, aligned, QD = 4	42930	64180	65100	69350	82420	81810
Random Write, 4KB, aligned, QD = 32	42530	67530	68770	66470	96540	95770
Random 70% Read / 30% Write, 4KB, aligned, QD = 1	15980	16980	17680	17050	17740	18350
Random 70% Read / 30% Write, 4KB, aligned, QD = 4	38840	47150	52080	44460	51940	54970
Random 70% Read / 30% Write, 4KB, aligned, QD = 32	86420	104920	108600	102090	113800	118160
Random 70% Read / 30% Write, 4KB, aligned, QD = 64	86320	104370	107330	101670	113130	118000
Random Read, 4KB, aligned, QD = 1	16960	16470	16860	16890	16800	16860
Random Read, 4KB, aligned, QD = 4	59790	60300	61060	59820	60820	61130
Random Read, 4KB, aligned, QD = 32	147930	148390	148450	148550	147260	149260
Random Write, 8KB, aligned, QD = 1	19810	23450	23320	24930	26230	26290
Random Write, 8KB, aligned, QD = 4	21340	34210	37260	34330	52660	52600
Random Write, 8KB, aligned, QD = 32	21330	33940	36960	33750	51380	52410
Random 70% Read / 30% Write, 8KB, aligned, QD = 1	12300	13200	14040	13290	14000	14570
Random 70% Read / 30% Write, 8KB, aligned, QD = 4	26210	33170	37440	31620	37930	40110
Random 70% Read / 30% Write, 8KB, aligned, QD = 32	48460	64620	67200	59720	71340	74410
Random 70% Read / 30% Write, 8KB, aligned, QD = 64	48410	64230	66630	59520	70920	74010
Random Read, 8KB, aligned, QD = 1	13970	13860	14050	13860	14070	14140
Random Read, 8KB, aligned, QD = 4	48020	48410	49320	48500	48960	48880
Random Read, 8KB, aligned, QD = 32	114520	117420	117800	120750	122110	121000
Random Write, 64KB, aligned, QD = 1	2660	4240	4800	4300	6760	6830
Random Write, 64KB, aligned, QD = 4	2660	4230	4830	4250	6660	6880
Random Write, 64KB, aligned, QD = 32	2660	4230	4820	4250	6670	6840
Random 70% Read / 30% Write, 64KB, aligned, QD = 1	3370	4180	4790	4050	4850	5090
Random 70% Read / 30% Write, 64KB, aligned, QD = 4	5330	6970	8170	7410	9300	9870
Random 70% Read / 30% Write, 64KB, aligned, QD = 32	5280	6910	8100	7360	9180	9790
Random Read, 64KB, aligned, QD = 1	5770	5700	6110	5850	5760	5990
Random Read, 64KB, aligned, QD = 4	14250	14470	15500	15010	15430	15490
Random Read, 64KB, aligned, QD = 32	14950	15260	16540	15990	16420	16490

Notes:
• Drive performance varies with model capacity and actual drive use.
• For this table, '1 MB / Sec' should be interpreted as ***1024X1024*** bytes per Second.
• These are preliminary measurements.
• Ongoing FW improvement may slightly change the performance.

4.4.5 Random writes over the life of the drive

Model / Worst Case (PB)	800GB	400GB	200GB
High Endurance (HE)	36.5PB	18.3PB	9.1PB
Mainstream Endurance (ME)	14.6PB	7.3PB	3.6PB
Read Intensive (RI)	4.8PB	2.4PB	1.2PB

Notes:
Lifetime Petabytes for 4K-aligned

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:

- SMART error is detected

5.2 Error Recovery Procedure

Errors occurring with the drive are handled by an internal error recovery procedure.

Errors that are uncorrectable after application of the error recovery procedures are reported to the host system as non-recoverable errors.

6.0 Electrical Interface

6.1 SAS Connector

The drive uses the standard 29 pin Serial Attached SCSI (SAS) connector which conforms to the mechanical requirements of SFF 8680. The connector is expected to be used in an environment which 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 29 pin Serial Attached SCSI (SAS) Connector Definition

Diagram of top and bottom of connector showing pinouts.

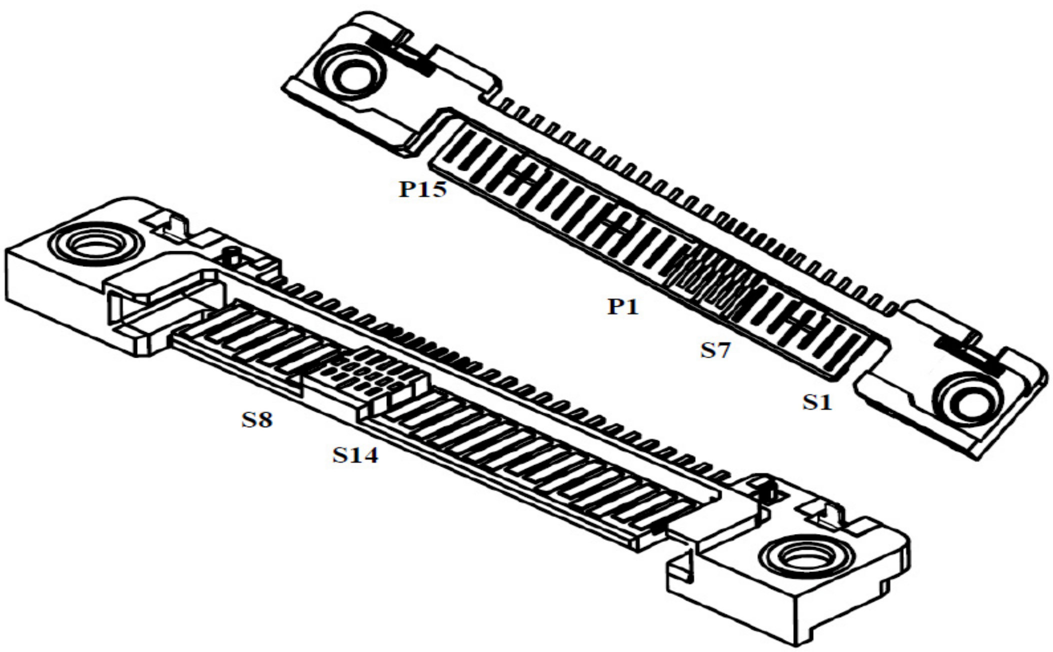


Table 18: 29-pin Connector Signal Definition

Pin Number	Signal	Description
S1	GND	GND for SAS Primary Port
S2	RP+	SAS Primary Port Receive (positive) signal
S3	RP-	SAS Primary Port Receive (negative) signal
S4	GND	GND for SAS Primary Port
S5	TP-	SAS Primary Port Transmit(negative) signal
S6	TP+	SAS Primary Port Transmit(positive) signal
S7	GND	GND for SAS Primary Port
S8	GND	GND for SAS Secondary Port
S9	RS+	SAS Secondary Port Receive(Positive) signal
S10	RS-	SAS Secondary Port Receive (negative) signal
S11	GND	GND for SAS Secondary Port
S12	TS-	SAS Secondary Port Receive (negative) signal
S13	TS+	SAS Secondary Port Receive (positive) signal
S14	GND	GND for SAS Secondary Port
P1	+3.3V	NOT USED (Pins P1-P3 tied internally)
P2	+3.3V	NOT USED (Pins P1-P3 tied internally)
P3	+3.3V	NOT USED (Pins P1-P3 tied internally)
P4	GND	GROUND
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	GND	GROUND
P11	READY LED	READY LED output

Pin Number	Signal	Description
P12	GND	GROUND
P13	+12V=Charge	Pre-charge pin for +12V
P14	+12V	+12V power supply input
P15	+12V	+12V power supply input

6.1.2 Voltage and Ground Signals

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

6.1.3 Ready LED output

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

7.0 Environment

7.1 Temperature and humidity

Table 19: Operating and non-operating conditions

Operating conditions	
Ambient Temperature	0°C to 60ºC
Relative humidity	5 to 90%, non-condensing
Maximum wet bulb temperature	29.4ºC, non-condensing
Maximum surface temperature gradient	20 ºC/hour
Altitude	-305 to 3,048 m
Shipping conditions	
Ambient Temperature	-55°C to 95ºC
Relative humidity	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	0°C to 60ºC
Relative humidity	5 to 95%, non-condensing
Maximum wet bulb temperature	35ºC, non-condensing
Altitude	-305 to 12,192 m

7.2 Storage requirements

7.2.1 Packaging

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

7.2.2 Storage time

Cumulative storage time in the package must not exceed one year.

After the drive is unpackaged, it must not remain inoperative for longer than six months.

7.3 Corrosion test

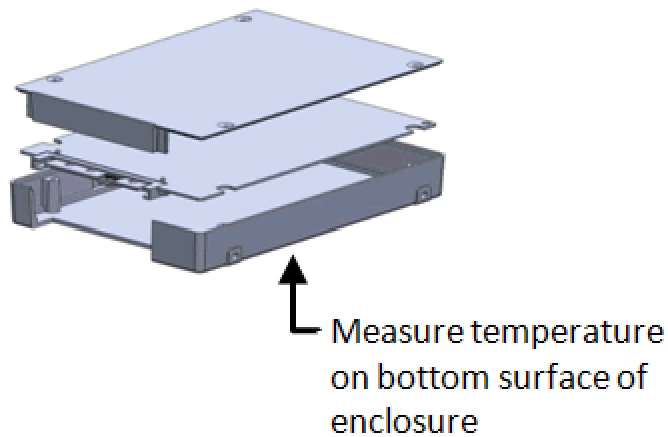
The SSD shows no signs of corrosion inside or outside of the drive assembly and remains functional after being exposed to a temperature of 50ºC and relative humidity of 90% for seven days.

7.4 Cooling requirements

Drive component temperatures must remain within the limits specified in the following table. Maximum component temperature ratings must not be exceeded under any operating condition. The drive may require forced air cooling to meet the specified, maximum operating temperatures.

Table 20: Maximum allowable surface temperatures

Module name	Location	Maximum allowable surface temperature
SDD base	as noted in picture	70ºC



7.5 Data Retention

The device is designed to retain data for three months when powered off and kept at 40ºC at the end of its design life (per Enterprise JESD218).

8.0 DC Power Requirements

The following voltage specification applies at the drive power connector. Connections to the drive should be made in 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 21: Input Voltage and Capacitance

Supply	Tolerance	Absolute Max Spike Voltage	Supply Rise Time	Capacitance
5 V	+10%/- 7%	5.5 V	0-200 ms	47 uF
12 V	+10%/- 7%	15 V	0-400 ms	47 uF

8.1 Power Supply Current, Average and Peak

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

Table 22: 9W Power Mode 12GB SAS Dual Port

	HE			ME			RI		
	800GB	400GB	200GB	800GB	400GB	200GB	1TB	500GB	250GB
12V Startup (max A)	0.94	0.85	0.45	0.85	0.70	0.40	0.64	0.74	0.29
5V Startup (max A)	1.25	1.17	0.94	1.06	0.90	0.84	1.18	1.01	0.95
12V active idle (mean A)	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03
12V active idle (max A)	0.12	0.12	0.09	0.12	0.11	0.10	0.13	0.08	0.10
5V active idle (mean A)	0.36	0.35	0.34	0.35	0.35	0.34	0.35	0.35	0.35
5V active idle (max A)	0.70	0.66	0.56	0.70	0.58	0.57	0.71	0.56	0.59
Power active idle (mean W)	2.2	2.1	2.1	2.2	2.1	2.1	2.2	2.2	2.1
12V standby (mean A)	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03
12V standby (max A)	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04
5V standby (mean A)	0.36	0.35	0.34	0.35	0.35	0.34	0.35	0.35	0.35
5V standby (max A)	0.56	0.54	0.51	0.55	0.55	0.53	0.54	0.53	0.53
Power standby (mean W)	2.2	2.2	2.1	2.2	2.1	2.1	2.2	2.2	2.1
12V ran70%r30%w (4K QD32) (mean A)	0.24	0.22	0.17	0.29	0.22	0.18	0.26	0.18	0.16
12V ran70%r30%w (4K QD32) (max A)	0.81	0.70	0.44	0.84	0.62	0.39	0.87	0.68	0.40
5V ran70%r30%w (4K QD32) (mean A)	0.73	0.66	0.57	0.72	0.62	0.57	0.65	0.57	0.53
5V ran70%r30%w (4K QD32) (max A)	1.23	1.07	0.85	1.15	0.91	0.85	1.13	0.92	0.86
Power ran70%r30%w (4K QD32) (mean W)	6.6	5.9	4.9	7.1	5.8	5.0	6.4	5.0	4.5
Perf ran70%r30%w (4K QD32) (IOPS)	114000	108000	93000	104000	94000	75000	40000	34000	26000
12V ranw (4K QD32) (mean A)	0.39	0.38	0.27	0.40	0.38	0.25	0.39	0.33	0.24
12V ranw (4K QD32) (max A)	0.92	0.85	0.47	0.59	0.73	0.41	0.61	0.69	0.40
5V ranw (4K QD32) (mean A)	0.75	0.70	0.57	0.72	0.65	0.56	0.71	0.62	0.55
5V ranw (4K QD32) (max A)	1.25	1.11	0.86	1.15	0.92	0.86	1.14	0.91	0.85
Power ranw (4K QD32) (mean W)	8.4	8.0	6.0	8.4	7.8	5.8	8.2	7.0	5.6
Perf ranw (4K QD32) (IOPS)	90000	90000	67000	60000	68000	43000	20000	23000	14000
12V ranr (4K QD32) (mean A)	0.17	0.15	0.12	0.17	0.13	0.12	0.17	0.13	0.12
12V ranr (4K QD32) (max A)	0.35	0.29	0.23	0.34	0.41	0.21	0.34	0.25	0.20
5V ranr (4K QD32) (mean A)	0.74	0.68	0.60	0.70	0.63	0.60	0.71	0.64	0.61
5V ranr (4K QD32) (max A)	1.12	1.00	0.82	1.05	0.85	0.80	1.07	0.88	0.82
Power ranr (4K QD32) (mean W)	5.8	5.2	4.4	5.6	4.8	4.4	5.6	4.8	4.4
Perf ranr (4K QD32) (IOPS)	144000	144000	142000	144000	142000	140000	144000	142000	140000
12V seqw (256K QD32) (mean A)	0.41	0.40	0.34	0.41	0.41	0.29	0.41	0.41	0.29
12V seqw (256K QD32) (max A)	0.65	0.66	0.51	0.65	0.73	0.45	0.66	0.69	0.44
5V seqw (256K QD32) (mean A)	0.71	0.66	0.57	0.67	0.61	0.55	0.67	0.62	0.55
5V seqw (256K QD32) (max A)	1.23	1.08	0.87	1.16	0.93	0.86	1.17	0.93	0.89
Power seqw (256K QD32) (mean W)	8.4	8.1	6.9	8.3	8.0	6.3	8.3	8.0	6.3
Perf seqw (256K QD32) (MB/s)	570	600	530	580	640	450	580	640	450
12V seqr (256K QD32) (mean A)	0.18	0.16	0.12	0.19	0.14	0.12	0.18	0.14	0.12
12V seqr (256K QD32) (max A)	0.37	0.32	0.26	0.36	0.29	0.27	0.36	0.30	0.25
5V seqr (256K QD32) (mean A)	0.82	0.74	0.64	0.77	0.68	0.64	0.78	0.68	0.64
5V seqr (256K QD32) (max A)	1.15	1.00	0.81	1.07	0.85	0.81	1.07	0.86	0.83
Power seqr (256K QD32) (mean W)	6.3	5.6	4.7	6.1	5.0	4.7	6.1	5.1	4.6
Perf seqr (256K QD32) (MB/s)	1020	1020	1020	1020	1020	1020	1020	1020	1010
5V Savings If Only 1 Port Connected (A)	0.09								
Power Savings If Only 1 Port Connected (W)	0.45								

Table 23: **11W Power Mode 12GB SAS Dual Port**

	HE			ME			RI		
	800GB	**400GB**	**200GB**	**800GB**	**400GB**	**200GB**	**1TB**	**500GB**	**250GB**
12V Startup (max A)	0.95	0.88	0.44	0.87	0.72	0.39	0.61	0.72	0.33
5V Startup (max A)	1.24	1.16	0.94	1.06	0.89	0.84	1.20	1.01	0.95
12V active idle (mean A)	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03
12V active idle (max A)	0.12	0.11	0.10	0.12	0.10	0.10	0.12	0.11	0.13
5V active idle (mean A)	0.36	0.35	0.33	0.35	0.34	0.34	0.35	0.35	0.35
5V active idle (max A)	0.70	0.68	0.56	0.69	0.57	0.57	0.69	0.60	0.62
Power active idle (mean W)	2.2	2.1	2.1	2.2	2.1	2.1	2.2	2.2	2.1
12V standby (mean A)	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03
12V standby (max A)	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.05
5V standby (mean A)	0.36	0.35	0.34	0.35	0.35	0.35	0.35	0.35	0.34
5V standby (max A)	0.56	0.54	0.52	0.54	0.54	0.54	0.55	0.55	0.53
Power standby (mean W)	2.2	2.1	2.1	2.2	2.1	2.1	2.1	2.2	2.1
12V ran70%r30%w (4K QD32) (mean A)	0.24	0.22	0.17	0.29	0.22	0.18	0.26	0.18	0.16
12V ran70%r30%w (4K QD32) (max A)	0.82	0.69	0.43	0.91	0.63	0.39	0.94	0.68	0.39
5V ran70%r30%w (4K QD32) (mean A)	0.73	0.66	0.57	0.72	0.62	0.57	0.65	0.57	0.53
5V ran70%r30%w (4K QD32) (max A)	1.24	1.07	0.85	1.14	0.90	0.85	1.11	0.92	0.85
Power ran70%r30%w (4K QD32) (mean W)	6.6	5.9	4.9	7.1	5.8	5.0	6.4	5.0	4.5
Perf ran70%r30%w (4K QD32) (IOPS)	114000	108000	93000	104000	95000	75000	40000	35000	26000
12V ranw (4K QD32) (mean A)	0.41	0.38	0.27	0.46	0.38	0.25	0.44	0.33	0.23
12V ranw (4K QD32) (max A)	0.98	0.86	0.46	0.99	0.71	0.40	0.96	0.69	0.40
5V ranw (4K QD32) (mean A)	0.75	0.70	0.57	0.76	0.64	0.56	0.74	0.62	0.55
5V ranw (4K QD32) (max A)	1.25	1.10	0.86	1.16	0.93	0.83	1.15	0.91	0.89
Power ranw (4K QD32) (mean W)	8.7	8.0	6.0	9.4	7.8	5.8	9.0	7.0	5.6
Perf ranw (4K QD32) (IOPS)	91000	90000	67000	70000	68000	43000	24000	23000	14000
12V ranr (4K QD32) (mean A)	0.17	0.15	0.12	0.17	0.13	0.12	0.17	0.13	0.12
12V ranr (4K QD32) (max A)	0.34	0.29	0.21	0.35	0.26	0.21	0.34	0.43	0.29
5V ranr (4K QD32) (mean A)	0.73	0.68	0.60	0.70	0.63	0.60	0.70	0.64	0.61
5V ranr (4K QD32) (max A)	1.12	0.99	0.81	1.06	0.86	0.80	1.04	0.87	0.83
Power ranr (4K QD32) (mean W)	5.7	5.2	4.4	5.6	4.7	4.4	5.5	4.8	4.4
Perf ranr (4K QD32) (IOPS)	144000	143000	142000	144000	143000	140000	144000	141000	140000
12V seqw (256K QD32) (mean A)	0.52	0.52	0.34	0.56	0.46	0.29	0.55	0.45	0.29
12V seqw (256K QD32) (max A)	1.13	1.02	0.51	1.09	0.81	0.45	1.06	0.80	0.45
5V seqw (256K QD32) (mean A)	0.76	0.71	0.56	0.74	0.63	0.55	0.74	0.64	0.56
5V seqw (256K QD32) (max A)	1.24	1.09	0.88	1.18	0.96	0.87	1.16	0.97	0.89
Power seqw (256K QD32) (mean W)	10.1	9.7	6.9	10.4	8.6	6.3	10.3	8.6	6.3
Perf seqw (256K QD32) (MB/s)	730	780	530	780	710	450	780	710	450
12V seqr (256K QD32) (mean A)	0.18	0.16	0.12	0.19	0.14	0.12	0.18	0.14	0.12
12V seqr (256K QD32) (max A)	0.36	0.33	0.25	0.36	0.30	0.27	0.35	0.30	0.30
5V seqr (256K QD32) (mean A)	0.83	0.74	0.63	0.77	0.67	0.64	0.77	0.68	0.64
5V seqr (256K QD32) (max A)	1.15	0.99	0.81	1.06	0.85	0.81	1.06	0.86	0.85
Power seqr (256K QD32) (mean W)	6.3	5.6	4.6	6.1	5.0	4.7	6.1	5.1	4.6
Perf seqr (256K QD32) (MB/s)	1020	1020	1020	1020	1020	1010	1020	1020	1010
5V Savings If Only 1 Port Connected (A)	0.09								
Power Savings If Only 1 Port Connected (W)	0.45								

Table 24: 9W Power Mode 6GB SAS Dual Port

	HE			ME			RI		
	800GB	**400GB**	**200GB**	**800GB**	**400GB**	**200GB**	**1TB**	**500GB**	**250GB**
12V Startup (max A)	0.93	0.85	0.47	0.87	0.72	0.43	0.91	0.73	0.41
5V Startup (max A)	1.08	1.09	0.82	1.06	0.88	0.84	1.06	0.88	0.89
12V active idle (mean A)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
12V active idle (max A)	0.11	0.11	0.09	0.11	0.09	0.10	0.11	0.10	0.10
5V active idle (mean A)	0.33	0.32	0.31	0.32	0.32	0.31	0.32	0.32	0.32
5V active idle (max A)	0.69	0.64	0.54	0.69	0.53	0.55	0.66	0.57	0.55
Power active idle (mean W)	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
12V standby (mean A)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
12V standby (max A)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
5V standby (mean A)	0.32	0.31	0.30	0.31	0.30	0.30	0.31	0.31	0.30
5V standby (max A)	0.53	0.49	0.47	0.51	0.49	0.49	0.50	0.50	0.49
Power standby (mean W)	1.9	1.9	1.8	1.9	1.8	1.8	1.9	1.9	1.8
12V ran70%r30%w (4K QD32) (mean A)	0.19	0.18	0.15	0.24	0.19	0.16	0.24	0.17	0.15
12V ran70%r30%w (4K QD32) (max A)	0.80	0.67	0.45	0.86	0.61	0.39	0.88	0.66	0.39
5V ran70%r30%w (4K QD32) (mean A)	0.64	0.59	0.52	0.65	0.56	0.52	0.60	0.52	0.49
5V ran70%r30%w (4K QD32) (max A)	1.16	1.01	0.80	1.12	0.85	0.79	1.07	0.85	0.80
Power ran70%r30%w (4K QD32) (mean W)	5.5	5.1	4.4	6.1	5.1	4.6	5.9	4.7	4.2
Perf ran70%r30%w (4K QD32) (IOPS)	88000	87000	80000	84000	80000	68000	37000	33000	26000
12V ranw (4K QD32) (mean A)	0.32	0.30	0.27	0.39	0.36	0.24	0.38	0.32	0.23
12V ranw (4K QD32) (max A)	0.90	0.83	0.47	0.60	0.70	0.41	0.60	0.69	0.40
5V ranw (4K QD32) (mean A)	0.67	0.61	0.54	0.70	0.60	0.53	0.68	0.58	0.51
5V ranw (4K QD32) (max A)	1.19	1.02	0.81	1.14	0.87	0.81	1.09	0.88	0.80
Power ranw (4K QD32) (mean W)	7.2	6.6	5.9	8.1	7.4	5.6	7.9	6.7	5.3
Perf ranw (4K QD32) (IOPS)	72000	72000	69000	59000	66000	42000	22000	23000	14000
12V ranr (4K QD32) (mean A)	0.14	0.12	0.10	0.14	0.11	0.10	0.14	0.11	0.09
12V ranr (4K QD32) (max A)	0.34	0.27	0.32	0.31	0.31	0.28	0.32	0.23	0.25
5V ranr (4K QD32) (mean A)	0.65	0.60	0.54	0.63	0.56	0.54	0.62	0.57	0.54
5V ranr (4K QD32) (max A)	1.03	0.89	0.74	0.98	0.79	0.73	0.94	0.78	0.75
Power ranr (4K QD32) (mean W)	4.9	4.5	3.8	4.8	4.1	3.8	4.7	4.1	3.8
Perf ranr (4K QD32) (IOPS)	111000	111000	111000	111000	111000	111000	111000	111000	111000
12V seqw (256K QD32) (mean A)	0.37	0.35	0.31	0.37	0.34	0.28	0.37	0.34	0.28
12V seqw (256K QD32) (max A)	0.93	0.84	0.51	0.89	0.80	0.46	0.90	0.77	0.45
5V seqw (256K QD32) (mean A)	0.65	0.60	0.52	0.63	0.55	0.52	0.62	0.56	0.52
5V seqw (256K QD32) (max A)	1.18	1.00	0.80	1.10	0.83	0.80	1.08	0.85	0.83
Power seqw (256K QD32) (mean W)	7.7	7.2	6.3	7.6	6.8	5.9	7.6	6.8	5.9
Perf seqw (256K QD32) (MB/s)	520	520	490	520	520	440	520	520	440
12V seqr (256K QD32) (mean A)	0.11	0.10	0.08	0.11	0.09	0.08	0.11	0.09	0.08
12V seqr (256K QD32) (max A)	0.38	0.32	0.27	0.34	0.30	0.24	0.35	0.29	0.23
5V seqr (256K QD32) (mean A)	0.63	0.59	0.53	0.61	0.55	0.53	0.60	0.55	0.53
5V seqr (256K QD32) (max A)	1.10	0.95	0.78	1.05	0.81	0.78	1.02	0.84	0.82
Power seqr (256K QD32) (mean W)	4.5	4.1	3.5	4.4	3.8	3.6	4.3	3.8	3.6
Perf seqr (256K QD32) (MB/s)	540	540	540	540	540	540	540	540	540
5V Savings If Only 1 Port Connected (A)	0.07								
Power Savings If Only 1 Port Connected (W)	0.35								

Table 25: 11W Power Mode 6GB SAS Dual Port

	HE			ME			RI		
	800GB	400GB	200GB	800GB	400GB	200GB	1TB	500GB	250GB
12V Startup (max A)	0.87	0.86	0.43	0.90	0.70	0.40	0.86	0.75	0.43
5V Startup (max A)	1.09	1.07	0.82	1.07	0.90	0.83	1.08	0.89	0.90
12V active idle (mean A)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
12V active idle (max A)	0.11	0.10	0.09	0.11	0.09	0.10	0.11	0.10	0.10
5V active idle (mean A)	0.33	0.32	0.31	0.32	0.32	0.31	0.32	0.32	0.32
5V active idle (max A)	0.69	0.65	0.53	0.70	0.53	0.53	0.61	0.57	0.58
Power active idle (mean W)	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
12V standby (mean A)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
12V standby (max A)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
5V standby (mean A)	0.32	0.31	0.29	0.31	0.30	0.30	0.31	0.31	0.30
5V standby (max A)	0.52	0.49	0.47	0.52	0.49	0.50	0.49	0.51	0.49
Power standby (mean W)	1.9	1.9	1.8	1.9	1.8	1.8	1.9	1.9	1.8
12V ran70%r30%w (4K QD32) (mean A)	0.19	0.18	0.15	0.24	0.19	0.16	0.24	0.17	0.15
12V ran70%r30%w (4K QD32) (max A)	0.82	0.64	0.44	0.85	0.61	0.39	0.96	0.67	0.39
5V ran70%r30%w (4K QD32) (mean A)	0.64	0.59	0.52	0.65	0.56	0.52	0.60	0.52	0.49
5V ran70%r30%w (4K QD32) (max A)	1.17	1.01	0.78	1.12	0.85	0.80	1.07	0.87	0.80
Power ran70%r30%w (4K QD32) (mean W)	5.5	5.1	4.4	6.1	5.1	4.5	5.9	4.7	4.3
Perf ran70%r30%w (4K QD32) (IOPS)	88000	87000	80000	84000	81000	68000	37000	33000	26000
12V ranw (4K QD32) (mean A)	0.32	0.30	0.27	0.39	0.36	0.24	0.44	0.32	0.23
12V ranw (4K QD32) (max A)	0.99	0.84	0.48	0.61	0.70	0.41	0.97	0.70	0.40
5V ranw (4K QD32) (mean A)	0.67	0.61	0.54	0.70	0.60	0.53	0.71	0.58	0.51
5V ranw (4K QD32) (max A)	1.18	1.02	0.82	1.14	0.86	0.79	1.10	0.88	0.80
Power ranw (4K QD32) (mean W)	7.2	6.6	5.9	8.2	7.4	5.5	8.8	6.7	5.3
Perf ranw (4K QD32) (IOPS)	72000	72000	69000	59000	66000	42000	24000	23000	14000
12V ranr (4K QD32) (mean A)	0.14	0.12	0.10	0.14	0.11	0.10	0.14	0.11	0.10
12V ranr (4K QD32) (max A)	0.32	0.26	0.20	0.30	0.23	0.29	0.31	0.24	0.32
5V ranr (4K QD32) (mean A)	0.65	0.60	0.54	0.63	0.56	0.54	0.62	0.57	0.54
5V ranr (4K QD32) (max A)	1.00	0.89	0.74	0.96	0.76	0.74	0.93	0.76	0.76
Power ranr (4K QD32) (mean W)	4.9	4.5	3.8	4.8	4.1	3.8	4.7	4.1	3.9
Perf ranr (4K QD32) (IOPS)	111000	111000	111000	111000	111000	111000	111000	111000	111000
12V seqw (256K QD32) (mean A)	0.38	0.35	0.31	0.38	0.34	0.28	0.37	0.33	0.28
12V seqw (256K QD32) (max A)	0.95	0.85	0.52	0.90	0.81	0.46	0.90	0.79	0.46
5V seqw (256K QD32) (mean A)	0.65	0.60	0.52	0.63	0.55	0.52	0.62	0.56	0.52
5V seqw (256K QD32) (max A)	1.18	1.00	0.79	1.10	0.83	0.79	1.07	0.84	0.82
Power seqw (256K QD32) (mean W)	7.8	7.2	6.3	7.7	6.8	5.9	7.5	6.8	5.9
Perf seqw (256K QD32) (MB/s)	520	520	490	520	520	440	520	520	440
12V seqr (256K QD32) (mean A)	0.11	0.10	0.08	0.11	0.09	0.08	0.11	0.09	0.08
12V seqr (256K QD32) (max A)	0.37	0.31	0.29	0.35	0.30	0.27	0.35	0.28	0.23
5V seqr (256K QD32) (mean A)	0.63	0.59	0.53	0.62	0.55	0.53	0.60	0.56	0.53
5V seqr (256K QD32) (max A)	1.08	0.96	0.78	1.04	0.83	0.79	1.02	0.84	0.81
Power seqr (256K QD32) (mean W)	4.5	4.1	3.5	4.4	3.8	3.6	4.3	3.8	3.5
Perf seqr (256K QD32) (MB/s)	540	540	540	540	540	540	540	540	540
5V Savings If Only 1 Port Connected (A)	0.07								
Power Savings If Only 1 Port Connected (W)	0.35								

8.2 Ripple Voltage

Table 26: Power Supply Generated Ripple at Drive Power Connector

	Maximum (mV pp)	MHz
+5 V DC	250	0-10
+12 V DC	250	0-10

During drive start up, 12 volt ripple is generated by the drive (referred to as dynamic loading). If the power of several drives is daisy chained, the power supply ripple plus other drive dynamic loading must remain within the regulation tolerance of +5%. A common supply with separate power leads to each drive is a more desirable method of power distribution.

To prevent external electrical noise from interfering with the drive's performance, the drive must be held by four screws in a user system frame that has no electrical level difference at the four screw positions. The drive enclosure must not be used in the current return path of the drive power supply. The maximum common-mode noise current passing through the drive must not exceed 20 mA.

8.3 Power Consumption Efficiency Index

Table 27: Power Consumption Efficiency Index

	800GB HE	400GB HE	200GB HE	800GB ME	400GB ME	200GB ME	1TB RI	500GB RI	250GB RI
Power Consumption Efficiency Index -Idle Mode (W/GB)	0.0028	0.0055	0.0104	0.0027	0.0055	0.0105	0.0022	0.0045	0.0085

8.4 Power Slew Requirements During Power Loss

Supply Voltage fall times during Power Loss:
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.

9.0 Reliability

9.1 Data Reliability

- ECC - 42bit/1KB Codeword
- LBA seeded 32 bit CRC for ECC miscorrect detection
- Probability of uncorrectable data error is 1 in 1x10^16 bits read

9.2 Failure prediction (S.M.A.R.T)

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 predict drive failure conditions before they occur. The primary parameters monitored for the SSD include:

1. Remaining Reserves: 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 drive is able to commit data to media during unsafe power loss operations.
3. Wear Indicator: Endurance tracking mechanism based on maximum number of NAND erase operations performed on any band over the life of the device.

See “Log Sense Page 2Fh - SMART Status and Temperature Reading” on page 138 for tracking percentage of failure threshold for these parameters.

Non-recoverable equipment errors indicate a defective drive.

9.3 MTBF (Mean Time Between Failure): 2M hours.

This MTBF target is based on a sample population and is estimated by statistical measurements and acceleration algorithms under nominal operating conditions. MTBF ratings are not intended to predict an individual drive’s reliability. MTBF does not constitute a warranty.

9.4 Preventive Maintenance

None.

9.5 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 Section “Mode Page 1Ch - Informational Exceptions Control” on page 175. The warning is issued as sense data (Sense Key 01h, Code 0Bh, Qual 01h).

The drive temperature is reported in Log Sense page 2F. Refer to Section “Log Sense Page 2Fh - SMART Status and Temperature Reading” on page 138.

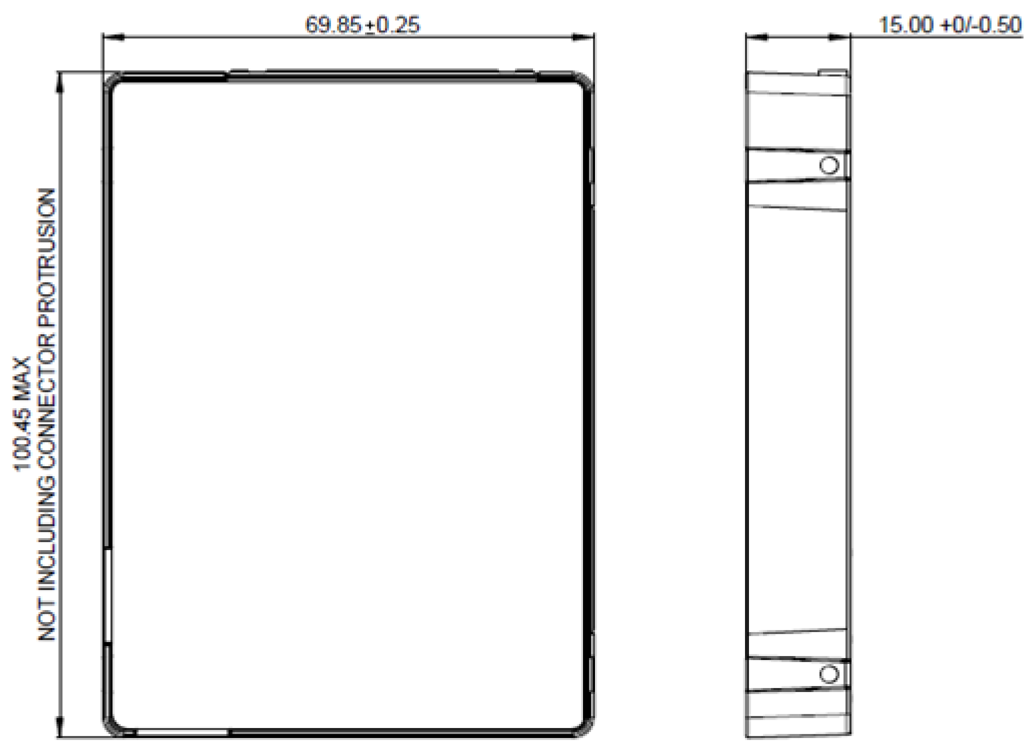
10.0 Mechanical Specifications

10.1 Outline

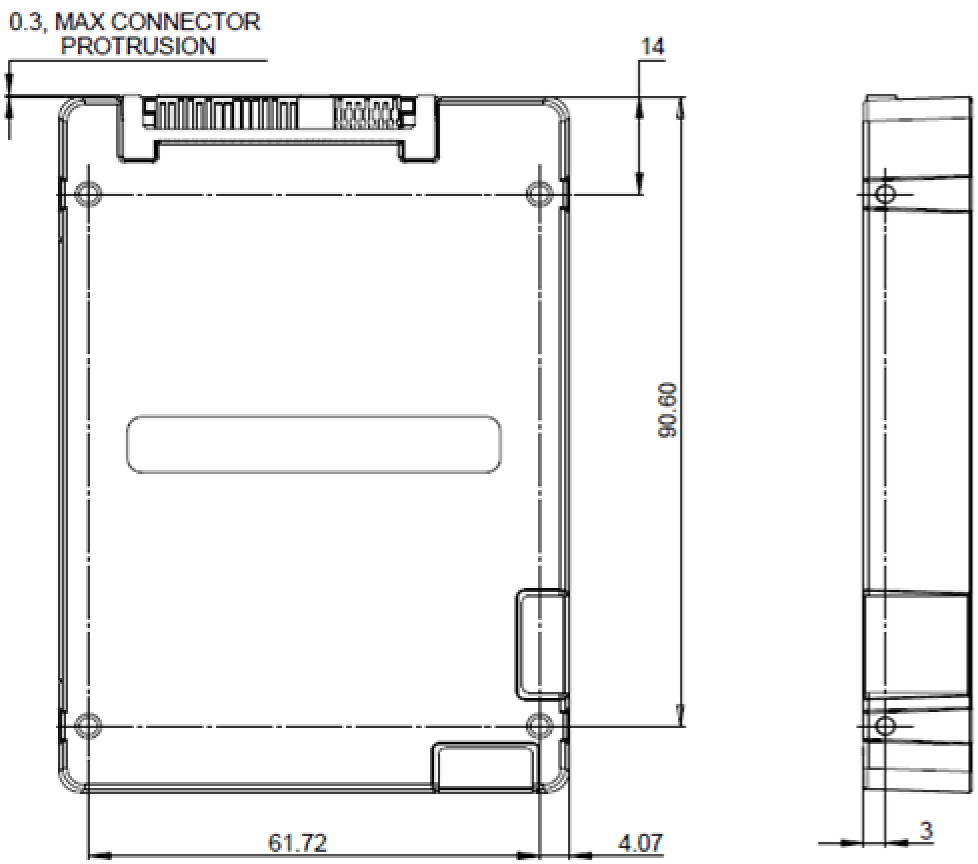
10.2 Mechanical Dimensions

Table 28: Physical Dimensions

Height [mm]	15.00 +0.00 / - 0.50
Width [mm]	69.85 ± 0.25
Length (base) [mm]	Max 100.45
Length (including connector) [mm]	Max 100.75
Weight [grams]	RI 250 GB Model 155 grams 500 GB Model 158 grams 1000 GB Model 160 grams ME 200 GB Model 155 grams 400 GB Model 158 grams 800 GB Model 160 grams HE 200 GB Model 158 grams 400 GB Model 162 grams 800 GB Model 164 grams

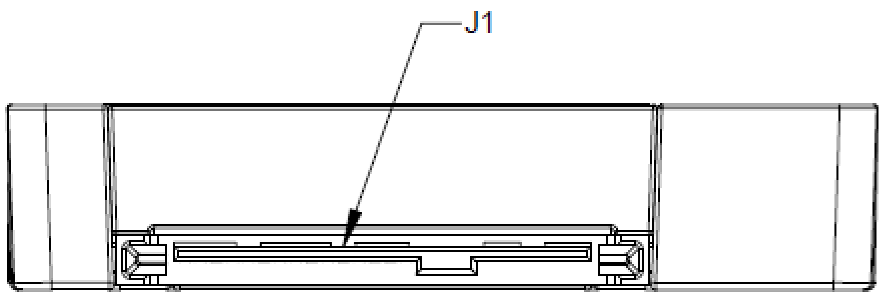

69.85±0.25
15.00 +0/-0.50
100.45 MAX
NOT INCLUDING CONNECTOR PROTRUSION

10.3 Mounting Positions and Tappings



10.4 Interface Connector

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



10.5 Drive Mounting

The drive will operate 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 reccommended mounting screw torque is 0.45 Nm (4.5 Kgf-cm). The recommended mounting screw depth is 2.5 mm maximum for bottom and 3.0 mm maximum for horizontal mounting.

Drive level vibration tests and shock tests are to be conducted with the drive mounted to a table using the bottom four screws.

11.0 Acoustics, Vibration and Shock

11.1 Acoustics

All SSD models have no acoustics, (0 bels).

11.2 Operating Vibration

11.2.1 Random Vibration

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

The assessments are carried out during 30 minutes of random vibration using the power spectral density (PSD) levels as follows.

No Errors: 2.17 G RMS, 5-700 Hz, flat PSD profile for each of the three mutually perpendicular axes.

Note: The specified levels are measured at the mounting points.

11.2.2 Swept Sine Vibration

The drive will meet the criterion while operating in the respective conditions as described below.

No errors: 2.17 G RMS, 5-700 Hz.

11.3 Non-operating Vibrations

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

11.3.1 Random Vibration

The test consists of a random vibration applied for each of the three mutually perpendicular axes. A time duration of ten minutes per axis.

3.13 G RMS, 5-800 Hz, flat PSD profile.

11.3.2 Swept Sine Vibration

The test consists of a swept sine vibration applied for each of the three mutually perpendicular axes.

3.13 G RMS, 10-800 Hz

11.4 Operating shock

The drive will meet the criterion while operating in the respective conditions as described below.

No data loss: 1000G, @0.5 ms duration, half sinewave shock pulse

500G, @ 2 ms duration, half sinewave shock pulse

The shock pulses of each level are applied to the drive, ten pulses for each direction and for all three mutually perpendicular axes. There must be a minimum of thirty seconds delay between shock pulses. The input level is applied to a base plate where the drive is attached using four mounting screws.

11.5 Non-operating shock

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

11.5.1 Half sinewave shock pulse

100 G, 11 ms duration, half sinewave pulse

500 G, 2 ms duration, half sine wave pulse

1000 G, 0.5 ms duration, half sinewave pulse

The shocks are applied in each direction of the drive for the three mutually perpendicular axes, one axis at a time. The input level is applied to a base plate where the drive is attached using four mounting screws.

12.0 Identification

12.1 Labels

The following labels are affixed to every drive shipped from the drive manufacturing location in accordance with appropriate drive assembly drawing:

- A label containing HGST, a Western Digital Company logo, HGST part number and the statement “Made by HGST,” or HGST approved equivalent.
- A label containing drive model number, manufacturing date, formatted capacity, country of origin or HGST approved equivalent and UL, C-UL, TUV, CE, MIC, BSMI,CTICK, RoHS and Recycle logos.
- A bar code label containing the drive serial number.
- A user designed label, per agreement
- Interface definition mark, SAS-3 Model

The labels may be integrated with other labels.

13.0 Electromagnetic Compatibility

The drive, when installed in a suitable enclosure and exercised with a random accessing 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 design of the drive serves to minimize radiated emissions when installed in an enclosure that provides reasonable shielding. As such, the drive is capable of meeting FCC Class B limits. However, it is the users 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 Class B Regulatory Notices

Radiated and Conducted EMI

CISPR22 2008		Class B
CNS 13438: 2006	(Taiwan)	Class B
EN 55022:2010	(EU, Australia)	Class B
FCC Title 47 Part 15	(USA)	Class B
GB9254-2008	(China)	Class B
ICES-003, Issue 5 2012	(Canada)	Class B
VCCI April 2012	(Japan)	Class B
KN 22: RRA Notice No. 2011-30	(Korea)	Class B
TCVN 7189: 2009	(Vietnam)	Class B

ITE Immunity

EN 55024:2010	(EU)
KN 24: RRA Notice No. 2011-31	(Korea)

Power Line Harmonic Emissions

EN61000-3-2:2006, A1:2009, A2:2009	(EU, Japan)
GB17625.1 2003	(China)

Voltage Fluctuations and Flicker

EN 61000-3-3:2008	(EU)
GB17625.2 1999	(China)

Electrostatic Discharge (ESD) Immunity

KN 61000-4-2: 2008-05

Radiated RF Immunity

KN 61000-4-3: 2008-05

Electrical Fast Transient / Burst (EFT/B) Immunity

KN 61000-4-4: 2008-05

Surge Immunity

KN61000-4-5: 2008-05

Conducted RF Immunity

KN 61000-4-6: 2008-05

Power Frequency Magnetic Fields Immunity

KN 61000-4-8: 2008-05

Voltage Dips and Interruptions Immunity

KN 61000-4-11: 2008-05

European Union

This product is in conformity with the protection requirements of EU Council Directive 2004/108/EC on the approximation of the laws of the Member States relating to electromagnetic compatibility. Conformity is based on compliance to the harmonized standards listed above.

This product is also in conformity with the protection requirements of EU Council Directive 2006/95/EC on the harmonization of the laws of the Member States relating to electrical equipment designed for use within certain voltage limits. Conformity is based on compliance to the following harmonized standards:

- EN 60950-1:2006 with Am. 11, Second Edition
- IEC 60950-1:2005, Second Edition
- UL 60950-1, Second Edition, 2007-03-27
- CSA C22.2 No. 60950-1-07, Second Edition, 2007-03

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 55022. The limits for Class B equipment were derived for typical residential environments to provide reasonable protection against interference with licensed communication devices.

Canada

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada.

Germany

Deutschsprachiger EU Hinweis:
Hinweis für Geräte der Klasse B EU-Richtlinie zur Elektromagnetischen Verträglichkeit Dieses Produkt entspricht den Schutzanforderungen der EU-Richtlinie 89/336/EWG zur Angleichung der Rechtsvorschriften über die elektromagnetische Verträglichkeit in den EU-Mitgliedsstaaten. und hält die Grenzwerte der EN 55022 Klasse B ein. Um dieses sicherzustellen, sind die Geräte wie in den Handbüchern beschrieben zu installieren und zu betreiben. Des Weiteren dürfen auch nur von der HGST empfohlene Kabel angeschlossen werden. HGST übernimmt keine Verantwortung für die Einhaltung der Schutzanforderungen, wenn das Produkt ohne Zustimmung der HGST verändert bzw. wenn Erweiterungskomponenten von Fremdherstellern ohne Empfehlung der HGST gesteckt/eingebaut werden.

Deutschland: Einhaltung des Gesetzes über die elektromagnetische Verträglichkeit von Geräten
Dieses Produkt entspricht dem "Gesetz über die elektromagnetische Verträglichkeit von Geräten (EMVG)". Dies ist die Umsetzung der EU-Richtlinie 89/336/EWG in der Bundesrepublik Deutschland.
Zulassungsbescheinigung laut dem Deutschen Gesetz über die elektromagneti-sche Verträglichkeit von Geräten (EMVG) vom 18. September 1998 (bzw. der EMC EG Richtlinie 89/336) für Geräte der Klasse B Dieses Gerät ist berechtigt, in Übereinstimmung mit dem Deutschen EMVG das EG-Konformitätszeichen - CE - zu führen. Verantwortlich für die Konformitätserklärung nach Paragraf 5 des EMVG ist die HGST, a Western Digital Company , 5600 Cottle road, San Jose, California 95193.
Informationen in Hinsicht EMVG Paragraf 4 Abs. (1) 4:
Das Gerät erfüllt die Schutzanforderungen nach EN 55024 und EN 55022 Klasse B.

Korea (MIC)

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

Taiwan (BSMI)

新加坡商日立環球儲存科技股份有限公司台灣分公司
台北市敦化北路 167 號 5 樓 (宏國大樓)

14.0 Standards

The following shows the safety standards for different countries.

14.1 UL and C-UL Standard Conformity

The drive is certified under the following safety standards for use in Information Technology Equipment, including Electrical Business Equipment:
EN 60950-1:2006 + Am11:2009 + Am1:2010 + Am12:2011
IEC 60950-1:2005 (2nd Edition); Am1:2009
UL 60950-1, 2nd Edition, 2011-12-19
CSA C22.2 No. 60950-1-07, 2nd Edition, 2011-12
The UL recognition, or the C-UL certification, is maintained for the duration of the product manufacturing life cycle. The UL and C-UL recognition marks appear on the drive label.

14.2 European Standards Compliance

This product is certified to the EN 60950-1:2006 with Am. 11, Second Edition safety standard for Europe.

14.3 German Safety Mark

The product is certified by TUV to meet EN 60950-1:2006 with Am. 11, Second Edition safety standard under the Bauart Mark.

14.4 Flammability

The printed wiring boards, and connectors used in this drive 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 .

Component	**Flammability Rating**
Rigid Printed Wiring Board	**Min. V-1**
2.5" SAS Connector	**Min. V-2**

15.0 SAS Attachment

This section defines some basic terminology and describes the behavior of the drive when attached to a ***S***erial ***A***ttached ***S***csi (i.e. SAS) domain.

15.1 General

This section introduces some of the terminology that is used in describing ***S***erial ***A***ttached ***S***CSI (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 a Port.

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 discussion will focus in on the aspects of SAS that are relevent to this product.

•SCSI Application Layer - Clause 10

•SSP Transport Layer (***S***erial ***S***CSI ***P***rotocol) - Clause 9

•SAS Port Layer - Clause 8

•SSP Link Layer - Clause 7

•SAS PHY Layer - Clause 6

•SAS Physical Layer - Clause 5

All layers are defined in the following ANSI standard.

•"SAS Protocol Layer - 2 (SPL-2)"

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

•SCSI Architecture Model (SAM-5)

•SCSI Block Commands (SBC-3)

15.2 SAS Features

The following SAS features are supported by the Drive.

- SAS Compliance
  - "Serial Attached SCSI - 3 (SAS-3)"
- SAS Protocol
  - This drive supports ***S***erial ***S***csi ***P***rotocol (SSP).
  - STP (Tunneled SATA) and SMP (Management protocol) protocols are NOT supported.
- SAS Dual Ported Operation
  - single PHY ports (i.e. Narrow port) or optionally Wide Port at 6G (Wide Port at 12G not supported)
  - ports function independently with separate firmware controls
  - Multiple DMA engines capable of accessing either port
  - Maximum outstanding credit of four per port

• Physical Link Rates
  - G2 (3.0 Gbps), G3 (6.0 Gbps), and G4 (12.0 Gbps) supported at narrow port
  - G2 (3.0 Gbps) and G3 (6.0 Gbps) supported at wide port
  - Largely Automated OOB and speed negotiation sequences
  - Optional Support for the hot-plug timeout in hardware
  - Spread Spectrum

• Interface Power Management
  - Partial Supported
  - Slumber Supported

•Partial support for Disconnect/Reconnect Mode Page (0x02)
  - Maximum Connect Time Limit - *SUPPORTED*
  - Bus Inactivity Time Limit - *NOT SUPPORTED*
  - Maximum Burst Size - SUPPORTED
  - First Burst Size - *NOT SUPPORTED*

•Others...
  - Connection Rate Matching
  - Hard Reset primitive sequence detection and validation in hardware
  - Support for NOTIFY (Enable Spin-up) and NOTIFY (Power Loss Expected)
  - Hashed WWN validation in hardware
  - Extended CDB support

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 29: Names and identifiers

Object	SAS Implementation
Port Identifier	SAS address
Port Name	Not defined
Device Name	SAS address
Phy Identifier	Phy identifier

Where the SAS Address format is defined by ANSI as follows:

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">BIT</th></tr>
<tr><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>0</td><td colspan="4">NAA (5h)</td><td colspan="4">MSB of IEEE Company ID</td></tr>
<tr><td>1</td><td colspan="8" rowspan="2">IEEE Company ID</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td colspan="4">LSB of IEEE Company ID</td><td colspan="4">MSB of Vendor Specific Identifier</td></tr>
</table>

4	**Vendor Specific Identifier**
5	
6	
7	

The SAS Device Name is a unique SAS address world wide name. This device name is reported through the SCSI Vital Products Data.

Each of the two SAS ports also has a unique SAS address world wide 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.

Since 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 illustrated in Table 30.

Table 30: 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:

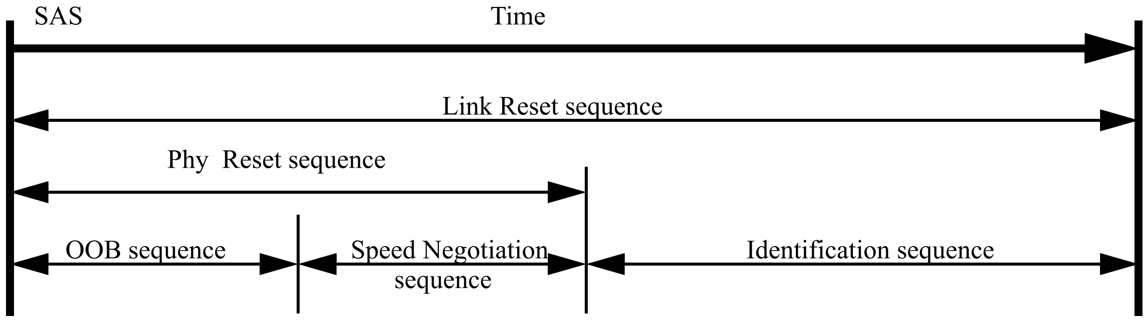
Field	**Description**
OUI	Organizationally Unique Identifier (24 bits). Canonical form means that each byte is stored in “bit reversed” order.
Block Assignment	Block assignment within HGST, a Western Digital Company
Object	Device Name/Port Identifier 00b Device 01b Port 1 10b Port 2 11b Not assigned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

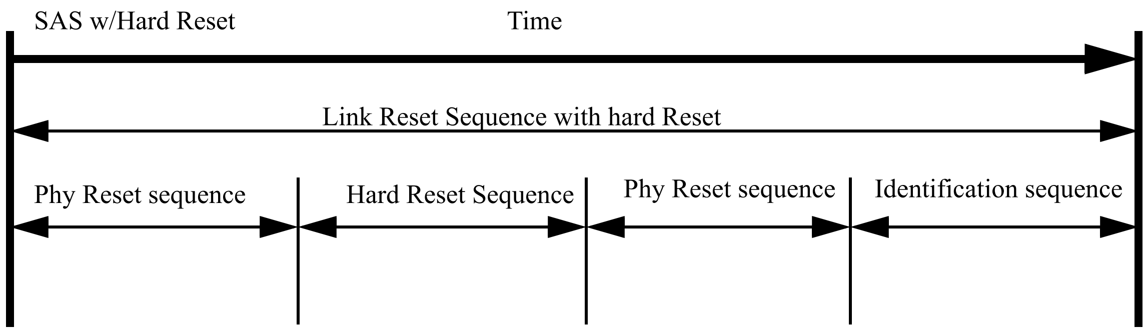
15.4 PHY Layer

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, please see the ANSI specification, SPL-2.

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. As shown in the diagram, a Phy Reset sequence consists 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.





15.4.2 Hard Reset

A Hard Reset sequence on a port will not affect the other port, but the outstanding commands on the other port will be aborted due to the LUN reset associated with the Hard Reset. The effect of a Hard Reset will be similar to a Power on Reset, and will result 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 will never be 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 OOB (Out of Band)

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.

As a SAS compliant device, the Drive uses three OOB signals: COMINIT/COMRESET and COMWAKE and COMSAS.OOB operations are beyond the scope of this specification. Please refer to the ANSI SPL-2 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 G2 (3.0 Gbps), G3 (6.0 Gbps), and G4 (12.0 Gbps) negotiation speeds. 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, SNW-3 speed negotiation with Phy capabilities exchange, and both transmitter training (Train_Tx-SNW, at 12G only) and receiver training (Train_Rx-SNW or Train-SNW). The drive's Phy capabilities are defined in table below:

Phy Capabilities:

Byte/Bit	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=0b	G1 With SSC=0b	G2 Without SSC=1b	G2 With SSC=1b	G3 Without SSC=1b	G3 With SSC=1b	G4 Without SSC=1b	G4 With SSC=1b
2	Reserved							
3	Reserved							Parity

• **Start bit** is set to 1 to indicate the beginning of the Phy capabilities
• **TX SSC TYPE** is set to 1 to indicate that Phy's transmitter uses center-spreading - SSC when SSC is enabled.
• **A TX SSC TYPE** bit is set to 0 to indicate that Phy's transmitter uses down-spreading SSC when SSC is enabled.
• **Request Logical Link Rate Field** is set to 0 to indicate that drive does not support multiplexing
• **G1 Without SSC** is set to 0 to indicate that drive does not support G1(1.5 Gbps) without SSC
• **G2 Without SSC** is set to 1 to indicate that drive supports G2(3.0 Gbps) without SSC
• **G3 Without SSC** is set to 1 to indicate that drive supports G3(6.0 Gbps) without SSC
• **G4 Without SSC** is set to 1 to indicate that drive supports G4(12.0 Gbps) without SSC
• **G1 With SSC** is bit set to 0 to indicate that drive does not support G1(1.5 Gbps) with SSC
• **G2 With SSC** is bit set to 1 to indicate that drive supports G2(3.0 Gbps) with SSC
• **G3 With SSC** is bit set to 1 to indicate that drive supports G3(6.0 Gbps) with SSC
• **G4 With SSC** is bit set to 1 to indicate that drive supports G4(12.0 Gbps) with SSC
• **Parity** is set to 1 for even parity of the total number of SNW-3 phy capabilities, including Start bit.

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. Table 18 defines the priority of the supported settings bits.

Table 31: 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**
Lowest	**G2 Without SSC bit**

15.4.5 PHY Error Handling

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

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 wait for COMINIT/COMSAS. Firmware is notified. This is not considered an error.
COMSAS Timeout	If COMINIT is detected, COMSAS is transmitted, and COMSAS is not received before the COMSAS Detect Timeout timer expires, firmware is notified and the drive continues to transmit DC zero and wait for COMINIT.
Speed Negotiation Errors	If speed negotiation fails with no match, or if the drive fails retrying the matched link rate, 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, 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. More information on SAS Partial/Slumber Power Down can be found in SAS Protocol Layer 2 (SPL-2)

Partial Capable - If enabled and supported by host, drive will request Partial after 500 us.

Slumber Capable - If enabled and supported by host, drive will request Slumber after 1000 ms.

SAS Power Management Features can be enabled or disabled by the host via a Mode Select to Mode Page 0x19 subpage 0x3 (More information can be found at Mode Page 0x19 subpage 0x3, currently 16.10.12.5)

15.5 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, please see the ANSI specification, SPL-2.

15.5.1 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 32: Address Frame Format

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

- **ADDRESS FRAME TYPE** indicates the type of address frame and is defined in table 33. This field determines the definition of the frame type dependent bytes.

Table 33: Frame type:

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

15.5.1.1 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 Idenfity Address Frame format is defined as follows:

Table 34: Identify Address Frame

Byte	Bit							
	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							
12-19	SAS Address							
20	PHY Identifier							

21	**RSVD**	**Power Capable**	**Slumber Capable**	**Partial Capable**	**Inside ZPSDS Persistent**	**Requested Inside ZPSDS**	**Break_Reply 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 Table 35 on page 68
- **Initiator Port bits** is set to 000b since this device is a target device only
- **Target Port bits** is set to 100b since this device is a SSP target device only
- **Device Name** contains 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.
- **Power Capable** is set to 00b to indicate drive does not support device power modes
- **Slumber Capable** is set to 1b to indicate 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 since this is an "End Device"
- **Requested Inside ZPSDS** is set to 0b since this is an "End Device"
- **Break_Reply Capable** is set to 1b to indicate that this port is capable of sending BREAK_REPLY primitive sequence in responding of receiving BREAK primitive sequences

Table 35: 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
Others	Reserved

15.5.1.2 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:

Byte	Bit							
	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 zero when the Drive is the source port acting as a SAS target.
- **Protocol** is set to 001b to indicate SSP Protocol.
- **Features** is set to zero 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, therefore if the Link to the drive is 3.0Gbps, and the Connection Rate is 1.5Gbps, the Drive will insert ALIGNs between DWords, to match the Connection Rate.
- **Initiator Connection Tag**: The Drive will set 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 (i.e. the drive’s port address).
- **Source Zone Group** is set to zero 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 will 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 step.
- **More Compatible Features** is set to zero and ignored by the Drive per SPL-2.

15.5.2 Link Layer Error Handling

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

Error	Error Handling Procedure
IDENTIFY Timeout	If IDENTIFY is not received before the IDENTIFY timer expires (1ms), 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. Firmware is not notified. If BREAK is received while the drive does NOT have ACK/NAK balance, BREAK or BREAK_REPLY is transmitted and the current command is aborted and will return 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 zero. 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 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 – Retryable 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. • 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 similar to BREAK in that it is treated as an abruptly closed connection. In cases where the command cannot be continued normally (e.g. a frame is corrupted by OOB signals, or we do not have ACK/NAK balance), the command is terminated with CHECK CONDITION status with sense data corresponding to ACK/NAK TIMEOUT.

15.6 Transport Layer

The Transport layer defines frame formats. The Transport layer is the interface between the application layer and port layer. It is responsible for constructing and parsing frame contents. For SSP, the transport layer only receives 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, please see the ANSI specification, SPL-2.

The transport layer defines the frame format as follows.

Table 36: SAS Frame Format

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="8">Frame Type</td></tr>
<tr><td>1-3</td><td colspan="8">Hashed Destination Address</td></tr>
<tr><td>4</td><td colspan="8">Reserved</td></tr>
<tr><td>5-7</td><td colspan="8">Hashed Source Address</td></tr>
<tr><td>8-9</td><td colspan="8">Reserved</td></tr>
<tr><td>10</td><td colspan="3">Reserved</td><td colspan="2">TLR Control = 00b</td><td>Retry Data Frames =0b</td><td>Retransmit</td><td>RSVD</td></tr>
<tr><td>11</td><td colspan="6">Reserved</td><td colspan="2"># of fill bytes</td></tr>
<tr><td>12-15</td><td colspan="8">Reserved</td></tr>
<tr><td>16-17</td><td colspan="8">Tag</td></tr>
<tr><td>18-19</td><td colspan="8">Target Port Transfer Tag</td></tr>
<tr><td>20-23</td><td colspan="8">Data Offset</td></tr>
<tr><td>24-m</td><td colspan="8">Information Unit</td></tr>
<tr><td></td><td colspan="8">Fill Bytes (if Needed)</td></tr>
<tr><td>(n-3)-n</td><td colspan="8">CRC</td></tr>
</table>

• **Frame Type** field, which defines the format of the INFORMATION UNIT field as follows:

<table>
<tr><th>Code</th><th>Name of Frame</th><th>Information Unit</th><th>Originator</th><th>IU Size (bytes)</th></tr>
<tr><td>01h</td><td>DATA</td><td>Data</td><td>Initiator or Target</td><td>1-1024</td></tr>
<tr><td>05h</td><td>XFER_RDY</td><td>Data Transfer Ready</td><td>Target</td><td>12</td></tr>
<tr><td>06h</td><td>COMMAND</td><td>Command</td><td>Initiator</td><td>28-284</td></tr>
<tr><td>07h</td><td>RESPONSE</td><td>Response</td><td>Target</td><td>24-1024</td></tr>
<tr><td>16h</td><td>TASK</td><td>Task Management Function</td><td>Initiator</td><td>28</td></tr>
<tr><td>f0-ffh</td><td colspan="4">vendor specific</td></tr>
<tr><td>all others</td><td colspan="4">reserved</td></tr>
</table>

• **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 one for RESPONSE frames when attempting to retransmit this frame due to receiving an error during the initial transmission. It shall be set to zero for all other frame types. The **Number Of Fill Bytes** field shall be set to zero 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 outbound data IU.

• **Information Unit** contains the information unit, the format of which is defined by the FRAME TYPE field.

• **Fill bytes** shall be included after the INFORMATION UNIT field so the CRC field is aligned on a four byte boundary.

15.6.1 Command Information Unit

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

Table 37: COMMAND Information Unit

Byte	Bit							
	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 (in Dwords)						Reserved	
12-27	CDB							
28-n	Additional CDB Bytes							

• **Logical Unit Number** contains the address of the logical unit. The drive only supports a LUN of 0’s.

• **Disable First Burst** is not supported by the drive

• **Task Attribute** is defined as follows:

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.

15.6.2 TASK Information Units

Table 38: TASK Information Unit

Byte	Bit							
	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 only supports a LUN of 0's.

• **Task Management Function** is defined as follows:

Value	Function
01h	ABORT TASK: The Drive shall perform the ABORT TASK associated with the value of the TAG OF TASK TO BE MANAGED field
02h	ABORT TASK SET: The Drive shall perform 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 shall be generated for all other Initiators with tasks in the task set. The Additional Sense Code shall be Commands cleared by another Initiator.
08h	LUN RESET: The LUN RESET causes the Target to execute a hard reset. This means: 1. Abort all tasks for all Initiators on either both ports. 2. Release any device reservation on either port. 3. Set a Unit Attention condition for all Initiators.
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 shall return 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 shall return 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 shall return 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 will return 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 table 39.

Table 39: Additional Response Information argument for Query Async Event

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

• **UADE Depth** is the number of pending unit attention conditions or deferred errors. It is defined as in Table 40:
• **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 40: 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**

15.6.3 XFER_RDY Information Units

The XFER_RDY frame is sent by the Drive to request write data (i.e. out bound data) from the initiator.

Table 41: XFER_RDY Information Unit

Byte	Bit							
	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 the Initiator may transmit to the Drive (using DATA frames). The requested offset shall be 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.

15.6.4 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 42: DATA Information Unit

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

15.6.5 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 43: Response Information Unit

Byte	Bit							
	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:

Status Code	Retry Delay Timer Code	Description
BUSY	0000h	Same as normal busy
	0001h-FFEFh	The number of 100 milliseconds increments which Initiator should wait before sending another command to Drive
	FFF0h-FFFDh	Reserved
	FFEFh	Initiator should stop sending commands to Drive
	FFFFh	Drive is not able to accept the command
QUEUE FULL	0001h-FFEFh	Initiator should wait before sending another command to the Drive until: a) At least the number of 100 milliseconds increments indicated in the Retry Delay Timer Code field have elapse; or b) A command addressed to the Drive completes.
	FFF0h-FFFFh	Reserved
GOOD	0000h-FFFFh	Reserved
CHECKCONDITION	0000h-FFFFh	Reserved
CONDITION MET	0000h-FFFFh	Reserved
RESERVATIONCONFLICT	0000h-FFFFh	Reserved
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 DATA field.

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

Table 44: RESPONSE DATA

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

• **Response Codes** are defined as follows:

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

15.6.6 Sequences of SSP Information Units

SSP Information Units are used in conjunction with one another 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.

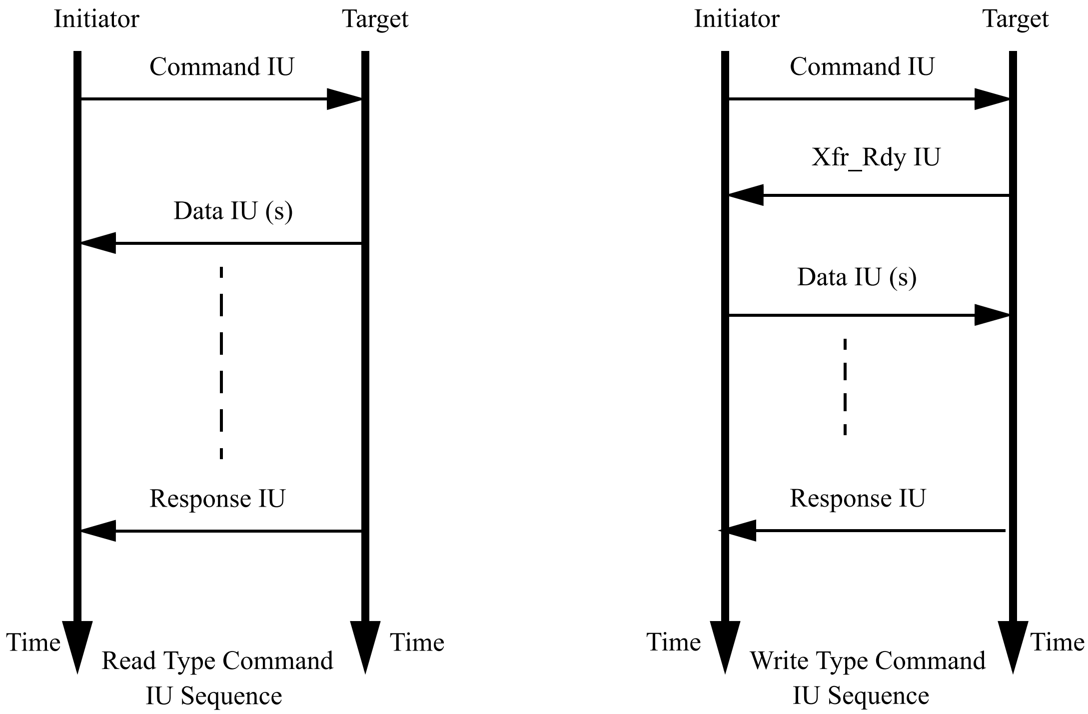


Figure 1: SSP Information Unit Sequences

15.6.7 Transport Layer Error Handling

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

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 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 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 CHECK CONDITION status with 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 and the command is aborted with CHECK CONDITION status and sense data corresponding to DATA_PHASE_ERROR is returned.

16.0 SCSI Command Set

Summaries of the SCSI commands supported by the drive are listed below. O = optional, M = mandatory

Table 45: SCSI Commands Supported

Type	Code	Description
M	04h	FORMAT UNIT (04), page 85
M	12h	INQUIRY (12), page 89
O	4Ch	LOG SELECT (4C), page 112
O	4Dh	LOG SENSE (4D), page 115
O	15h	MODE SELECT (15), page 142
O	55h	MODE SELECT (55), page 143
O	1Ah	MODE SENSE (1A), page 144
O	5Ah	MODE SENSE (5A), page 178
O	5Eh	PERSISTENT RESERVE IN (5E), page 179
O	5Fh	PERSISTENT RESERVE OUT (5F), page 182
O	90h	PRE-FETCH (16) - (90), page 187
O	34h	PRE-FETCH (10) - (34), page 187
M	08h	READ (6) - (08), page 188
M	28h	READ (10) - (28), page 189
O	A8h	READ (12) - (A8), page 191
O	88h	READ (16) - (88), page 192
O	7Fh/09h	READ (32) - (7F/09), page 193
O	3Ch	READ BUFFER (3C), page 195
M	25h	READ CAPACITY (10) - (25), page 199
O	9Eh/10h	READ CAPACITY (16) (9E/10), page 201
O	37h	READ DEFECT DATA (37), page 204
O	B7h	READ DEFECT DATA (B7), page 206
O	9Eh/11h	READ LONG (16) - (9E/11) 16-bit CDB, page 209
O	3Eh	READ LONG (3E) -10 bit CDB, page 208
O	07h	REASSIGN BLOCKS (07), page 209
O	1Ch	RECEIVE DIAGNOSTICS RESULTS (1C), page 212
M	17h	RELEASE (17), page 213
O	57h	RELEASE (57), page 214
O	A3h/05h	REPORT DEVICE IDENTIFIER (A3/05), page 215
O	A0h	REPORT LUNS (A0), page 217
O	A3h/0Ch	REPORT SUPPORTED OPERATION CODES (A3/0C), page 219
O	A3h/0Dh	REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS (A3/0D), page 225
M	03h	REQUEST SENSE (03), page 227
M	16h	RESERVE (16), page 228
O	56h	RESERVE (56), page 229
O	01h	REZERO UNIT (01), page 230
O	48h	SANITIZE (48), page 231
O	0Bh	SEEK (6) - (0B), page 233
O	2Bh	SEEK (10) - (2B), page 233

M	1Dh	SEND DIAGNOSTIC (1D), page 234
O	A4h/06h	SET DEVICE IDENTIFIER (A4/06), page 240
O	1Bh	START STOP UNIT (1B), page 241
O	35h	SYNCHRONIZE CACHE (10) - (35), page 242
O	91h	SYNCHRONIZE CACHE (16) - (91), page 243
M	00h	TEST UNIT READY (00), page 244
O	42h	UNMAP (42), page 245
O	2Fh	VERIFY (10) - (2F), page 248
O	AFh	VERIFY (12) - (AF), page 250
O	8Fh	VERIFY (16) - (8F), page 251
O	7Fh/0Ah	VERIFY (32) - (7F/0A), page 252
M	0Ah	WRITE (6) - (0A), page 254
M	2Ah	WRITE (10) - (2A), page 255
O	AAh	WRITE (12) - (AA), page 258
O	8Ah	WRITE (16) - (8A), page 259
O	7Fh/0Bh	WRITE (32) - (7F/0B), page 260
O	2Eh	WRITE AND VERIFY (10) - (2E), page 262
O	AEh	WRITE AND VERIFY (12) - (AE), page 263
O	8Eh	WRITE AND VERIFY (16) - (8E), page 264
O	7Fh/0Ch	WRITE AND VERIFY (32) - (7F/0C), page 265
O	3Bh	WRITE BUFFER (3B), page 267
O	3Fh	WRITE LONG (10) - (3F), page 271
O	9Fh/11h	WRITE LONG (16) - (9F/11), page 275
O	41h	WRITE SAME (10) - (41), page 276
O	93h	WRITE SAME (16) - (93), page 277
O	7Fh/0Dh	WRITE SAME (32) - (7F/0D), page 278

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 46: SCSI Control Byte

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

- **VU** stands for Vendor Unique.
- **FLAG*** If Link is zero, Flag must also be zero. If Link is one, Flag may also be one. Typically this bit is used to cause an interrupt in the Initiator between linked commands.
- **LINK*** is set to one to indicate that the Initiator desires an automatic link to the next command upon successful completion of the current command.

Note: * - The drive ignores the link bit and flag bit in the CDB.

16.2 Abbreviations

These abbreviations are used throughout the following sections:

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

16.3 FORMAT UNIT (04)

Table 47: FORMAT UNIT (04)

Byte	BIT							
	7	6	5	4	3	2	1	0
0	Command Code = 04h							
1	FMTPINFO		LONG LIST	FMTDATA	CMPLIST	Defect List Format		
2	VU = 0							
3-4	Obsolete							
5	Control Byte - refer to Section 16.1							

- **FMTPINFO** Format Protection Information in combination with the Protection Field Usage field in the Parameter List Header specifies whether or not the drive enables or disables the use of protection information (see table defined in the Parameter List Header section).
- **LONGLIST** is set to one to specify that the long parameter list header is to be used, or set to zero to specify that the short parameter list header is to be used
- **FmtData** is set to one 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.
- **CmpLst** is ignored.
- **Defect List Format** is ignored.
- Notes:It is recommended that the MODE SELECT command be issued prior to the FORMAT UNIT command to specify parameters that affect the formatting process.

  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 start-up (bring-up) sequence, then the Block Length from the previous format operation is used.

  Subsequent to receiving a FORMAT UNIT command, the Target responds to commands as follows:

  - All commands except REQUEST SENSE and INQUIRY return 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 in which reading and writing are 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 one.

Table 48: Short Parameter List Header

Byte	BIT							
	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 49: Long Parameter List Header

Byte	BIT							
	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							

• **Protection Field Usage** in combination with the format protection information (FMTPINFO) field in the CDB specifies whether or not the drive enables or disables the use of protection information:

FMTPINFO	Protection Field Usage	Description
00h	000h	The drive will be formatted to type 0 protection
01h	xxxh	Check Condition status will be 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 will be formatted to type 1 protection
11h	000h	The drive will be formatted to type 2 protection
11h	001h	Type 3 protection is not supported - Check Condition status will be 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 will result in Check Condition status to be returned 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 shall disable the use of protection information and format to the block size specified. Following a successful format, the PROT_EN bit in the READ CAPACITY (16) parameter data will indicate that protection information is disabled.

Type 1 and type 2 protection specifies that the drive shall enable the use of protection information and format 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 shall be written with a default value of all 0xFF's. Following a successful format, the PROT_EN bit in the READ CAPACITY (16) parameter data will indicate that protection information is enabled and the P_TYPE field in the READ CAPACITY (16) parameter data will indicate the protection type.

Byte	BIT							
	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/checked per the SBC standard.
- **Logical Block Application Tag** may be modified by the initiator if the ATO bit is set to zero in mode page 0x0A. If the ATO bit is set to one, then the initiator shall not modify the Logical Block Application Tag field. This field is generated / checked per the SBC standard. The Logical Block Guard field contains a CRC that covers the preceding user data. This field is generated/checked per the SBC standard.
- **Logical Block Reference Tag** is generated/checked depending on protection types. With Type 1 protection, the Logical Block Reference Tag in the first logical block of the data transfer shall contain the least significant four bytes of the LBA contained in the Logical Block Address field of the command. Subsequent blocks shall 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 shall contain the value in the Expected Initial Logical Block Reference Tag field of the command. Subsequent blocks shall contain the previous logical block reference tag plus one.
- **FOV** Format Options Valid bit is 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 zero in the Parameter List Header when FOV=0, or the command will be terminated with Check Condition status, sense key of Illegal Request, and additional sense code of Invalid Field in Parameter List.. FOV=1 indicates that the values set in DPRY, DCRT, STPF, IP, and DSP will be defined as specified below.
- **DPRY** Disable Primary bit is set to zero disables error injection mode. A DPRY bit set to one enables error injection mode.
- **DCRT** Disable Certification is ignored, Certification is not supported.
- **STPF** Stop Format is ignored.
- **IP** Initialization Pattern bit is set to zero specifies that an initialization pattern descriptor is not included and all customer data will be initialized to zeroes. An IP bit of one 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 Check Condition status, sense key of Illegal Request, and additional sense code of Invalid Field in Parameter List.

Table 50: Initialization Pattern Descriptor:

Byte	BIT							
	7	6	5	4	3	2	1	0
0	IP Modifier = 0		SI = 1	Reserved				
1	IP Type = 0							
2 -3	Initialization Pattern Length = 0							

- **IP Modifier** must be set to 0, indicating that the drive will not modify the initialization pattern.
- **SI** Security Initialize bit must be set to 1 when an Initialization Pattern Descriptor is sent. This specifies that the drive shall attempt to erase all locations that may contain customer data, including known defects.

- **Initialization Pattern Type** must be 0, indicating that the drive will use the default initialization pattern. All customer data will be initialized to zeroes.
- **Initialization Pattern Length** must be 0, as user-specified initialization patterns are not supported.
- **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 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, with the immediate bit set to one, 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 (i.e. one protection interval per logical block) for logical block sizes 512 and 520. This value may be 0 or 3 (i.e. 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 Check Condition status with the sense key set to Illegal Request and the additional sense code set to Invalid Field in Parameter List.

16.4 INQUIRY (12)

Table 51: INQUIRY (12)

Byte	BIT							
	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 Section 16.1							

The INQUIRY command requests the parameters of the Target to be sent to the Initiator.

- **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 52: Page Code descriptions

EVPD	PAGE CODE	Description
0	0	The Target returns the standard INQUIRY data.
0	Non Zero	The drive returns *Check Condition* status with the sense key of *Illegal Request* and the additional sense code of *Invalid Field in CDB*.
1	Non Zero	The drive returns the vital product data of page code requested.

- **Allocation Length** specifies the number of bytes that 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 will terminate the DATA IN phase when all available INQUIRY data has been transferred or when allocation length bytes have been transferred, whichever is less.

Note: 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.

Note: The INQUIRY command is a Priority command and is not queued.

Note: 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.

Note: The inquiry data returned when media is not available will not be complete.

Byte 0 of the returned data on an INQUIRY command is the same no matter which page(s) is(are) returned. This description is to be used for all the following page definitions.

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).

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 53: Inquiry Data- EVPD = 0

Byte	BIT							
	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=00b		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)							
146-163	Reserved							

- **Qualifier** is set to zero to indicate that the LUN specified is currently supported. Qualifier is set to 011b when the LUN specified is not present [1]
- **Peripheral Device Type** is set to zero to indicate that the device is a Direct-Access Peripheral Device.
- **RMB** Removable Medium Bit is always set to zero to indicate no removable media exists.
- **Version** indicates the level of the ANSI standard that the product supports. The drive supports ANSI SPC-4.
- **NormACA** Normal ACA is 0 indicates the device server does not support setting the NACA bit to one in the Control Byte of the CDB as defined in the SAM.
- **HiSup** bit of 1 indicates that the drive uses the hierarchical addressing model to assign LUNs to logical units.
- **Response Data Format** is set to two to indicate that the INQUIRY Data Format as specified in the ANSI SCSI version 2 is supported by the Target.
- **Additional Length** indicates the number of bytes of INQUIRY information that follows.
- **SCCS** bit of zero indicates that the device does not contain an embedded storage array controller component.
- **ACC** bit of zero indicates that no access controls coordinator may be addressed through this logical unit.
- **TGPS** field of zero indicates that the device does not support asymmetric logical unit access.
- **3PC** bit of zero indicates that the device does not support third-party copy commands.
- **Protect** bit of one indicates that the drive supports protection information
- **EncSer** Enclosure Services bit of 0 indicates that the Target does not contain an embedded enclosure services component.
- **Port** bit of 0 indicates that the drive received the Inquiry command on port A, while a Port bit of 1 indicates that the drive received the Inquiry command on port B.
- **MultiP** MultiPort bit of 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.

1.If an INVALID LUN is specified, a *Check Condition* status will be returned for all commands except INQUIRY and REQUEST SENSE.

- **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 54: Inquiry Data - EVPD = 1 (Page Code = 00h)

Byte	BIT							
	7	6	5	4	3	2	1	0
0	Qualifier = 0			Peripheral Device Type = 0				
1	Page Code = 00h							
2	Reserved							
3	Page Length = 0Ch							
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 =B0h							
15	Supported Page Code =B1h							
16	Supported Page Code =B2h							
17	Supported Page Code = D2h							

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to zero to indicate that the device is Direct Access.
- **Page Code** is set to 0, 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 55: Inquiry Data - EVPD = 1 (Page Code = 03h)

Byte	BIT							
	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							
172-175	Functional Mode							
176-179	Degraded Reason							
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	PwrCt-lUpd	PwrCtlHw	Power Controller Firmware Level					
207	Power Controller Firmware Level							

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to zero 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** contains 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 this code is for.
• **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 this 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 Stat** is the drive operating state. The least significant bit contains the following:

0 = OM_BROKEN	We have detected a hardware failure or there was an error loading context .
1 = OM_DEGRADED	We have a soft failure; i.e., incomplete format.
2 = OM_INACCESSIBLE	Drive is good.
3 = OM_STARTING	Loading context.
4 = OM_NORMAL	Context is loaded and ready to read/write.
5 = OM_STOPPED	Drive has come ready but now has been stopped
6 = OM_NOTIFY	Drive is good but NOTIFY has not arrived (SAS)
7 = OM_WAKEUP	Loading context, 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 degraded 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. A 0 indicates the power controller is an ADM1168. A 1 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 56: Inquiry Data - EVPD = 1 (Page Code = 80h)

Byte	BIT							
	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 zero to indicate that the LUN specified in the Command Block is currently supported.

• **Peripheral Device Type** is set to zero 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, and this field specifies the length of the following page data.

• **Serial Number** gives the drive serial number, right aligned.

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

Table 57: Inquiry Data Format - EVPD = 1, (Page Code - 83h)

Byte	BIT							
	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		Designator Type = 3			
6	Reserved							
7	Designator Length = 8							
8-15	LUN Designator (World Wide ID)							
16	Protocol Identifier = 6h				Code Set = 1			
17	PIV=1	RSVD	Association = 1		Designator Type = 3			
18	Reserved							
19	Designator Length = 8							
20-27	Target Port Designator (World Wide ID)							
28	Protocol Identifier = 6h				Code Set = 1			
29	PIV=1	RSVD	Association = 1		Designator Type = 4			
30	Reserved							
31	Designator Length = 4							
32-35	Relative Port Designator							
36	Protocol Identifier = 6h				Code Set = 1			
37	PIV=1	RSVD	Association = 2		Designator Type = 3			
38	Reserved							
39	Designator Length = 8							
40-47	Target Device Name Designator (World Wide ID)							
48	Protocol Identifier = 6h				Code Set = 3			
49	PIV=1	RSVD	Association=2		Designator Type = 8			
50	Reserved							
51	Designator Length = 18h							
52-75	SCSI name string Designator							

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to zero 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 72, and this field specifies the length of the following page data.
- **Protocol Identifier** is valid only when PIV=1. Protocol Identifier = 6 specifies SAS devices.
- **Code Set** specifies the data type for the identifier field. Code Set = 1 indicates binary data, Code Set = 3 indicates ASCII.

- **PIV**, Protocol Identifier Valid, is set to zero indicates that the Protocol Identifier field should be ignored. PIV set to one indicates that the Protocol Identifier field contains a valid value.
- **Association** specifies the entity with which the Identifier field is associated: 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
  - The Relative Port Identifier indicates the port which 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), plus 4 bytes ending in 00h to provide multiple of 4 in length and null termination.

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

Table 58: Inquiry Data Format - EVPD = 1, (Page Code - 86h)

Byte	BIT							
	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			
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:
  1) activates the microcode before completion of the final command in the WRITE BUFFER sequence; and
  2) 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 task is not supported.
- **SIMPSUP** Simple Supported is set to 1 to indicate support for Simple task attributes.
- **WU_SUP** Write Uncorrectable Supported is set to 1 to indicate support for WR_UNCOR in the WRITE LONG command.
- **CRD_SUP** Correction Disable Supported is set to 1 to indicate support for COR_DIS in the WRITE LONG command.

- **NV_SUP** Non-volatile Supported is set to 0 to indicated 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 0 to indicate that the device server does not support a WRITE BUFFER command with the MODE field set to 0Dh and the PO_ACT bit set to one.
- **HRA_SUP** Hard Reset Activation Supported bit is set to 0 to indicate that the device server does not support a WRITE BUFFER command with the MODE field set to 0Dh and the HR_ACT bit set to one.
- **VRA_SUP** Vendor Specific Activation Supported bit is set to 0 to indicate that the device server does not support a WRITE BUFFER command with the MODE field set to 0Dh and the VSE_ACT bit set to one.
- **Maximum Supported Sense Data Length** indicates the maximum length in bytes of sense data that the device server is capable of returning in the same I_T_L_Q nexus transaction as the status.

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

Byte	BIT							
	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 PagePolicy = 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 indicates the policy is shared by multiple logical units.
- **Mode Page Policy** is set to 00b indicates that all mode pages and subpages are shared.

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

Byte	BIT							
	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							
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 (World Wide ID)							

- **Protocol Identifier** is valid only when PIV=1. Protocol Identifier = 6 specifies SAS devices.
- **Code Set** specifies the data type for the identifier field. Code Set = 1 indicates binary data
- **PIV** Protocol Identifier Valid is set to one indicates that the Protocol Identifier field contains a valid value.
- **Association** specifies the entity with which the Identifier field is associated: 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 Target Port.
- **Identifier** contain the actual Identifier Descriptor.
  - The Target Port Identifiers are defined in the NAA IEEE WWID format where:

    World Wide 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.

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

Table 59: Inquiry Data Format - EVPD = 1, (Page Code - 8Ah)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">BIT</th></tr>
<tr><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>0</td><td colspan="3">Qualifier = 0</td><td colspan="5">Peripheral Device Type = 0</td></tr>
<tr><td>1</td><td colspan="8">Page Code = 8Ah</td></tr>
<tr><td>2-3</td><td colspan="8">Page Length = 14 (000Eh)</td></tr>
<tr><td>4</td><td colspan="6">Reserved</td><td>STANDBY_ Y = 0</td><td>STANDBY_ Z = 0</td></tr>
<tr><td>5</td><td colspan="5">Reserved</td><td>IDLE_C=0</td><td>IDLE_B=0</td><td>IDLE_A=0</td></tr>
<tr><td>6-7</td><td colspan="8">Stopped Condition Recovery Time = 0</td></tr>
<tr><td>8-9</td><td colspan="8">Standby_Z Condition Recovery Time = 0</td></tr>
<tr><td>10-11</td><td colspan="8">Standby_Y Condition Recovery Time = 0</td></tr>
<tr><td>12-13</td><td colspan="8">Idle_A Condition Recovery Time = 0</td></tr>
<tr><td>14-15</td><td colspan="8">Idle_B Condition Recovery Time = 0</td></tr>
<tr><td>16-17</td><td colspan="8">Idle_C Condition Recovery Time = 0</td></tr>
</table>

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to zero 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, and 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 60: Inquiry Data Format - EVPD = 1, (Page Code - 8Dh)

Byte	BIT							
	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							

- **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 three 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.

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

Table 61: Inquiry Data - EVPD = 1 (Page Code = 90h)

Byte	BIT							
	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 zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to zero 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, and specifies the length of the following page data.
- **Protocol-specific logical unit information descriptor 0** is defined in Table 62
- **Protocol-specific logical unit information descriptor 1** is defined in Table 62

Table 62: Protocol-specific logical unit information descriptor

Byte	BIT							
	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							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 zero to indicate that the drive does not support Transport Layer Retries

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

Table 63: Inquiry Data - EVPD = 1 (Page Code = B0h)

Byte	BIT							
	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	UGA-VALID=1	Unmap Granularity Alignment = 0						
36-43	Maximum Write Same Length = 0							
44-63	Reserved							

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to zero 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), and specifies the length of the following page data.
- **WSNZ** Write Same No Zero is set to 0 which indicates the device server supports a value of zero in the NUMBER OF LOGICAL BLOCKS field in the WRITE SAME command CDB.
- **Maximum Compare and Write Length** is set to zero which indicates 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 which indicates 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 which indicates 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,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 zero to be less than or equal to the Maximum Transfer Length (above).
- **Maximum Unmap LBA Count** is set to FFFFFFFFh and indicates the maximum number of LBAs that may be unmapped by an UNMAP command.

- **Maximum Unmap Block Descriptor Count** is set to FFFFFFFFh and indicates the maximum number of UNMAP block descriptors that shall be 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 blocksize (512.../4k...) the drive is formatted with.
- **UGAVALID** Unmap Granularity Alignment VALID is set to 1 which indicates that the UNMAP GRANULARITY ALIGNMENT field is valid.
- **Unmap Granularity Alignment** is set to 0 which indicates the LBA of the first logical block to which the OPTIMAL UNMAP GRANULARITY field applies.
- **Maximum Write Same Length** is set to 0 which indicates that there is no reported limit on the number of logical blocks that may be requested for a single WRITE SAME command.

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

Table 64: Inquiry Data - EVPD = 1 (Page Code = B1h)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">BIT</th></tr>
<tr><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>0</td><td colspan="3">Qualifier = 0</td><td colspan="5">Peripheral Device Type = 0</td></tr>
<tr><td>1</td><td colspan="8">Page Code = B1h</td></tr>
<tr><td>2-3</td><td colspan="8">Page Length = 60 (003Ch)</td></tr>
<tr><td>4-5</td><td colspan="8">Medium Rotation Rate = 1 (1h)</td></tr>
<tr><td>6</td><td colspan="8">Reserved</td></tr>
<tr><td>7</td><td colspan="4">Reserved</td><td colspan="4">Nominal Form Factor = 3h</td></tr>
<tr><td>8-63</td><td colspan="8">Reserved</td></tr>
</table>

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to zero 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, and this field specifies the length of the following page data.
- **Medium Rotation Rate** is set to 1, which indicates the drive is an SSD.
- **Nominal Form Factor** is set to 3h.

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

Table 65: Inquiry Data - EVPD = 1 (Page Code = B2h)

Byte	BIT							
	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							

- **Threshold Exponent** is set to 0 which indicates 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 zero 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

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

Table 66: Inquiry Data - EVPD = 1 (Page Code = D2h)

Byte	BIT							
	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 zero to indicate that the LUN specified in the Command Block is currently supported.

• **Peripheral Device Type** is set to zero 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 100, and this field specifies the length of the following page data.

Note: 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).

Note: 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)

Table 67: Log Select (4C)

Byte	Bit							
	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 Section 16.1							

The LOG SELECT command provides a means for the Initiator to clear statistical information maintained by the drive and reported via the LOG SENSE command.

- **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 be cleared, while a value of zero (except when PC = 11b) indicates that the parameters 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 value of 0 indicates that the page parameters not be saved. A value of 1 indicates that the page parameters that are savable be saved after they have been changed. SP bit MUST be 1 if parameter list length is greater than zero. Otherwise it will result in a Check Condition status being returned. The sense key shall be set to Illegal Request and additional sense code of Invalid Field in CDB.
- **PC** Page Control defines the type of parameters to be selected. The PC field set to 11b (and PCR is then a don't care) 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 shall be set to Illegal Request and additional sense code of Invalid Field in CDB.
- **Page Code** identifies which page is 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 additional sense code of Invalid Field in CDB.
  - If page code field is set to zero, then the selection applies to all log parameters in all valid log pages.
  - If page code field is set to a non zero, then 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 that shall be located in the DATA OUT buffer. A parameter list length zero indicates that no pages shall be transferred.
  - If the PARAMETER LIST LENGTH field is set to zero, then the PCR bit, the SP bit, and the PC fields apply to the page (pages) addressed by the page code field.
  - If The PARAMETER LIST LENGTH field is set to non zero, and the if PAGE CODE field is non-zero or the SUBPAGE CODE field is non-zero, then the command shall be terminated with CHECK CONDITION status, with the sense key set to ILLEGAL REQUEST, and the additional sense code set to INVALID FIELD IN CDB.

Note: A specified length greater than 0x00FF will result in a Check Condition status being returned. A length that results in log data being truncated will generate a Check Condition status.

Note: 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. (Ex: Parameter length =104h for one parameter, 204h for 2 parameters,... 4004h for all 40h parameters).

The drive allows updates to the current cumulative values only. A value of zero 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 then 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 and they should be sent in ascending order by parameter code value. The drive shall return Check Condition status if the application client sends pages out of order, parameter codes out of order or missing parameter code. The sense key shall be set to Illegal Request and additional sense code set to Invalid Field in Parameter List. If one or more fields of the CDB are not set correctly the command will be terminated with a Check Condition status. The sense key shall be set to Illegal Request and additional sense code of Invalid Field in 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.

The following list contains all individual page parameters (counters) that are set to their default value of zero by the LOG SELECT command (when PCR=1).

- Page 02h parameters: (Counters for write errors)
  - Write errors recovered without delay
  - Write errors recovered with possible delays
  - LBAs with write fault error
  - Total errors recovered
  - Number of times recovery invoked
  - Total write byte count
  - LBAs with hard error
- Page 03h parameters: (Counters for read errors)
  - Read errors recovered without delay
  - Read errors recovered with possible delays
  - LBAs with ECC detected error
  - Total errors recovered
  - Number of times recovery invoked
  - Total read byte count
  - LBAs with hard error.
- Page 05h parameters: (Counters for Verify Errors)
  - Errors recovered without delay
  - Errors recovered with possible delays
  - LBAs with ECC detected error
  - Total errors recovered
  - Number of times recovery invoked
  - Total bytes verified
  - LBAs with hard error.
- 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 30h parameters:
  - Overrun Counter
  - Under run Counter
  - Device Cache Full Read Hits
  - Device Cache Partial Read Hits
  - Device Cache Write Hits
  - Device Cache Fast Writes
  - Device Cache Misses on Reads
- Page 37h parameters:
  - Media Exception
  - Hardware Exception
  - Total Read Commands
  - Total Write Commands

16.6 LOG SENSE (4D)

Table 68: Log Sense (4D)

Byte	Bit 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 Section 16.1							

The LOG SENSE command allows the Initiator to retrieve the statistical data regarding the drive.

- **PPC** Parameter Pointer Control bit must be set to zero. This specifies that the drive start transferring 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, Check Condition status is returned with a sense key of Illegal Request and additional sense code of Invalid Field in CDB.
- **SP** Save Parameters bit set to 0 specifies that the drive does not save any log parameters. If it is set to 1, all page parameters that are savable (those pages denoted by a DS = 0 in the parameter header control byte) are 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 will cause 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 CDB.
- **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 additional sense code of Invalid Field in 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 zero a Check Condition status is returned with a sense key of Illegal Request and additional sense code of Invalid Field in 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 zero. This condition is not considered an error. TheTarget 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 is less.

16.6.1 Log Page parameters

Each log page begins with a 4-byte page header followed by zero or more variable-length log parameters.

Page header

Page Code field identifies which log page is being transferred.
The Page Length field specifies the length in bytes of the following log parameters.

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 The 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 The Target Save Disable bit is set to zero to indicate that the drive provides a Target defined method for saving log parameters.
- ETC The Enable Threshold Comparison bit is set to 0 to indicate the drive does not perform comparisons between cumulative and any threshold values.
- TMC The Threshold Met Criteria field is not valid because this drive does not perform threshold comparisons. This field is set to 0.
- Format and Linking The F & L field 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 shall stop incrementing until reinitialized by a Log Select command.
  - 01b: List format ASCII data: No maximum values to handle
  - 10b: Data counter: If another parameter reported in this log page reaches its maximum value, then this parameter shall not stop incrementing. This parameter may be reinitialized by a Log Select command.
  - 11b: List format binary data: 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 an Initiator can request.

Table 69: Log Sense Page 0h - Supported Log Sense Pages

Byte	Bit 7	6	5	4	3	2	1	0
0	Reserved		Page code = 0					
1	Reserved							
2-3	Page Length = 0010h (Number of Pages Supported)							
4	First supported page 00h							
5	Second supported page 02h							
6	Third supported page 03h							
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 18h							
16	Thirteenth supported page 1Ah							
17	Fourteenth supported Page Code =2Fh							
18	Fifteenth supported Page Code = 30h							
19	Sixteenth supported Page Code = 37h							

16.6.3 Log Sense Page 2h - Counters for Write Errors

Table 70: Log Sense Page 2h - Counters for Write Errors

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Reserved		Page code = 02h					
1	Reserved							
2-3	PageLength = 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 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							

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 71: Log Sense Page 3h - Counters for Read Errors

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Reserved		Page code = 03h					
1	Reserved							
2-3	PageLength = 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 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							

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.

16.6.5 Log Sense Page 5h - Counters for Verify Errors

Table 72: **Log Sense Page 5h - Counters for Verify Errors**

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Reserved		Page code = 05h					
1	Reserved							
2-3	PageLength = 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	
79	Parameter Length = 08h							
80-87	Count of hard errors							

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 73: Log Sense Page 6h - Counters for Non-Medium Errors

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Reserved		Page code = 06h					
1	Reserved							
2-3	PageLength = 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 74: Log Sense Page Dh - Temperature Information

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Reserved		Page code = 0Dh					
1	Reserved							
2-3	PageLength = 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 (degrees Celsius)							
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 (degrees Celsius)							

Reference temperature: the threshold, in degrees Celsius, for case temperature warnings

16.6.8 Log Sense Page Eh - Manufacturing Date Information

Table 75: Log Sense Page Eh - Manufacturing Date Information

Byte	Bit 7	6	5	4	3	2	1	0
0	Reserved		Page code = 0Eh					
1	Reserved							
2-3	PageLength = 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							
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							

The week and year that the device was manufactured shall be 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 76: Log Sense Page Fh - Application Client Log

Byte	Bit							
	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	1st application client log parameter							
...								
16132-16387	64th application client log parameter							

Table 77: Log Sense Page Fh, Application Client Log Parameter Structure

Byte	Bit							
	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							

Parameter code 0000h through 003Fh are supported.

The values stored in the parameter bytes represent data sent to the device in a previous LOG SELECT command.

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 78: Log Sense Page 10h - Self-Test Results

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

Table 79: Log Sense Page 10h - Self-Test Results Log Parameter Structure

Byte	Bit							
	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 will be 0001h. The parameter for the next most recent will be 0002h.

• **Function Code** contains the content of the Function Code field in the SEND DIAGNOSTIC command that initiated this self-test.

• **Self-Test Results Value** is described in the table below.

Table 80: 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 and 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.

• **Extended Segment Number** identifies the number of the segment that failed during self-test. If no segment failed, this field will be 00h.

Table 81: 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 300 MB - Verify Last 100 MB	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 will be FFFFFFFFFFFFFFFFh.

• **Sense Key**, **Additional Sense Code** and **Additional Sense Code Qualifier** will contain the additional information relating to the error or exception conditions during self-test.

See Section 16.42 “SEND DIAGNOSTIC (1D)” on page 234, for detailed listing of operations carried out by SEND DIAGNOSTIC command and Power on Diagnostics.

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

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

Table 82: Log Sense Page 11h - Solid State Media Log Page

Byte	Bit							
	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 83:							
...	First Medium Scan Parameter							
...								
n	Solid State Media parameter (last) see Table 83:							

- **DS** Disable Save bit, SPF subpage format bit, PAGE CODE, SUBPAGE CODE and PAGE LENGTH are described in SPC-4.

Table 83: Log Sense Page 11h - Solid State Media Log Page Parameter Codes

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

Table 84: Log Sense Page 11h - Percentage Used Endurance Indicator Parameter Format

Byte	Bit							
	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** shall be 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 SPC-4.
- **Parameter Length** indicates the number of bytes to follow in the log parameter.
- **Percentage Used Endurance Indicator** indicates an estimate of the percentage of device life that has been used. The value in the field shall be set to zero 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 is allowed to exceed 100. Values greater than 254 shall be 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 85: Log Sense Page 15h - Background Medium Scan Operations

Byte	Bit							
	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.

Byte	Bit							
	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
- **BMS Status** is described in the following table

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 thedrive.
- **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.

Byte	Bit							
	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 and no action needs to be taken by the Initiator

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

Table 86: Log Sense Page 17h - Non-volatile Cache Log Parameters

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td>DS = 0</td><td>SPF = 0</td><td colspan="6">Page Code = 17h</td></tr>
<tr><td>1</td><td colspan="8">SubPage Code = 00h</td></tr>
<tr><td>2-3</td><td colspan="8">Page Length = 0010h</td></tr>
<tr><td>4-5</td><td colspan="8">Parameter Code = 0000h</td></tr>
<tr><td>6</td><td>DU = 0</td><td>Obsolete</td><td>TSD = 0</td><td>ETC = 0</td><td colspan="2">TMC = 0</td><td colspan="2">Format and Linking = 11b</td></tr>
<tr><td>7</td><td colspan="8">Parameter Length = 04h</td></tr>
<tr><td>8</td><td colspan="8">Obsolete</td></tr>
<tr><td>9-11</td><td colspan="8">Remaining Non-volatile Time</td></tr>
<tr><td>12-13</td><td colspan="8">Parameter Code = 0001h</td></tr>
<tr><td>14</td><td>DU = 0</td><td>Obsolete</td><td>TSD = 0</td><td>ETC = 0</td><td colspan="2">TMC = 0</td><td colspan="2">Format and Linking = 11b</td></tr>
<tr><td>15</td><td colspan="8">Parameter Length = 04h</td></tr>
<tr><td>16</td><td colspan="8">Obsolete</td></tr>
<tr><td>17-19</td><td colspan="8">Maximum Non-volatile Time</td></tr>
</table>

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

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

Table 87: Log Sense Page 18h - Protocol-Specific Log Parameters

Byte	Bit 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 parameters - Secondary Port							

Table 88: Log Sense Page 18h - SAS Log Descriptor

Byte	Bit 7	6	5	4	3	2	1	0
0-1	Parameter Code (0001h for primary port; 0002h for secondary)							
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 IDENTIFY)							
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)**
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 Problen)**
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 35 on page 68) 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 shall be 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 shall be set to 0h.
- **Reason** indicates the reason for the last link reset sequence as reported in the last transmitted IDENTIFY address frame. (see Table 34 on page 67). 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. For Reason field, refer Table 35 on page 68.
- **Negotiated PHY Link Rate** is set to the link rate negotiated during last Link Reset Sequence.
    - set to 8h when the PHY is enabled and the negotiated speed is 1.5G
    - set to 9h when the PHY is enabled and the negotiated speed is 3.0G
    - set to Ah when the PHY is enabled and the negotiated speed is 6.0G
    - set to Bh when the PHY is enabled and the negotiated speed is 12.0G
- **Generation Code** is a one-byte counter that shall be incremented by one by the device server every time the values in this mode page or the SAS-2 Phy mode page (see section 16.9.12.5) 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.

- **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** increments by one 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.
- **Phy Event Descriptor Length** indicates the number of bytes in the phy event descriptor, which is 0Ch.
- **Number of Event Descriptors** indicates the number of phy event descriptors in the phy event descriptor list, which is 04h.
- **Event Source (01h) - Invalid Dword Count**. The "Phy Event" field following this event source contains the number of invalid dwords detected by the phy since power on. The "Peak Value Detector Threshold" is set to 00000000h to indicate this is a counter and not a peak value detector.
- **Event Source (02h) - Running Disparity Error Count**. The "Phy Event" field following this event source contains the number of disparity errors detected by the phy since power on. The "Peak Value Detector Threshold" is set to 00000000h to indicate this is a counter and not a peak value detector.
- **Event Source (03h) - Loss of Dword Synchronization Count**. The "Phy Event" field following this event source contains the number of times the receiver has lost dword synchronization since power on. The "Peak Value Detector Threshold" is set to 00000000h to indicate this is a counter and not a peak value detector.
- **Event Source (04h) - Phy Reset Problem Count.** The "Phy Event" field following this event source contains the number of times the phy has encountered a phy reset problem condition since power on. The "Peak Value Detector Threshold" is set to 00000000h to indicate this is a counter and not a peak value detector.

16.6.15 Log Sense Page 19h - General Statistics and Performance

Table 89: Log Sense Page 19h - General Statistics and Performance

Byte	Bit							
	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					

- **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 90: Time Interval Descriptor

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

4-7	**Integer**

• **Exponent** contains the negative power of 10 exponent 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 91: Log Sense Page 1A- Accumulated Transitions

Byte	Bit							
	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	
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 92: **Log Sense Page 2Fh - SMART Status and Temperature Reading**

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Reserved		Page code = 2Fh					
1	Reserved							
2-3	PageLength = 4Ch							
4-5	Parameter Code = 0000h							
6	DU = 0	DS = 0	TSD = 0	ETC = 0	TMC = 0		F&L = 11b	
7	Parameter Length = 8							
8	SMART Sense Code Byte							
9	SMART Sense Qualifier							
10	Most Recent Temperature Reading							
11	Vendor Temperature Trip Point							
12	Vendor Unique Maximum Temperature							
13-15	Vendor Unique - Reserved							
16-79	Vendor Unique Parameters (see Table 93:)							

Table 93: Log Sense Page 2Fh - Vendor Unique parameter Code = 0000

Byte	Bit							
	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	PageLength = 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 zero at the time of manufacture. A value of 100 indicates that the threshold has been reached and SMART trip will be 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.

For the vendor unique parameters codes > 0000h:

Parameter code = 0001h Remaining Reserve 1

Parameter code = 0002h Remaining Reserve XOR

Parameter code = 0003h XOR Depletion

Parameter code = 0004h Volatile Memory Backup Failure

Parameter code = 0005h Wear Indicator

Parameter code = 0006h System Area Wear Indicator

Parameter code = 0007h Channel Hangs
Parameter code = 0008h Flash Scan Failure
Parameter code > 0008h Reserved

16.6.18 Log Sense Page 30h - Reserved Content

Table 94: Log Sense Page 30h - Reserved Content

Byte	Bit							
	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							

16.6.19 Log Sense Page 37h - Miscellaneous Data Counters

Table 95: Log Sense Page 37h - Miscellaneous Data Counters

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="2">Reserved</td><td colspan="6">Page code = 37h</td></tr>
<tr><td>1</td><td colspan="8">Reserved</td></tr>
<tr><td>2-3</td><td colspan="8">Page Length = 0030h (48)</td></tr>
<tr><td>4-5</td><td colspan="8">Parameter Code = 0000h</td></tr>
<tr><td>6</td><td>DU=0</td><td>DS=0</td><td>TSD=0</td><td>ETC=0</td><td colspan="2">TMC = 0</td><td colspan="2">F&L = 00b</td></tr>
<tr><td>7</td><td colspan="8">Parameter Length = 2Ch</td></tr>
<tr><td>8-11</td><td colspan="8">Power on Hours (hours only)</td></tr>
<tr><td>12-19</td><td colspan="8">Total Bytes Read</td></tr>
<tr><td>20-27</td><td colspan="8">Total Bytes Written</td></tr>
<tr><td>28</td><td colspan="8">Max Drive Temp (degrees Celsius)</td></tr>
<tr><td>29-30</td><td colspan="8">Reserved</td></tr>
<tr><td>31</td><td colspan="8">Number of Information Exceptions</td></tr>
<tr><td>32</td><td>MED EXC</td><td>HDW EXC</td><td colspan="6">Reserved</td></tr>
<tr><td>33-40</td><td colspan="8">Total Read Commands</td></tr>
<tr><td>41-48</td><td colspan="8">Total Write Commands</td></tr>
<tr><td>49-51</td><td colspan="8">Reserved</td></tr>
</table>

- **Power on Hours** specifies the total time the drive has been powered on in hours only.
- **Max. Drive Temperature** specifies the maximum temperature, in degrees Celsius, the drive has ever reached.
- **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** counter is incremented for each Read (6) and Read (10) command received.
- **Total Write Commands** counter is incremented for each Write (6), Write (10), Write Verify and Write Verify (16) command received.

16.7 MODE SELECT (15)

Table 96: Mode Select (15)

Byte	Bit							
	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 Section 16.1							

The MODE SELECT (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.

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

- **PF** Page Format bit value of one indicates that the data sent by the Initiator after the Mode Select Header and the Block Descriptor, if any, complies to the Page Format. The Target ignores this field since it only accepts mode parameters in the Page Format.
- **SP** Save Pages indicates

0 The drive shall not save the pages sent during the Data Out phase but will use them for all following commands until the power is removed, a reset is received, or a new MODE SELECT command is received.

1 The drive will save 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 zero suppresses data transfer and is not considered an error.

The MODE SELECT parameter list contains a 4-byte header followed by zero or one block descriptor followed by zero 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 find out which pages are implemented by the drive and the length of those pages. In the Pages of the MODE SENSE command the drive will return 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 will return Check Condition status with sense key of Illegal Request.

Note: If an Initiator sends a MODE SELECT command that changes any parameters that apply to other Initiators, the drive shall generate an unit attention condition for all Initiators except for the one that issued the MODE SELECT command. The drive shall set the additional sense code to Parameters Changed (2Ah).

16.8 MODE SELECT (55)

Table 97: Mode Select (55)

Byte	Bit							
	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 Section 16.1							

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

16.9 MODE SENSE (1A)

Table 98: Mode Sense (1A)

Byte	Bit							
	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 Section 16.1							

The MODE SENSE (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.

- **DBD** Disable Block Descriptor if set to 0, the Target will return the Block Descriptor. If the DBD bit is set to 1, 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 zero 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.

PCF Meaning

0 0 Report current values. The drive returns the current values under which the logical unit is presently configured for the page code specified. The current values returned are

1. Initially following power-up but before the media is accessed, the default values become current. Once the media can be accessed, the saved values are read from the Reserved Area and become current.
2. The parameters set in the last successful MODE SELECT command.
3. The saved values 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 start-up, execution of the MODE SELECT command can modify the current values.

Note: Those parameters associated with format are not considered current and are not saved until the successful completion of a FORMAT UNIT command.
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.
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.

Note: The drive will not process the MODE SELECT command until the completion of spin-up. Therefore, 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 page requested is returned containing information that indicates which fields are changeable. All bits of parameters that are changeable shall be set to one. Parameters that are defined by the drive shall be set to zero. If any part of a field is changeable, all bits in that field shall be set to one.

Note: 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 zero.

1 1 Report saved value. The drive returns the saved value for the page code specified.

Saved values are one of the following:

- the values saved as a result of MODE SELECT command
- identical to the default values
- zero when the parameters are not supported

The Page Length byte value of each page returned by the drive indicates up to which fields are supported on that page.

• **Page Code** specifies which page or pages to return. Page code usage is defined in the figure below.

Table 99: 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 available sense of ILLEGAL REQUEST/INVALID FIELD IN 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 followed by zero or more block descriptors followed by zero or more variable length pages.

16.9.1.1 Header

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

Table 100: Mode parameter header (6)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="8">Mode Data Length</td></tr>
<tr><td>1</td><td colspan="8">Medium Type = 0</td></tr>
<tr><td>2</td><td>WP=0</td><td colspan="2">Reserved</td><td>DPOFUA =1</td><td colspan="4">Reserved</td></tr>
<tr><td>3</td><td colspan="8">Block Descriptor Length (= 0 or 8)</td></tr>
</table>

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

Table 101: Mode parameter header (10)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0-1</td><td colspan="8">Mode Data Length</td></tr>
<tr><td>2</td><td colspan="8">Medium Type = 0</td></tr>
<tr><td>3</td><td>WP=0</td><td colspan="2">Reserved</td><td>DPOFUA =1</td><td colspan="4">Reserved</td></tr>
<tr><td>4-5</td><td colspan="8">Reserved</td></tr>
<tr><td>6-7</td><td colspan="8">Block Descriptor Length (= 0 or 8)</td></tr>
</table>

- **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 zero 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, a Write Protect (WP) bit of zero indicates that the medium is write enabled.
- **DPOFU** when set to 1 indicates that the Target supports the FUA and DPO bits in the Read and Write Commands.
- **Block Descriptor Length** specifies the length in bytes of the block descriptors. When used with the MODE SELECT command, zero or eight is supported by the drive. When used with the MODE SENSE command, the drive returns eight to indicate that only a single block descriptor is available.

Note: 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.

16.9.1.2 Block Descriptor

Table 102: Mode Parameter Block Descriptor

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

The Block descriptor provides formatting information about the Number of Blocks (user addressable) to format at the specified Block Length.

• **Number of Blocks**

When used with the MODE SELECT command, the Number of Blocks field must be

- Zero to indicate not to change available blocks
- 0xFFFFFFFF 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

Any other value is invalid and causes the command to fail with 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, 4224 (8 bytes step) or zero. Otherwise the drive will terminate the command with Check Condition status.

A FORMAT UNIT command is required to cause these parameters to become current only if the block length parameter is different from the current block length.

When used with the MODE SENSE command, the field is dependent on how the media is currently formatted.

16.9.1.3 Page Descriptor

Table 103: Mode Parameter Page Format

Byte	Bit							
	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 Savable when using the MODE SENSE command and set to 1 indicates that the mode page can be saved by the drive in the reserved area of the drive. A PS bit of zero indicates that the supported parameters cannot be saved. When using the MODE SELECT command, the PS bit is reserved (zero).

• **SPF** Sub-Page Format is set to zero to indicate the short page format is used. The bit is set to one to indicate the long format is used, supporting sub-pages. The drive supports the following mode page codes:

Table 104: 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

• **Page Length** specifies the length in bytes of the mode parameters that follow. If the Initiator does not set this value to the value that is returned for the page by the MODE SENSE command, the drive will terminate the command with Check Condition status.

16.9.2 Mode Page 00h - Vendor Unique Parameters

Table 105: Mode Page 00h - Vendor Unique Parameters

Byte	Bit								Default
	7	6	5	4	3	2	1	0	
0	PS	0	Page Code = 00h						80h
1	Page Length = 0Eh								0Eh
2	Ignored					EMTE	EM		00h
3	Ignored								00h
4	Ignored								00h
5	Ignored			FDD	Ignored		CAEN	Ignored	02h
6	Ignored				OCT (high nibble)				00h
7	Overall Command Timer (low byte)								00h
8	Ignored								00h
9	Temperature Threshold								00h
10	Ignored								00h
11	Ignored								30h
12	Error Injection	Read Reporting Threshold							2Ah
13	Ignored								00h
14	Ignored				FFMT	Ignored			00h
15	Ignored					SPI Flash Test	SRS	Reserved	04h

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.

- **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.
- **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.
- **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 one, Format Degraded sense data will not be reported for a Test Unit Ready command. When the FDD bit is zero, Format Degraded sense data will be reported for Test Unit Ready commands when the drive is in a format degraded state. This bit does not affect the reporting of Format Degraded conditions for any media access commands.
- **CAEN** Command Aging Enable when set to 1, it causes the Command Age Limit timer to be used to avoid commands waiting in the command queue for an indefinite period. When commands have been in the queue for a period of time greater than the timer limit they will be reordered to be executed on a first come first served basis. When this bit is reset, commands are always executed based on the queue reordering rules.
- **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 Check Condition status, 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 zero disabled the feature.
- **Temperature Threshold** specifies the threshold value in degrees Celsius for the thermal sensor Information Exception Warning; the reporting of which is controlled by Mode Page 0x1C. A value of 0 selects the default value (70 degrees Celsius).

- **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 only be used in a drive test mode to validate drive and system error reporting and handling functionality.'.
- **Read Reporting Threshold** specifies the bits-in-error threshold at which recovered errors will be reported when PER in Mode Page 0x01 is set to 1. The bit error on the media needs to exceed this threshold before it will be reporting. Valid values for this field range from 6 to 44 bits in error.1
- **FFMT** when set to 1, it enables Fast Format. Fast format makes all LBAs immediately available for writing. Block erase errors may not be reported until after the format command has completed. Refer to section 18.12.1 for format times.
- **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.

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

Table 106: 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	C0h
3	Read Retry Count								01h
4	Obsolete								00h
5	Obsolete								00h
6	Obsolete								00h
7	Reserved								00h
8	Write Retry Count								00h
9	Reserved								00h
10-11	Recovery Time Limit								00h

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

- **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 if LBAs are to be transferred to the host even if they are in error. The device shall return 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 or not 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 is ignored.
- **DCR** Disable Correction bit, is ignored.
- **Read Retry Count** is ignored. Read recovery is always performed.
- **Write Retry Count** is ignored.
- **Recovery Time Limit** is ignored.

16.9.4 Mode Page 02h - Disconnect/Reconnect Parameters

Table 107: Mode Page 02h - Disconnect/Reconnect Parameters

Byte	Bit								
	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
12-13	Reserved								00h
14-15	First Burst Size = 0								00h

The disconnect/reconnect page provides the Initiator with the means to tune the performance of the SAS Link.

The drive uses the disconnect/reconnect 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).

- **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 will prepare 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.
- **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.

16.9.5 Mode Page 03h - Format Device Parameters

Table 108: Mode Page 03h - Format Device Parameters

Byte	Bit 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

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

- **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. The value depends upon the current formatted Block Length.
- **Interleave** value of 1 or 0 is valid. However, the drive will ignore this.
- **Track Skew Factor** is obsolete for SSDs.
- **Cylinder Skew Factor** is obsolete for SSDs.
- **SSEC** when 0, indicates that the drive does not support soft sector formatting.
- **HSEC** when 1, indicates that the drive supports hard sector formatting.
- **RMB** when 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

Table 109: Mode Page 04h - Rigid Disk Drive Geometry Parameters

Byte	Bit								
	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 Precompensation = 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						RPL = 0		00h
18	Rotational Offset = 0 (Not used)								00h
19	Reserved								00h
20-21	Medium Rotation Rate								00h 01h
22-23	Reserved								00h

The rigid disk drive geometric page specifies various parameters for the drive.

• **Medium Rotation Rate** when 1, indicates the drive is an SSD.

16.9.7 Mode Page 07h - Verify Error Recovery Parameters

Table 110: Mode Page 07h - Verify Error Recovery Parameters

Byte	Bit								
	7	6	5	4	3	2	1	0	Default
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	Obsolete								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 associated with the verification of the Initiator's Data for the following commands:

• VERIFY

• WRITE AND VERIFY is the verify portion of the command only.

• **EER** is ignored.

• **PER** is ignored. The PER setting in Mode Page 01h is used for Verify commands.

• **DTE** is ignored.

• **DCR** is ignored.

• **Verify Recovery Time Limit** is ignored.

16.9.8 Mode Page 08h - Caching Parameters

Table 111: Mode Page 08h - Caching Parameters

Byte	Bit								
	7	6	5	4	3	2	1	0	Default
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
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

The caching parameters page defines parameters that affect the use of the cache.

- **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** 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 will be 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 112: Mode Page 0Ah - Control Mode Page Parameters

Byte	Bit								Default
	7	6	5	4	3	2	1	0	
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
8-9	Busy Timeout Period								00h
10-11	Extended Self-test Routine Completion Time								XXh

Following are parameter options for Page 0A.

- **DPICZ** Disable Protection Information Check Zero bit set to zero 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:

  a) the RDPROTECT field (see SBC-3) set to zero;
  b) the VRPROTECT field (see SBC-3) set to zero; or
  c) the ORPROTECT field (see SBC-3) set to zero.

- **Queue Algorithm Modifier** specifies restrictions on the algorithm used for reordering commands that are tagged with the SIMPLE message.
  0h: Restricted reordering. The Target shall reorder the actual execution sequence of the queued commands from each Initiator such that data integrity is maintained 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.

  8: Command reordering is disabled

  9-Fh: Reserved

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

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 are allowed to resume execution in a normal fashion after the CA condition is cleared.**

01b	**Specifies that all tasks from all Initiators are aborted when the Target returns *Check Condition* status. A unit attention condition will be generated for each Initiator that had commands in the queue except for the Initiator that received the *Check Condition* status. The sense key will be set to *Unit Attention* and the additional sense code will be set to *Commands Cleared by Another Initiator.***
10b	**Reserved**
11b	**Blocked tasks in the task set belonging to the Initiator to which a *Check Condition* status is sent shall be aborted when the status is sent.**

- **DQue** Disable Queuing set at zero specifies that tagged queuing shall be enabled if the Target supports tagged queuing. A DQue bit set at one specifies that tagged queuing shall be disabled. Command queuing is always enabled on the drive, therefore this bit is ignored.
- **ATO** Application Tag Owner set to one specifies that the contents of the Logical Block Application Tag field in the protection information, if any, shall not be modified by the drive. An ATO bit set to zero 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 zero, the drive will ignore the contents of the Logical Block Application Tag field in the protection information.
- **ATMPE** Application Tag Mode Page Enabled bit set to zero specifies that the Application Tag mode page (see SBC-3) is disabled and the contents of logical block application tags are not defined. An ATMPE bit set to one specifies that the Application Tag mode page is enabled.

  If:

  a) the ATMPE is set to one;
  b) the ATO bit is set to one;
  c) the value in the DPICZ bit allows protection information checking for the specified command; and
  d) the APP_CHK bit is set to one in the Extended INQUIRY VPD page.

  then:

  knowledge of the value of the Application Tag shall come from the values in the Application Tag mode page as specified by the DPICZ bit.

- **RWWP** Reject Write Without Protection bit set to zero specifies that the device server shall process write commands that are specified to include user data without protection information (e.g., a WRITE(10) command with the WRPROTECT field set to 000b (see SBC-3)). A RWWP bit set to one specifies that the device server in a logical unit that has been formatted with protection information shall terminate with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code 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 to determine 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 execution of the self-test routine.

16.9.9.1 Control Extension Subpage

Table 113: Control Extension Subpage

Byte	Bit 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 and indicates 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 shall return in the same I_T_L_Q nexus transaction as the status. A Maximum Sense Data Length field set to zero specifies that there is no limit. The device server shall not return more sense data bytes in the same I_T_L_Q nexus transaction as the status than the smaller of the length indicated by the:

  a) Maximum Sense Data Length field; and

  b) 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 (see table 184) specifies the Application Tag that a device server configured for protection information (see 4.22.2) shall use for each LBA range if the ATO bit in the Control mode page (see SPC-4) is set to one. The mode page policy (see SPC-4) for this page shall be shared.

If a method not defined by this standard changes the parameter data to be returned by the device server in the Application Tag mode page, then the device server shall establish a unit attention condition for the SCSI initiator port associated with every I_T nexus with the additional sense code set to MODE PARAMETERS CHANGED.

Table 114: Application Tag mode page

Byte	Bit 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 saveable (PS) bit, the subpage format (SPF) bit, the Page Code field, the Subpage Code field, and the Page Length field are defined in SPC-4.

The SPF bit, the Page Code field, the Subpage Code field, and the Page Length field shall be set to the values shown in previous table.
The application tag descriptors are defined in next table.

Table 115: Application Tag descriptor format

Byte	Bit							
	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							

A Last bit set to one specifies that this Application Tag descriptor is the last valid Application Tag descriptor in the Application Tag mode page. A Last bit set to zero specifies that the Application Tag descriptor is not the last valid Application Tag descriptor in the Application Tag mode page.

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 shall be set to 0000_0000_0000_0000h. For subsequent Application Tag descriptors, the contents of the Logical Block Address field shall contain the sum of the values in:

a) the Logical Block Address field in the previous Application Tag descriptor; and
b) the Logical Block Count field in the previous Application Tag descriptor.

The sum of the Logical Block Address field in the Application Tag descriptor with the Last bit set to one and the Logical Block Count field in the Application Tag descriptor with the Last bit set to one shall equal 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 shall terminate the Mode Select command (see SPC-4) with Check Condition status 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 shall be ignored.

This drive supports a maximum of 16 Application Tag descriptors.

16.9.10 Mode Page 0Ch - Notch Parameters

Table 116: Mode Page 0Ch - Notch Parameters

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th><th></th></tr>
<tr><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th><th>Default</th></tr>
<tr><td>0</td><td>PS</td><td>0</td><td colspan="6">Page Code = 0Ch</td><td>8Ch</td></tr>
<tr><td>1</td><td colspan="8">Page Length = 16h</td><td>16h</td></tr>
<tr><td>2</td><td>ND=1</td><td>LPN=0</td><td colspan="6">Reserved</td><td>80h</td></tr>
<tr><td>3</td><td colspan="8">Reserved</td><td>00h</td></tr>
<tr><td rowspan="2">4-5</td><td colspan="8" rowspan="2">Maximum Number of Notches</td><td>00h</td></tr>
<tr><td>00h</td></tr>
<tr><td rowspan="2">6-7</td><td colspan="8" rowspan="2">Active Notch</td><td>00h</td></tr>
<tr><td>00h</td></tr>
<tr><td rowspan="2">8-11</td><td colspan="8" rowspan="2">Starting Boundary</td><td>00h</td></tr>
<tr><td>00h</td></tr>
<tr><td rowspan="2">12-15</td><td colspan="8" rowspan="2">Ending Boundary</td><td>00h</td></tr>
<tr><td>00h</td></tr>
<tr><td>16-23</td><td colspan="8">Pages Notched</td><td>0000h
0000h
0000h
0000h</td></tr>
</table>

The notch page is obsolete for SSDs.

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

(SAS only)

Table 117: Mode Page 18h - Protocol-Specific Logical Unit

Byte	Bit								
	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

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

- **Transport Layer Retries** is unchangeable and set to zero. 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. There is one copy of the mode page shared by all SSP initiator ports.

16.9.12.1 Short Format of Port Control Page

Table 118: Short (Port Control Parameters) Short Format

Byte	Bit 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
10-15	Reserved								00h

- **PS** Parameters Savable is set to 1, indicating the parameters are saveable.
- **SPF** shall be set to zero for access to the short format mode page.
- **Protocol Identifier** has a value of 6h indicating this is a SAS SSP specific mode page.
- **Continue AWT** bit set to one specifies that the SAS port shall not stop the Arbitration Wait Time timer and set the Arbitration Wait Time timer to zero when the SAS port receives an OPEN_REJECT (RETRY). A CONTINUE AWT bit set to zero specifies that the SAS port shall stop the Arbitration Wait Time timer and set the Arbitration Wait Time timer to zero when it receives an OPEN_REJECT (RETRY).
- **Broadcast Asynchronous Event** bit set to one specifies that the device server shall enable origination of Broadcast (Asynchronous Event). A BROADCAST ASYNCHRONOUS EVENT bit set to zero specifies that the device server shall disable 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 flashes on and off when commands are processed. When the bit is 1, the LED is usually off, but 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 our SSP target port shall retry connection requests to an SSP initiator port that are 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 time period. A value of FFFFh indicates an unlimited period. The default value of 7D0h, specifies a 2 second time period.
- **Initiator Response Timeout** contains the time in milliseconds that the SSP target port shall wait for the receipt of a Data frame after sending the XFER_RDY frame requesting data. When the INITIATOR RESPONSE TIMEOUT expires, the associated command will be aborted. An INITIATOR RESPONSE TIMEOUT field value of zero indicates that the SSP target port shall 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 shall wait to establish a connection request with an initiator port on an I_T nexus after receiving an OPEN_REJECT (RETRY), OPEN_REJECT (CONTINUE 0), or OPEN_REJECT (CONTINUE 1). This value may be rounded as defined in SPC-4. A REJECT TO OPEN LIMIT field set to 0000h indicates that 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

Table 119: Long Format of Port Control Page

Byte	Bit								Default
	7	6	5	4	3	2	1	0	
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									...

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

• **SPF** shall be set to one for access to the long format mode page.
• **Subpage Code** indicates which subpage is being accessed. The drive support the following subpage codes. If the Subpage Code is not supported, the drive returns a CHECK CONDITION status, the sense key is set to ILLEGAL REQUEST and the additional sense code set to ILLEGAL FIELD IN PARAMETER LIST.

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

Table 120: PHY Control and Discover - Subpage 1

Byte	Bit								Default
	7	6	5	4	3	2	1	0	
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								...

The Phy Control And Discover subpage contains phy-specific parameters. MODE SENSE command returns the current settings for the initiator.

- **Protocol Identifier** has a value of 6h indicating this is a SAS SSP specific mode page.
- **Generation Code** is a one-byte counter that shall be incremented by one by the device server every time the values in this mode page or the SAS Phy mode page (see 16.9.12.5) 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.
- **Number of PHYS** is set to 2, to represent the dual ported drive (one PHY per port)
- **SAS PHY Mode Descriptor** are defined in Table 121 on page 169. There are two SAS PHY Mode Descriptor fields, one per port.

Table 121: SAS PHY Mode Descriptor

Byte	Bit							
	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 Initia-tor Port	Attached STP Initia-tor Port	Attached SMP Initia-tor 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** indicates the Unique PHY Identifier for 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 associated with the PHY Identifier list in this SAS PHY Mode Descriptor. See Table 34 on page 67.

• **Attached Device Type** indicated the value of the DEVICE TYPE field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor. See Table 34 on page 67.
• **Attached SAS Address** indicates the value of the attached SAS address in the last received IDENTIFY address frame associated with the PHY Identifier list in this SAS PHY Mode Descriptor. See Table 34 on page 67.
• **Attached PHY Identifier** indicated the value of the attached PHY Identifier field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.See Table 34 on page 67.
• **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.
• **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 122: Shared Port Control - Subpage 2

Byte	Bit								Default
	7	6	5	4	3	2	1	0	
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 will respond to connection requests with OPEN_REJECT(RETRY) after receiving NOTIFY(POWER LOSS EXPECTED). The Power Loss Timeout will be restarted after each NOTIFY(POWER LOSS EXPECTED) that is received. A POWER LOSS TIMEOUT field set to 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 123: SAS Phy Mode Page - Subpage 3

Byte	Bit								
	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								--

- **Generation Code** is a one-byte counter that shall be incremented by one by the device server every time the values in this mode page or the SAS Phy mode page (see section 16.9.12.5) 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.

Table 124: PHY Mode Descriptor (0 and 1)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="8">Reserved</td></tr>
<tr><td>1</td><td colspan="8">PHY Identifier</td></tr>
<tr><td>2-3</td><td colspan="8">Descriptor Length (0010h)</td></tr>
<tr><td>4-7</td><td colspan="8">Programmed PHY Capabilities</td></tr>
<tr><td>8-11</td><td colspan="8">Current PHY Capabilities</td></tr>
<tr><td>12-15</td><td colspan="8">Attached PHY Capabilities</td></tr>
<tr><td>16-17</td><td colspan="8">Reserved</td></tr>
<tr><td>18</td><td colspan="3">Reserved</td><td>Negotiated SSC</td><td colspan="4">Negotiated Physical Link Rate</td></tr>
<tr><td>19</td><td colspan="5">Reserved</td><td>Enable Slumber</td><td>Enable Partial</td><td>Hardware Muxing Supported='0'</td></tr>
</table>

• **Phy Capabilities** are defined under the "SAS Speed Negotiation" on page 65
• **Enable Partial** enables the drive to support partial slumber power down
• **Enable Slumber** enables the drive to support slumber power down

More information on Power Management at 15.4.6

16.9.13 Mode Page 1Ah - Power Control

Table 125: Page 1Ah - Power Control

Byte	Bit 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
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** if set to one, then the standby_y condition timer is enabled. If the STANDBY_Y bit is set to zero, then the device shall ignore the standby_y condition timer.
- **Idle_C** if set to one, then the idle_c condition timer is enabled. If the IDLE_C bit is set to zero, then the device shall ignore the idle_c condition timer.
- **Idle_B** if set to one, then the idle_b condition timer is enabled. If the IDLE_B bit is set to zero, then the device shall ignore the idle_b condition timer.
- **Idle_A** if set to one, then the idle_a condition timer is enabled. If the IDLE_A bit is set to zero, then the device shall ignore the idle_c condition timer.
- **Standby_Z** if set to one, then the standby_z condition timer is enabled. If the STANDBY_Z bit is set to zero, then the device shall ignore 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 will automatically default 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 will automatically default to two minutes. In addition, a limit of 60 timer initiated head unloads per 24 hour period is enforced.

- **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 will automatically default to two minutes. In addition, a limit 60 timer initiated head unloads per 24 hour period is enforced.
- **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 will automatically default to two minutes. In addition, a limit of 60 timer initiated head unloads per 24 hour period is enforced.
- **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 will automatically default to two minutes. In addition, a limit 60 timer initiated head unloads per 24 hour period is enforced

16.9.13.1 Power Consumption - Subpage 1

Table 126: Power Consumption - Subpage 1

Byte	BIT								
	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								00h
8-15	Reserved								0000h

- **Power Consumption ID** specifies the current power consumption mode enabled on the drive. Valid values are:

0x00 - 9 Watt mode
0x01 - 11 Watt mode

16.9.14 Mode Page 1Ch - Informational Exceptions Control

Table 127: Page 1Ch - Informational Exceptions Control

Byte	BIT								
	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	EBACK-ERR	LOGERR	10h
3	Reserved				Method of Reporting				03h
4-7	Interval Time								00h
									00h
									00h
									00h
8-11	Report Count								00h

- **PERF** Performance bit is not supported and is ignored. Informational Exception operations will not cause performance delays.
- **EBF** Enable Background Function bit is not supported and is ignored. Background functions are always enabled.
- **EWASC** Enable Warning ASC bit of 0 indicates that warnings will not be reported. An EWASC bit of one allows warnings to be reported. The Method of Reporting field controls the reporting method. EWASC is independent of DEXCPT.
- **DEXCPT** Disable Exception Control bit of 0 indicates information exception operations are enabled. The reporting of information exception conditions when the DEXCPT bit is set to zero is determined from the Method of Reporting field. A DEXCPT bit of one indicates the Target disabled all information exception operations.
- **TEST** bit of 1 instructs the drive to 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 would apply. The false drive failure is reported as sense qualifier 5DFFh. The TEST bit of zero instructs the drive to stop generating any false drive notifications.
- **EBACKERR** Enable Background Error bit of 0 disables reporting of background self-test errors and background scan errors via Information Exceptions Control. An EBACKERR bit of one enables reporting of 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.

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, 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, 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 for reporting that an informational exception condition has occurred. The target shall not report informational exception conditions more frequently than the time specified by the Interval Timer field and 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 or 0xFFFFFFFF in the Interval Timer field indicates that the target only reports the informational exception condition one time 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. The Report Count of ZERO indicates no limits on the number of times the Target reports an informational exception condition.

16.9.14.1 Background Control - Subpage 01h

Table 128: Background Control - Subpage 01h

Byte	BIT								
	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 is set to 0 to allow background scans to continue if the results log (Log Sense Page 15h) is full. S_L_FULL bit set to one will cause background scans to suspend when the log is full.
- **LOWIR** Log Only When Intervention Required bit set to 0 allows logging of all medium errors in the results log (Log Sense Page 15h). When the LOWIR bit is set to one, only unrecovered medium errors will be logged.
- **EN_BMS** Enable Background Medium Scan bit set to 0 specifies that the background medium scan is disabled. EN_BMS bit set to one specifies that background medium scan operations are enabled. If a background medium scan is in progress when the EN_BMS bit is changed from one to zero, then the medium scan shall be suspended until the EN_BMS bit is set to one, at which time the medium scan shall resume from the suspended location.
- **EN_PS** Enable Pre-Scan bit set to 0 specifies that the pre-scan is disabled. If a pre-scan operation is in progress when EN_PS is changed from a one to a zero, then pre-scan is halted. An EN_PS bit set to one specifies that a pre-scan operation is started after the next power-on cycle. Once this pre-scan has completed, another pre-scan shall not occur unless the EN_PS bit is set to zero, then set to one, 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, then it is halted. A value of zero specifies an unlimited 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 will be treated as the default value of 1.0 second. Any value less than 100 milliseconds will be treated as 100 milliseconds. The internal timer granularity is 50 milliseconds.
- **Maximum Time To Suspend Background Scan** is ignored.

16.10 MODE SENSE (5A)

Table 129: Mode Sense (5A)

Byte	Bit							
	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 Section 16.1							

The MODE SENSE (5A) command provides a means for 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.

16.11 PERSISTENT RESERVE IN (5E)

Table 130: Persistent Reserve In (5E)

Byte	Bit							
	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 Section 16.1							

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

- **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 will be 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

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 CDB*.

Table 131: PERSISTENT RESERVE IN, Service Action Codes

Code	Name	Descriptions
00h	Read Keys	Reads all registered Reservation Keys
01h	Read Reservations	Reads all current persistent reservations
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 132: PERSISTENT RESERVE IN, parameter data for Read Keys

Byte	Bit							
	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 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 shall increment every time a PERSISTENT RESERVE OUT command requests a Register, a Clear, a Preempt, or a Preempt and Abort service action. The counter shall not be incremented by a PERSISTENT RESERVE IN command, by a PERSISTENT RESERVE OUT command that performs a Reserve or Release service action, or by a PERSISTENT RESERVE OUT command that is not performed due to an error or reservation conflict. Regardless of the APTPL value the generation value shall 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 shall be sent to the Initiator. The incremental remaining bytes shall be truncated, although the Additional Length field shall still contain the actual number of bytes in the reservation key list without consideration of any truncation resulting from an insufficient allocation length. This shall not be 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 133: PERSISTENT RESERVE IN, parameter data for Read Reservations

Byte	Bit 7	6	5	4	3	2	1	0
0-3	Generation							
4-7	(Additional length (n-7)							
8-n	Reservation descriptors							

- **Generation** shall be 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 not sufficient to contain the entire parameter list, then only the bytes from 0 to the maximum allowed allocation length shall be sent to the Initiator. The remaining bytes shall be truncated, although the Additional Length field shall still contain the actual number of bytes of the Reservation Descriptor(s) and shall not be affected by the truncation. This shall not be considered an error.
- **Reservation Descriptors**' format is defined in the Persistent Reserve In Reservation Descriptor table. There shall be a Reservation Descriptor for the persistent reservation, if any, present in the Target having a persistent reservation.

Table 134: PERSISTENT RESERVE IN, Read Reservation Descriptor

Byte	Bit 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							

- **Scope** of each persistent reservation created by a PERSISTENT RESERVE OUT command will be returned. See the PERSISTENT RESERVE OUT command section for details.

16.12 PERSISTENT RESERVE OUT (5F)

Table 135: PERSISTENT RESERVE OUT (5F)

Byte	Bit							
	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 Section 16.1							

The PERSISTENT RESERVE OUT command 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, and should not be used with the RESERVE and RELEASE commands.

Note: If a PERSISTENT RESERVE OUT command is received when a RESERVE is active for the drive, the command will be rejected with **Reservation Conflict** status.

• **Parameter List Length** must be 18h. If not, Check Condition status will be returned, with sense key of Illegal Request and additional sense code of Parameter List Length Error.

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16.12.1 Service Action

The following service action codes are supported.

Table 136: PERSISTENT RESERVE OUT, Service Action Code

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

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 137: PERSISTENT RESERVE OUT, Type Code

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

16.12.3 Parameter list

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

Table 138: Parameter List

Byte	**Bit**							
	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** If the Specify Initiator Ports bit is set to zero, the device server shall apply the registration only to the I_T nexus that sent the PERSISTENT RESERVE OUT command. If the SPEC_I_PT bit is set to one for any service action except the REGISTER service action, then the command shall be terminated with CHECK CONDITION status, with the sense key set to ILLEGAL REQUEST, and the additional sense code set to INVALID FIELD IN PARAMETER LIST. If the SPEC_I_PT bit is set to one for the REGISTER service action, the additional parameter data (see table XXX) shall include a list of transport IDs and the device server shall also apply 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 shall be made, and the command shall be terminated with CHECK CONDITION status.

For Transport IDs, please refer to Table 218 on page 389 of Spc4r36.

- **ALL_TG_PT** All Target Ports bit is valid only for the REGISTER service action and the REGISTER AND IGNORE EXISTING KEY service action, and shall be ignored for all other service actions. Support for the ALL_TG_PT bit is optional. If the device server receives a REGISTER service action or a REGISTER AND IGNORE EXISTING KEY service action with the ALL_TG_PT bit set to one, it shall create the specified registration on all target ports in the SCSI target device known to the device server (i.e., as if the same registration request had been received individually through each target port). If the device server receives a REGISTER service action or a REGISTER AND IGNORE EXISTING KEY service action with the ALL_TG_PT bit set to zero, it shall apply the registration only to the target port through which the PERSISTENT RESERVE OUT command was received.
- **APTPL** Activate Persist Through Power Loss bit 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 zero, power loss will cause all persistent reservations to be released, and all reservation keys to be removed. If the last valid APTPL bit value received is one, any persistent reservation and all reservation keys for all initiators will be retained across power cycles.

16.12.4 Summary

Table 139: PERSISTENT RESERVE OUT, Service Action, Parameters

Service Action	Parameters						Generation counter
	Scope Type	Rsv Key	SvcAct RsvKey	S-spec addr	Extent length	APTPL	
(0) Register	ignore	verify	save	ignore	ignore	apply	+ 1
(1) Reserve	apply	verify	ignore	ignore	ignore	ignore	---
(2) Release	apply	verify	ignore	ignore	ignore	ignore	---
(5) Preempt and Abort	apply	verify	save	ignore	ignore	ignore	+ 1

16.12.4.1 Scope, Type

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

16.12.4.2 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.

16.12.4.3 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 Initiator requesting PERSISTENT RESERVE OUT command.

On Preempt and Clear service action, the reservation that has a key specified in the Service Action Reservation Key field is preempted.

On other service actions, this field is ignored.

16.12.4.4 APTPL

The APTPL (Active Persist Through Power Loss) 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 140: APTPL and information held by a drive

Information held by the drive	**The last valid APTPL value**	
	0	**1**
Registration	**all keys are set to 0**	**retained**
Persistent Reservation	**all are removed**	**retained**
Generation counter	**set to 0**	**set to 0**

16.12.4.5 Generation counter

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

16.13 PRE-FETCH (10) - (34)

Table 141: PRE-FETCH (10) - (34)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 34h							
1	Reserved						Immed = 0	Obso-lete
2-5	Logical Block Address							
6	Reserved							
7-8	Transfer Length							
9	Control Byte - refer to Section 16.1							

The PRE-FETCH command requests the drive to transfer data to the cache. This command is implemented as a no-op and returns good status on the SSD.

16.14 PRE-FETCH (16) - (90)

Table 142: PRE-FETCH (16) - (90)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 90h							
1	Reserved						IMMED	RSVD
2-9	Logical Block Address							
10-13	Prefetch Length							
14	Reserved			Group Number				
15	Control Byte - refer to Section 16.1							

The PRE-FETCH command requests the drive to transfer data to the cache. This command is implemented as a no-op and returns good status on the SSD.

16.15 READ (6) - (08)

Table 143: READ (6) - (08)

Byte	Bit							
	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 Section 16.1							

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

• **Logical block address** specifies the logical unit at which the READ operation shall begin.

• **Transfer length** specifies the number of blocks to be transferred. A value of zero implies 256 blocks are to be transferred.

16.16 READ (10) - (28)

Table 144: READ (10) - (28)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 28h							
1	RDPROTECT			DPO	FUA	RSVD	FUA_ NV	Obso- lete
2-5	Logical Block Address							
6	Reserved							
7-8	Transfer Length							
9	Control Byte - refer to Section 16.1							

The READ (10) command 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 and are required to access the full LBA range of the larger capacity drives.

- **FUA_NV** Force Unit Access Non-Volatile Cache may be set to 0 or 1, but is ignored since NV_SUP=0 in Inquiry Page 86h.
- **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. If read ahead is enabled, a read ahead is started after the seek completes.
- **DPO** Disable Page Out bit is ignored.
- **FUA** Force Unit Access bit is ignored.
- **RDPROTECT** defines the manner in which protection information read from drive shall be checked during processing of the command. Protection information is stored on 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, else **Check Condition** status will be returned with sense key of Illegal Request and additional sense code of Invalid Field in CDB.

  - RDPROTECT=000b

    Protection information is checked (if applicable), but not transmitted to the initiator.

    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.

    Note Protection information is not checked if DPICZ = 1.

  - RDPROTECT=001b

    Protection information is transmitted to the initiator 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

- RDPROTECT=010b

  Protection information is transmitted to the initiator 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

- RDPROTECT=011b

  Protection information is transmitted to the initiator with the user data

  Logical Block Guard is not checked

  Logical Block Application Tag is not checked

  Logical Block Reference Tag is not checked

- RDPROTECT=100b

  Protection information is transmitted to the initiator with the user data

  Logical Block Guard is checked

  Logical Block Application Tag is not checked

  Logical Block Reference Tag is not checked

- RDPROTECT=101b

  Protection information is transmitted to the initiator 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

- RDPROTECT=110b, 111b

  These values are reserved. **Check Condition** status will be returned with sense key of Illegal Request and additional sense code of Invalid Field in CDB.

• If a check of the protection information fails, **Check Condition** status will be returned with sense key of Aborted Command and 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 zero, no data is transferred. The CDB is validated and protocol checked and, if no problems are found, **Good** status is returned immediately. This condition is not considered an error.

16.17 READ (12) - (A8)

Table 145: Read (12) - (A8)

Byte	Bit							
	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 Section 16.1							

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

16.18 READ (16) - (88)

Table 146: READ (16) - (88)

Byte	Bit							
	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 Section 16.1							

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

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

Table 147: READ (32) - (7F/09)

Byte	Bit 7	6	5	4	3	2	1	0
0	Command Code = 7Fh							
1	Control Byte - refer to Section 16.1							
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							

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

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 will be processed normally. Any other protection types will result in Check Condition status to be returned with sense key of Illegal Request and 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 of the first logical block accessed by the command.

If the ATO bit is set to one in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a value that is a bit mask for enabling the checking of 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 one 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 zero, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

16.20 READ BUFFER (3C)

Table 148: READ BUFFER (3C)

Byte	Bit							
	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 Section 16.1							

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

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

MODE	Description
00000	Read Combined Header and Data
00010	Read Data
00011	Descriptor
01010	Read Data from Echo Buffer
01011	Echo Buffer Descriptor
11010	Enable Expander Communications Protocol and Echo Buffer
All others	Not supported

16.20.1 Combined Header And Data (Mode 00000b)

In this mode a 4-byte header followed by data bytes is returned to the Initiator during the DATA IN phase. The Buffer ID and the buffer offset field are reserved.

The drive terminates the DATA IN phase when allocation length bytes of header plus data have been transferred or when the header and all available data have been transferred to the Initiator, whichever is less.

The 4-byte READ BUFFER header (see figure below) is followed by data bytes from the data buffer of the drive.

Table 149: Read Buffer Header

Byte	Bit						
	7	6	5	4	3	2	1
0	Reserved						
1-3	Buffer Capacity						

The buffer capacity specifies the total number of data bytes that are available in the data buffer of the drive. This number is not reduced to reflect the allocation length nor is it reduced to reflect the actual number of bytes written using the WRITE BUFFER command.

Following the READ BUFFER header the drive will transfer data from its data buffer.

16.20.2 Read Data (Mode 00010b)

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

- **Buffer ID** must be set to zero, indicating the data transfer buffer. If another value is specified, the command is terminated with **Check Condition** status. The drive shall set sense key to *Illegal Request* and additional sense code to *Illegal Field in 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 **Check Condition** status. The drive shall set sense key to *Illegal Request* and additional sense code to *Illegal Field in 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 is less.

16.20.3 Descriptor (Mode 00011b)

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

- **Buffer ID** should normally be set to zero, 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 transfered.The allocation length of greater than zero and less than four (size of the Descriptor) is an invalid request and will cause the command to be terminated with **Check Condition** status. The drive shall set sense key to *Illegal Request* and additional sense code to *Illegal Field in CDB*.

The READ BUFFER descriptor is defined in the figure below.

Table 150: Read Buffer Description

Byte	Bit						
	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 two to the power of the offset boundary. The offset boundary is always set to nine, which indicates Sector Boundaries.

16.20.4 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.

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 **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 will cause 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. The echo buffer capacity may be determined by using Read Buffer mode 1011b. Any additional data transferred over and above the echo buffer capacity is regarded as indeterminate.

The Buffer ID and Buffer Offset fields are ignored in this mode.

Note: 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.

16.20.5 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 of following Echo Buffer Descriptor.

Table 151: Echo Buffer Descriptor

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

• **EBOS** Echo Buffer Overwritten Supported bit of zero indicates that the echo buffer is shared by all Initiators.

• **Buffer Capacity** returns the size of the echo buffer in byte aligned to a 4-byte boundary.

16.20.6 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 shall process it as if it were a READ BUFFER command with mode 01010b (see 17.17.4 Read Data from Echo Buffer).

16.21 READ CAPACITY (10) - (25)

Table 152: READ CAPACITY (10) - (25)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 25h							
1	Reserved							
2-5	Logical Block Address							
6-7	Reserved							
8	Reserved							
9	Control Byte - refer to Section 16.1							

The READ CAPACITY command returns information regarding the capacity of the drive.

• **Logical Block Address** is used in conjunction with the PMI bit.

16.21.0.1 Returned Data Format

The data returned to the Initiator in response to the READ CAPACITY command is described here. The data is returned in the DATA IN phase.

Table 153: Format of READ CAPACITY command reply

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

• **Block Length** specifies the length in bytes of each block of user data (not including protection information).

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

Table 154: Read Capacity (16) (9E/10)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 9Eh							
1	Reserved			Service Action = 10h				
2-9	Logical Block Address							
10-13	Allocation Length							
14	Reserved							
15	Control Byte - refer to Section 16.1							

The READ CAPACITY (16) (9E/10) command returns information regarding the capacity of the drive.
This command is processed like the standard READ CAPACITY (25) command.
The contents of the CONTROL byte are defined in SAM-4.

16.22.1 Returned Data Format

Table 155: Returned Data Format

Byte	Bit							
	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							

• **Returned Logical Block Address** and **Logical Block Length In Bytes** field of the READ CAPACITY (16) parameter data are the same as the in the READ CAPACITY (10) parameter data. The maximum value that shall be returned 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 table below:

Table 156: 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 157: LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field

Code	Description
0	One or more physical blocks per logical block (a)
n > 0	2^n logical blocks per physical block
1	The logical unit is formatted to type 2 protection
(a) 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 zero in the Data-In Buffer. If protection information is also transferred on the read operation, it will be all 0xFFs.

• **Lowest Aligned Logical Block Address** indicates the LBA of the first logical block that is located at the beginning of a physical block.

NOTE: The highest LBA that the lowest aligned logical block address field supports is 3FFFh (i.e.,16,383).

16.23 READ DEFECT DATA (37)

Table 158: READ DEFECT DATA (37)

Byte	Bit							
	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 Section 16.1							

The READ DEFECT DATA command requests that the Target transfer the medium defect data to the Initiator.

If the Target is unable to access any medium defect data it will return a **Check Condition** status with the appropriate sense key. The sense key will be set to either *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 set to 1 indicates that the Target returns the Plist. A Plist bit of 0 indicates that the Target shall not return the Plist of defects.
- **Glist** bit set to 1 indicates that the Target returns the Glist. A Glist bit of 0 indicates that the Target shall not return the Glist.

  Note: With both bits set to one Plist and Glist the Target will return both the primary and grown defect lists. With both bits set to zero, the Target will return 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 will return the defect list in its default format '110' and then terminate the command with Check Condition status. The sense key will be set to Recovered Error(01h) and the additional sense code will be set to Defect List Not Found (1Ch).

The Target will transfer all of the Read Defect Data up to the number of bytes allocated by the Initiator.

Note: The drive will terminate the Data In phase when the Allocation Length has been transferred or when all available Defect Data has been transferred to the Initiator, whichever is less.

The Read Defect Data contains a 4-byte header followed by zero or more defect descriptors.

16.23.1 Defect List Header

Table 159: Defect List Header

Byte	Bit							
	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							

16.23.2 Defect List Descriptor

Table 160: 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 will set the Defect List Length field to the amount of space needed to contain the entire defect list. However, the Target is capable of building 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. The Target will transfer a partial defect list and return **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 will be 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 (B7)

Table 161: READ DEFECT DATA (B7)

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 Section 16.1							

(See Section 16.23 READ DEFECT DATA (37)" on page 204.)

16.24.1 Defect List Header

Table 162: Defect List Header

Byte	Bit							
	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 Defect List Header for Read Defect Data (37) in Section Table 16.23.1, "Defect List Header," on page 205.)

16.24.2 Defect List Descriptor

Table 163: 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							

(See Defect List Descriptor for Read Defect Data (37) in Section 16.23.2 Defect List Descriptor" on page 205.)

16.25 READ LONG (3E) -10 bit CDB

Table 164: READ LONG (3E)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 3Eh							
1	Reserved					PBLOCK	Correct = 0	Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Byte Transfer Length							
9	Control Byte - refer to Section 16.1							

The READ LONG command requests the drive to transfer one block of data to the Initiator. The transfer data includes data and ECC field data.

- **Correct** bit is ignored. ECC correction is always performed. If ECC correction fails, the Target terminates the command with **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 at which the read operation shall occur.
- **Byte Transfer Length** must specify exactly the number of bytes of data that are available for transfer. If a non-zero byte transfer length does not match the available data length, the Target terminates the command with **Check Condition** status, the sense key is set to *Illegal Request*, and an additional sense code set to *Invalid Field in CDB*. The valid and ILI bits are set to one 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.
- **PBLOCK** is supported by the drive f there is more than one logical block per physical block (i.e. the LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field in the READ CAPACITY (16) parameter data is set to a non-zero value). If the PBLOCK bit is 0, the drive will return bytes representing only the specified logical block. If the PBLOCK bit is 1, the drive will return the entire physical block containing the specified logical block.

  The transfer length is calculated as follows:

  transfer length = logical block size + protection information size + CRC size *(PBLOCK=0)*

  transfer length = (8 logical block size) +(8* protection information size)+(8* CRC size)* *(PBLOCK=1)*

  where protection information size is either 0 (protection mode 0) or 8(protection mode 1 or 2) and CRC size is 4

The data read by this command is neither read from nor retained in the cache.

16.26 READ LONG (16) - (9E/11) 16-bit CDB

Table 165: READ LONG (16) - (9E/11)

Byte	Bit							
	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						PBLOCK	CORRCT
15	Control							

Refer to description READ LONG (3E) -10 bit CDB, page 208

16.27 REASSIGN BLOCKS (07)

Table 166: REASSIGN BLOCKS (07)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 07h							
1	Reserved							
2-4	Reserved							
5	Control Byte - refer to Section 16.1							

The REASSIGN BLOCKS command is implemented as a no-op on the SSD. To maintain compatibility, the SSD performs protocol checking on the CDB and a range check of the LBA(s) transferred to the drive during the DATA OUT phase.

The REASSIGN BLOCKS command will not modify the specified LBAs or attempt to recover or reallocate them. An unreadable LBA will remain unreadable after execution of a REASSIGN BLOCKS command.

Following is the format of the data sent by the Initiator during the DATA OUT phase.

Table 167: Format of Reassign Blocks data

Byte	Bit						
	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 *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 will be terminated with Check Condition with a sense key of Illegal Request.

16.28 RECEIVE DIAGNOSTICS RESULTS (1C)

Table 168: RECEIVE DIAGNOSTIC RESULTS (1C)

Byte	Bit							
	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 Section 16.1							

The RECEIVE DIAGNOSTIC RESULTS command requests that analysis data requested by a SEND DIAGNOSTIC command be sent to the Initiator.

- **PCV** Page Code Valid bit of 0 indicates that the most recent SEND DIAGNOSTIC command shall define the data returned by this command. PCV bit of one indicates that the contents of the Page Code field shall define the data returned by this command.
- **Allocation Length** specifies the amount of data to be returned to the Initiator. This value may be zero and this 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.

16.28.1 Receive Diagnostic Results Page 0

This page contains a list of supported pages.

Table 169: Receive Diagnostic Results page 0

Byte	Bit							
	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							

The supported diagnostic page returns a list of supported pages in ascending order.

16.29 RELEASE (17)

Table 170: RELEASE (17)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="8">Command Code = 17h</td></tr>
<tr><td>1</td><td colspan="3">Reserved</td><td>3rdPty=0</td><td colspan="3">3rd Party ID</td><td>Ext=0</td></tr>
<tr><td>2</td><td colspan="8">Reservation Identification</td></tr>
<tr><td>3-4</td><td colspan="8">Reserved</td></tr>
<tr><td>5</td><td colspan="8">Control Byte - refer to Section 16.1</td></tr>
</table>

The RELEASE command is used to release a LUN 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.

- **3rdPty** must be 0. Third Party reservations are not supported. If the 3rdPty bit is not zero, Check Condition status is returned with a sense key of Illegal Request and additional sense code of Invalid Field in CDB.
- **3rd Party ID** is ignored.
- **Ext** Extents must be 0. Extension is not supported by the drive.
- **Reservation Identification** field is ignored.

16.30 RELEASE (57)

Table 171: RELEASE (57)

Byte	Bit							
	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 Section 16.1							

The RELEASE command is used to release a LUN 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.

- **3rdPty** must be 0. Third Party reservations are not supported. If the 3rdPty bit is not zero, Check Condition status is returned with a sense key of Illegal Request and additional sense code of Invalid Field in CDB.
- **3rd Party ID** is ignored.
- **Ext** Extent must be 0. Extension is not supported by the drive.
- **Reservation Identification** field is ignored.

16.31 REPORT DEVICE IDENTIFIER (A3/05)

Table 172: REPORT DEVICE IDENTIFIER (A3/05)

Byte	Bit							
	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	

The **REPORT DEVICE IDENTIFIER** command requests that the device server send device identification information to the application client.

- **LUN** Logical Unit number is expected to be 0. Other value for this parameter will cause the command to terminate 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.
- **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.

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 173: Report Device Identifier parameter list

Byte	Bit							
	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 persist through resets, power cycles, media format operations.

The Target return 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 **Check Condition** status rather than wait 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)

Table 174: REPORT LUNS (A0)

Byte	Bit							
	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	

The REPORT LUNS command 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.

- **Allocation Length** must be at least 16 bytes. If the Allocation Length is less than 16 bytes, the Target will return a **Check Condition** status with sense key of *Illegal Reques*t and additional sense code of *Invalid Field in 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 will send the LUN list in the subsequent Data Out Phase. The format of the LUN list is shown in the following table.

Table 175: LUN Reporting parameter list format

Byte	Bit							
	7	6	5	4	3	2	1	0
0-3	LUN List Length = 8							
4-7	Reserved							
8-15	LUN = 0							

- **LUN List Length** shall contain the length in bytes of the LUN list that is available to be transferred. This product only supports one LUN. Therefore, the LUN list length must be set to 8. The only supported LUN is zero.

16.33 REPORT SUPPORTED OPERATION CODES (A3/0C)

Table 176: REPORT SUPPORTED OPERATION CODES (A3/0C)

Byte	Bit							
	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 Section 16.1							

The REPORT SUPPORTED OPERATION CODES command 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.

- **RCTD** Return Command Timeouts Descriptor set to one specifies that the command timeouts descriptor shall be included in each command descriptor (see section 16.33.1) that is returned or in the one_command parameter data (see section 16.33.2) that is returned. A RCTD bit set to zero specifies that the command timeouts descriptor shall not be included in any parameter data returned.

• **Reporting Options** specifies the information to be returned in the parameter data.

Table 177: Reporting Options

Reporting Options	Description
000b	A list of all operation codes and service actions supported by the drive will be returned in the all_commands parameter data format. The Requested Operation Code field and Requested Service Action field will be ignored.
001b	The command support data for the operation code specified in the Requested Operation Code field will be returned in the one_command parameter data format. The Requested Service Action field will be ignored. If the Requested Operation Code field specifies an operation code that has service actions, Check Condition status will be reported with a sense key of Illegal Request and additional sense code of Invalid Field in CDB.
010b	The command support data for the operation code and service action specified in the Requested Operation Code field and Requested Service Action field will be returned in the one_command parameter data format. If the Requested Operation Code field specifies an operation code that does not have service actions, Check Condition status will be reported with a sense key of Illegal Request and additional sense code of Invalid Field in CDB.
011b-111b	**Reserved**

• **Requested Operation Code** specifies the operation code of the command to be returned in the one_command parameter data format.

• **Requested Service Action** specifies the service action of the command to 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 shall be 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

The Report Supported Operation Codes all_command parameter data format begins with a four-byte header that contains the length in bytes of the parameter data, followed by a list of supported commands. Each command descriptor contains information about a single supported command CDB (i.e. one operation code and service action combination, or one non-serviceaction operation code).

Table 178: All_command parameter data format

Byte	Bit							
	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 179: Command Descriptor format

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Operation Code							
1	Reserved							
2-3	Service Action							
4	Reserved							
5	Reserved						CTDP	Serva-ctv
6-7	CDB Length							
8-19	Command Timeouts Descriptor, if any (see 16.33.3)							

- **Operation Code** contains the operation code of a supported command.
- **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 will be set to zero.
- **CTDP** Command Timeouts Descriptor Present bit set to 1 indicates that the command timeouts descriptor (see

18.32.3) 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** set to 0 indicates the operation code does not have service actions and the Service Action field should be ignored. SERVACTV set to 1 indicates 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 Report Supported Operation Codes one_command parameter data format contains information about the CDB and a usage map for bits in the CDB for the command specified by the Reporting Options, Requested Operation Code, and Requested Service Action fields in the Reported Supported Operation Codes CDB.

Table 180: One_command parameter data format

Byte	Bit							
	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 16.33.3)							

- **CTDP** Command Timeouts Descriptor Present bit set to 1 indicates that the command timeouts descriptor is included in this command descriptor (see section 16.33.3). A CTDP bit set to 0 indicates that the command timeouts descriptor is not included in this command descriptor.
- **Support** is defined in the table below.

Table 181: 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 command requested.
- **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, then that 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-for-one correspondence to the CDB for the command requested. If the drive evaluates a bit in the CDB, the usage map will contain a one in the corresponding bit position. The usage map will contain a 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 (see Table 182:) returns timeout information for commands supported by the logical unit 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 that are outside the control of the device server (e.g., prior commands with the IMMED bit set to one 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, 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 (e.g., the time to spinup rotating media).
Values returned in the command timeouts descriptor should not be used to compare products.

Table 182: Command timeouts descriptor format

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 Table 183:) 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.

Table 183: Command timeouts descriptor Command Specific Field usage

Command	Reference
WRITE BUFFER	See Section 16.33.3.2

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 othe 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 subclause, then the COMMAND SPECIFIC field indicates the maximum time, in one second increments, that access to the SCSI device is limited or not possible through any SCSI ports associated with a logical unit that processes a WRITE BUFFER command that specifies one of the named modes. A value of zero in the COMMAND SPECIFIC field indicates that the no maximum time is indicated.

16.34 REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS (A3/0D)

Table 184: Report Supported Task Management Functions (A3/0D)

Byte	Bit							
	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 Section 16.1							

The REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS command requests information on task management functions supported by the drive.

- **Allocation Length** specifies the number of bytes that have been allocated for the returned parameter data. The allocation length must be at least four. If the allocation length is less than four, Check Condition Status will be returned with sense key of Illegal Request and additional sense code of Invalid Field in CDB.

The format of the returned parameter data is shown below.

Byte	Bit							
	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 set to 1 indicates that ABORT TASK is supported. An ATS bit of 0 indicates that ABORT TASK is not supported.
- **ATSS** Abort Task Set bit set to 1 indicates that ABORT TASK SET is supported. An ATSS bit of 0 indicates that ABORT TASK SET is not supported.
- **CACAS** Clear ACA bit set to 1 indicates that CLEAR ACA is supported. A CACAS bit of 0 indicates that CLEAR ACA is not supported.
- **CTSS** Clear Task Set bit set to 1 indicates that CLEAR TASK SET is supported. A CTSS bit of 0 indicates that CLEAR TASK SET is not supported.

- **LURS** Logical Unit Reset bit set to 1 indicates that LOGICAL UNIT RESET is supported. An LUR bit of 0 indicates that LOGICAL UNIT RESET is not supported.
- **QTS** Query Task bit set to 1 indicates that QUERY TASK is supported. A QTS bit of 0 indicates that QUERY TASK is not supported.
- **TRS** Target Reset bit set to 1 indicates that TARGET RESET is supported. A TRS bit of 0 indicates that TARGET RESET is not supported.
- **WAKES** Wakeup bit set to 1 indicates that WAKEUP is supported. A WAKES bit of0 indicates that WAKEUP is not supported.
- **QUAS** Query Unit Attention Supported bit set to 1 indicates the QUERY UNIT ATTENTION task management function (see SAM-4) is supported by the logical unit. A QUAS bit set to 0 indicates the QUERY UNIT ATTENTION task management function is not supported.

- **QTSS** Query Task Set Supported bit set to 1 indicates the QUERY TASK SET task management function (see SAM-4) is supported by the logical unit. A QTSS bit set to 0 indicates the QUERY TASK SET task management function is not supported.

- **ITNRSA** I_T Nexus Reset Supported bit set to 1 indicates the I_T NEXUS RESET task management function (see SAM-4) is supported by the logical unit. An ITNRS bit set to 0 indicates the I_T NEXUS RESET task management function is not supported.

16.35 REQUEST SENSE (03)

Table 185: REQUEST SENSE (03)

Byte	Bit							
	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 Section 16.1							

The REQUEST SENSE command requests the drive to transfer sense data.

If REQUEST SENSE command with an invalid LUN is received, the drive returns **Good** status and 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 shall return 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 will return the number of bytes in the allocation length or 32 bytes, whichever is less.

16.36 RESERVE (16)

Table 186: RESERVE (16)

Byte	Bit							
	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 Section 16.1							

The RESERVE command 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.

Extents are not supported by the drive. The Ext bit must be zero. If Ext bit is set to one, **Check Condition** status is returned with a sense key of *Illegal Request* and additional sense code of *Invalid Field in 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

- 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, Check Condition status is returned with a sense key of Illegal Request and additional sense code of Invalid Field in 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)

Table 187: RESERVE (56)

Byte	Bit							
	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 Section 16.1							

The RESERVE command 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.

Extents are not supported by the drive. The Ext bit must be zero. If Ext bit is set to one, **Check Condition** status is returned with a sense key of *Illegal Request* and additional sense code of *Invalid Field in 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

- 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, Check Condition status is returned with a sense key of Illegal Request and additional sense code of Invalid Field in CDB.
- **3rd Party Device 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)

Table 188: REZERO UNIT (01)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 01h							
1	Reserved							
2-4	Reserved							
5	Control Byte - refer to Section 16.1							

The REZERO UNIT command is implemented as a no-op on the SSD.

16.39 SANITIZE (48)

Table 189: SANITIZE (48)

Byte	Bit							
	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 = 0							
9	Control Byte - refer to Section 16.1							

• **Immed** bit is to specify

0 status is to be returned at the end of the operation.

1 Good status shall always be returned immediately after command has been received. The TEST UNIT READY command may be used to determine when the drive becomes ready.

• **AUSE** bit can be set to 1 to allow EXIT FAILURE MODE service action on a subsequent SANITIZE. If AUSE is set to 0, and the sanitize fails, a subsequent SANITIZE with EXIT FAILURE MODE will be rejected.

• **Parameter List Length** must be 0. If not, 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 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 CDB.

Table 190: SANITIZE Service Action Codes

Code	Name	Descriptions
00-01h	**Reserved**	**Returns 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 Check Condition**
1Fh	**Exit Failure Mode**	**If a prior Sanitize operation was issued with AUSE = 1 and it failed, this will take the drive out of degraded mode, Sanitize Failed state. The condition of the NAND blocks is not guaranteed in this case.**

16.40 SEEK (6) - (0B)

Table 191: SEEK (6) - (0B)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="8">Command Code = 0Bh</td></tr>
<tr><td>1</td><td colspan="3">Reserved</td><td colspan="5">Logical Block Address</td></tr>
<tr><td>2-3</td><td colspan="8">Logical Block Address (continued)</td></tr>
<tr><td>4</td><td colspan="8">Reserved</td></tr>
<tr><td>5</td><td colspan="8">Control Byte - refer to Section 16.1</td></tr>
</table>

The SEEK (6) command is implemented as a no-op on the SSD. No checking is performed on the LBA in the CDB.

16.41 SEEK (10) - (2B)

Table 192: SEEK (10) - (2B)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="8">Command Code = 2Bh</td></tr>
<tr><td>1</td><td colspan="7">Reserved</td><td>0</td></tr>
<tr><td>2-5</td><td colspan="8">Logical Block Address</td></tr>
<tr><td>6-8</td><td colspan="8">Reserved</td></tr>
<tr><td>9</td><td colspan="8">Control Byte - refer to Section 16.1</td></tr>
</table>

The SEEK (10) command is implemented as a no-op on the SSD. No checking is performed on the LBA in the CDB.

16.42 SEND DIAGNOSTIC (1D)

Table 193: SEND DIAGNOSTIC (1D)

Byte	Bit							
	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 Section 16.1							

The SEND DIAGNOSTIC command 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.

• **PF** Page Format bit set to 1 indicates the data sent by the Initiator conform 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 194: 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, **Check Condition** status will be generated with a sense key of *Illegal Request* and additional sense of *Invalid Field in CDB*. If the SlfTst bit is zero, 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 will be also generated with a sense key of *Illegal Request* and additional sense of *Invalid Field in 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.

See Section 21.19 "Diagnostics" on page 292 for a detailed listing of operations carried out by the SEND DIAGNOSTIC command and Power on Diagnostics.

16.42.1 Send Diagnostic Page 0

This page requests that the drive return a list of supported pages on the next RECEIVE DIAGNOSTICS command.

Table 195: Diagnostic Page 0

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Page Code = 0							
1	Reserved							
2-3	Page Length = 0							

16.42.2 Send Diagnostic Page 3F

Table 196: Diagnostic Page 3F

Byte	Bit							
	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 to stop performing a phy test function. If the phy does not exist, Check Condition status will be returned with a sense key of Illegal Request and 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, Check Condition status will be returned with a sense key of Illegal Request and additional sense of Invalid Field in Parameter List.

Phy Test Function	Descripton
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	Unsupported
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, Check Condition status will be returned with a sense key of Illegal Request and additional sense of Invalid Field in Parameter List.

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

• **Phy Test Pattern Physical Link Rate** specifies the physical link rate at which the phy test pattern shall be 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, Check Condition status will be returned with a sense key of Illegal Request and additional sense of Invalid Field in Parameter List.

- **Phy Test Pattern SATA** bit set to 0 indicates that the phy transmits the phy test pattern as a SAS phy. If this bit is set to 1, Check Condition status will be returned with a sense key of Illegal Request and 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, Check Condition status will be returned with a sense key of Illegal Request and additional sense of Invalid Field in Parameter List.

Note: The drive's SSC hardware 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, drive will apply the SSC modulation type to both ports in order for spreading to occur. This could cause link disruption if the connected HBA is unable to receive a SSC signal.

Phy Test Pattern SSC Code	**Descripton**
00h	No SSC
01h	Center-spreading SSC (Not supported)
10h	Down-spreading SSC
11h	Reserved

- **Phy Test Pattern Dwords Control** controls whether the bytes in the Phy Test Pattern Dwords field are sent as control characters or data characters.

Phy Test Pattern Dwords Control	**Descripton**
00h	Each byte in the Phy Test Pattern Dwords field shall be sent as a data character (i.e., Dxx.y) viothout scrambling.
08h	The fifth byte in the Phy Test Pattern Dwords field shall be sent as a control character (i.e., Kxx.y). Each other byte shall be sent as a data character viothout scrambling.
80h	The first byte in the Phy Test Pattern Dwords field shall be sent as a control character. Each other byte shall be sent as a data character viothout scrambling.
88h	The first and fifth bytes in the Phy Test Pattern Dwords field shall be sent as a control character. Each other byte shall be sent as a data character viothout scrambling.
All others	Reserved

- **Phy Test Pattern Dwords** contains the two Dwords that are sent during a TWO_DWORDS test pattern.

16.43 SET DEVICE IDENTIFIER (A4/06)

Table 197: SET DEVICE IDENTIFIER (A4/06)

Byte	Bit 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							
11	Vendor specific		Reserved			NACA	Obsolete	

The SET DEVICE IDENTIFIER command requests that the device identifier information be set to the value received in the SET DEVICE IDENTIFIER parameter list.

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 reporting the unit attention condition 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 zero indicates that no data is transferred, and that subsequent REPORT DEVICE IDENTIFIER commands return an Identifier length of zero.

The SET DEVICE IDENTIFIER parameter list contains the identifier to be set by the addressed logical unit.

Table 198: SET DEVICE IDENTIFIER, Parameter List

Byte	Bit 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.

16.44 START STOP UNIT (1B)

Table 199: START STOP UNIT (1B)

Byte	Bit							
	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 Section 16.1							

The START STOP UNIT command is used to make the media accessible or inaccessible. At power-on, the SSD automatically makes the media accessible, but START STOP UNIT emulates HDD behaviors by making the drive ready or not ready.

• **Immed** bit is to specify

0 status is to be returned at the end of the operation.

1 **Good** status shall always be 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 zero to allow the Start bit setting to affect the state of the drive.

• **Start bit is to specify:**

0 make the media inaccessible

1 make the media accessible

Note: NOTIFY(ENABLE_SPINUP) is not required for the SSD to come ready after power on. Once the drive has become 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

16.45 SYNCHRONIZE CACHE (10) - (35)

Table 200: SYNCHRONIZE CACHE (10) - (35)

Byte	BIT							
	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							
9	Control Byte - refer to Section 16.1							

The SYNCHRONIZE CACHE command is implemented as a no-op on the SSD. Data integrity is maintained across power cycles by PLI circuitry.

- **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.
- **Logical Block Address** must be a valid LBA on the drive, but otherwise is ignored and has no impact on command execution
- **Number of Blocks** specifies the total number of contiguous logical blocks within the range. Number of Blocks of 0 indicates that all remaining logical blocks on the logical unit shall be within the range.

16.46 SYNCHRONIZE CACHE (16) - (91)

Table 201: Synchronize Cache (16) - (91)

Byte	BIT							
	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 Section 16.1							

The SYNCHRONIZE CACHE command is implemented as a no-op on the SSD. Data integrity is maintained across power cycles by PLI circuitry. See the SYNCHRONIZE CACHE (10) description for definitions of the fields in this command.

16.47 TEST UNIT READY (00)

Table 202: TEST UNIT READY (00)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 00h							
1	Reserved							
2-4	Reserved							
5	Control Byte - refer to Section 16.1							

The TEST UNIT READY 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.

The drive will verify that the media is accessible. If the media is not accessible, **Check Condition** status is returned with 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 one. 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.

Note: 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 command until the Power On sequence is complete. The drive will return **Check Condition** status with Not Ready sense key and In Process of Becoming Ready sense code for all other commands during the Power On period.

16.48 UNMAP (42)

Table 203: UNMAP (42)

Byte	Bit							
	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							

The UNMAP command requests that the drive cause one or more LBAs to be unmapped. When an LBA is "unmapped", subsequent reads to the LBA will return all 0x00s. Protection information for the LBA (if applicable) will be 0xFFFFFFFF_FFFFFFFF. For additional information, refer to section 18.x Logical Block Provisioning.

- **Anchor** bit is ignored. Since the drive is “resource provisioned”, any LBA on which an unmap operation is performed will become anchored (regardless of the setting of the ANCHOR bit in the UNMAP command).
- **Group Number** shall be 0.

16.48.1 UNMAP parameter list

The UNMAP parameter list contains the data sent by an application client along with an UNMAP command. Included in the data are 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 will become anchored (regardless of previous state).

Table 204: UNMAP Parameter list

Byte	Bit							
	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 table 185)							
...								
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. If the unmap block descriptor data length is not a multiple of 16, then the last unmap block descriptor is incomplete and shall be ignored. If the UNMAP BLOCK DESCRIPTOR DATA LENGTH is set to zero, then no unmap block descriptors are included in the UNMAP parameter data. This condition shall not be considered an error

.

Table 205: UNMAP Block Descriptor

Byte	Bit							
	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 shall be unmapped for this UNMAP block descriptor. This condition shall not be considered an error.

If the LBA specified by the UNMAP LOGICAL BLOCK ADDRESS field plus the number of logical blocks exceeds the capacity of the medium, then the device server shall terminate the command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to LOGICAL BLOCK ADDRESS OUT OF RANGE.

If the total number of logical blocks specified in the UNMAP block descriptor data exceeds the value indicated in the MAXIMUM UNMAP LBA COUNT field in the Block Limits VPD page (see 6.5.3), or if the number of UNMAP block descriptors exceeds the value of the MAXIMUM UNMAP BLOCK DESCRIPTOR COUNT field in the Block Limits VPD page, then the device server shall terminate the command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

16.49 VERIFY (10) - (2F)

Table 206: VERIFY (10 - (2F)

Byte	BIT							
	7	6	5	4	3	2	1	0
0	Command Code = 2Fh							
1	VRPROTECT			DPO	Reserved		Byte Chk	RSVD
2-5	Logical Block Address							
6	Reserved							
7-8	Verification Length							
9	Control Byte - refer to Section 16.1							

The VERIFY command 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.

- **ByteChk** bit set to 0 indicates that the data is read from the drive and verified using ECC.If an ECC error is detected in the verify process, **Check Condition** status is returned with sense key set to *Medium Error*. ByteChk bit set to 1 indicates that byte-by-byte comparison is performed between the data on the drive and data transferred from the initiator during the data-out phase.

  If the comparison is unsuccessful, the command is terminated with **Check Condition** status and the sense key is set to *Miscompare*.

- **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 the manner in which protection information read from drive shall be checked during processing of the command. Protection information is stored on drive, and may be validated using the drive's internal checking algorithms, and also byte-by-byte compared using data from the initiator when ByteChk=1.

If the drive is not formatted with protection information, VRPROTECT must be set to 000b, else Check Condition status will be returned with sense key of Illegal Request and additional sense code of Invalid Field in CDB.

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. Check Condition status will be returned with sense key of Illegal Request and additional sense code of Invalid Field in CDB.

If a check of the protection information fails, Check Condition status will be returned with sense key of Aborted Command and additional sense code indicating which protection field check failed.

Refer to the ANSI T10 standards for additional details of protection information.

16.50 VERIFY (12) - (AF)

Table 207: Verify (12) - (AF)

Byte	BIT							
	7	6	5	4	3	2	1	0
0	Command Code = AFh							
1	VRPROTECT			DPO	FUA	RSVD	Byte Chk	RSVD
2-5	Logical Block Address							
6-9	Verification Length							
10	Reserved							
11	Control Byte - refer to Section 16.1							

The VERIFY(12) command causes the drive to verify data written on the media. See the VERIFY(10) description for the definitions of the fields in this command.

16.51 VERIFY (16) - (8F)

Table 208: Verify (16) - (8F)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 08Fh							
1	VRPROTECT			DPO	Reserved		Byte Chk	RSVD
2-9	Logical Block Address							
10-13	Verification Length							
14	Reserved							
15	Control Byte - refer to Section 16.1							

The VERIFY command 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.

16.52 VERIFY (32) - (7F/0A)

Table 209: Verify (32) - 7F/0A)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 07Fh							
1	Control Byte - refer to Section 16.1							
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							

The VERIFY command requests that the 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.

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 will be processed normally. Any other protection types will result in Check Condition status to be returned with sense key of Illegal Request and 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 one in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a value that is a bit mask for enabling the checking of 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 one 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 zero, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

16.53 WRITE (6) - (0A)

Table 210: WRITE (6) - (0A)

Byte	Bit 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 Section 16.1							

The WRITE 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**).

• **Logical Block Address** specifies the logical unit at which the WRITE operation shall begin.

• **Transfer Length** specifies the number of blocks to be transferred. A value of zero implies 256 blocks are to be transferred.

16.54 WRITE (10) - (2A)

Table 211: WRITE (10) - (2A)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 2Ah							
1	WRPROTECT			DPO	FUA	RSVD	FUA_NV	Obso-lete
2-5	Logical Block Address							
6	Reserved							
7-8	Transfer Length							
9	Control Byte - refer to Section 16.1							

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.

- **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 since NV_SUP=0 in Inquiry Page 86h.

If a WRITE(6) command is received after protection information is enabled, the drive will set the protection information as follows as it writes each block to drive:

- 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 one in Mode Page 0Ah ; or
  - Any value, if the ATO bit is set to zero
- **WRPROTECT** defines the manner in which protection information written to drive shall be 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, else Check Condition status will be returned with sense key of Illegal Request and additional sense code of Invalid Field in CDB.

WRPROTECT=000b

- Protection information is not transmitted to the drive.

- If the drive is formatted with protection information, the drive will write protection information to drive 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. Check Condition status will be returned with sense key of Illegal Request and additional sense code of Invalid Field in CDB.

If a check of the protection information fails, Check Condition status will be returned with sense key of Aborted Command and additional sense code indicating which protection field check failed.

Refer to the ANSI T10 standards for additional details of protection information.

16.55 WRITE (12) - (AA)

Table 212: Write (12) - (AA)

Byte	Bit							
	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 Section 16.1							

The WRITE(12) command 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.

16.56 WRITE (16) - (8A)

Table 213: Write (16) - (8A)

Byte	Bit							
	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 Section 16.1							

The WRITE(16) command 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.

16.57 WRITE (32) - (7F/0B)

Table 214: Write (32) - (7F/0B)

Byte	Bit 7	6	5	4	3	2	1	0
0	Command Code = 7Fh							
1	Control Byte - refer to Section 16.1							
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							

The WRITE command requests that the drive write data transferred from the initiator to drive. 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 and, if the drive is formatted with protection information enabled, protection information.

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 will be processed normally. Any other protection types will result in Check Condition status to be returned with sense key of Illegal Request and 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 one in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a value that is a bit mask for enabling the checking of 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 one 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 zero, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

16.58 WRITE AND VERIFY (10) - (2E)

Table 215: WRITE AND VERIFY (10) - (2E)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 2Eh							
1	WRPROTECT			DPO	Reserved		Byte Chk	Obso-lete
2-5	Logical Block Address							
6	Reserved							
7-8	Transfer Length							
9	Control Byte - refer to Section 16.1							

WRITE AND VERIFY 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.

•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 zero, the seek occurs, but no data is transferred. This condition is not considered an error.

• **ByteChk** is set to 0 to indicate that the 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, **Check Condition** status is returned with sense key set to *Medium Error*. ByteChk bit set to 1 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 **Check Condition** status and the sense key is set to *Miscompare*.

• **DPO** Disable Page Out is ignored.

16.59 WRITE AND VERIFY (12) - (AE)

Table 216: Write andVerify (12) - (AE)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="8">Command Code = AEh</td></tr>
<tr><td>1</td><td colspan="3">WRPROTECT</td><td>DPO</td><td colspan="2">Reserved</td><td>ByteChk</td><td>Obsolete</td></tr>
<tr><td>2-5</td><td colspan="8">Logical Block Address</td></tr>
<tr><td>6-9</td><td colspan="8">Transfer Length</td></tr>
<tr><td>10</td><td colspan="8">Reserved</td></tr>
<tr><td>11</td><td colspan="8">Control Byte - refer to Section 16.1</td></tr>
</table>

The WRITE AND VERIFY command 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.

16.60 WRITE AND VERIFY (16) - (8E)

Table 217: Write and Verify (16) - (8E)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 8Eh							
1	WRPROTECT			DPO	Reserved		Byte Chk	Obso-lete
2-9	Logical Block Address							
10-13	Transfer Length							
14	Reserved							
15	Control Byte - refer to Section 16.1							

The WRITE AND VERIFY command 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.

16.61 WRITE AND VERIFY (32) - (7F/0C)

Table 218: Write and Verify (32) - (7F/0C)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 7Fh							
1	Control Byte - refer to Section 16.1							
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							
28-31	Transfer Length							

The WRITE AND VERIFY command requests that the drive write the data transferred from the initiator to drive and then verify that the data is correctly written.

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 will be processed normally. Any other protection types will result in Check Condition status to be returned with sense key of Illegal Request and 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 one in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a value that is a bit mask for enabling the checking of 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 one 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 zero, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

16.62 WRITE BUFFER (3B)

Table 219: WRITE BUFFER (3B)

Byte	Bit							
	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 Section 16.1							

The WRITE BUFFER command is used in conjunction with the READ BUFFER 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.

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

MODE	**Description**
00000	Write combined header and data
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
01110	Download microcode with offsets, save, and defer activate
01111	Activate deferred microcode
11010	Enable expander Communications Protocol
All Others	Not Supported

If any values other than shown above are specified, **Check Condition** status is returned with a sense key of *Illegal Request* and additional sense code of *Invalid Field in CDB*.

16.62.1 Combined Header And Data (Mode 00000b)

In this mode, the data to be transferred is preceded by a four-byte header.

• **Buffer ID** must be 0. If another value is specified, no download function is performed and the command is terminated with **Check Condition** status. And the drive shall set the sense key to *Illegal Request* and additional sense code to *Illegal Field in CDB*.
• **Buffer Offset** must be 0. If another value is specified, no download function is performed and the command is terminated with **Check Condition** status. And the drive shall set the sense key to *Illegal Request* and additional sense code to *Illegal Field in CDB*.
• **Parameter List Length** specifies the number of bytes that shall be transferred during the DATA OUT phase. This number includes four bytes of header, so the data length to be stored in the drive buffer is transfer length minus four. If the length exceeds the buffer size, the command is terminated with **Check Condition** status. And the drive shall set sense key to *Illegal Request* and additional sense code to *Illegal Field in CDB*. A Parameter List Length of less than four (size of header) indicates no data is transferred.

The 4-byte header consists of all reserved bytes.

Table 220: Write Buffer Header

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

16.62.2 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 Check Condition status. And the drive shall set the sense key to *Illegal Request* and additional sense code to *Illegal Field In 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 **Check Condition** status. And the drive shall set the sense key to *Illegal Request* and additional sense code to *Illegal Field In 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 and on a sector boundary A Parameter List Length of 0 indicates no data is to be transferred and command status is returned.

If an invalid value is specified, the command is terminated with **Check Condition** status. And the drive shall set the sense key to *Illegal Request* and additional sense code to *Illegal Field In CDB.*

16.62.3 Download Microcode (Mode 00100b)

NOTE: It is not expected that a customer will ever issue this format of the command.

In this mode, the microcode is transferred to the control memory space of the drive. When downloaded, the drive will operate with the newly downloaded code immediately until the next power cycle.
• **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
- nnh: ID of Vendor Unique Reserved Area

Any unsupported value for the Buffer ID will cause the command to terminate with **Check Condition** status. And the drive shall set the sense key to *Illegal Request* and additional sense code to *Illegal Field In CDB*.

- **Buffer Offset** must be 0. If an invalid value is specified, the command is terminated with **Check Condition** status. The drive shall set the sense key to *Illegal Request* and additional sense code to *Illegal Field in 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 **Check Condition** status. And the drive shall set the sense key to *Illegal Request* and additional sense code to *Illegal Field In CDB*.

This process generates a unit attention condition for MICROCODE HAS BEEN CHANGED for all Initiators except the one which sent the WRITE BUFFER command. Upon the completion of the WRITE BUFFER command the new microcode is immediately ready for operation.

Note: The Download Microcode mode described in this specification is to indicate that the drive will accept a command with this mode, though it is not expected that 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. If such a microcode is released from development, then it will include appropriate instructions on the function of new microcode and its effect on the drive operations after download.

16.62.4 Download Microcode and Save (Mode 00101b) -Single Binary File

In this mode the data is transferred to the drive to save into the System reserved area on the drive. This is for functional upgrade and configuration change reflecting the user's requirements and the manufacturer's reason or both, and it 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.

Note: The drive supports fast update of microcode to the drive, which is power safe and completes in several seconds. This does not update the Flash ROM.

Note: New code to be downloaded to the drive will be provided by development either by request of a customer for an additional function or as a result of a functional change by development. However please note that not all possible fixes or new functions can be applied to a drive in this manner and that 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.

Buffer ID field is used to indicate 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.

16.62.5 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 shall be a multiple of 4K bytes. The total length of all segments received shall be 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, **Check Condition** status is returned with sense key of Illegal Request and additional sense code of *Invalid Field in 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.

16.62.6 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 for a WRITE operation. Data will be sent aligned on 4-byte boundaries.

Upon successful completion of a WRITE BUFFER command the data will be preserved in the echo buffer unless there is an intervening command to any logical unit, in which case it may be changed.

16.62.7 Download microcode with offsets, save, and defer activate (Mode 01110b)

In this mode, microcode shall be transferred to the device server using one or more WRITE BUFFER commands, saved to nonvolatile storage, and considered deferred.

The deferred microcode shall be activated and no longer considered deferred when one of the following occurs:
a) a power on;
b) a WRITE BUFFER command with the activate deferred microcode mode (0Fh) is processed.
c) a Self Initated Reset occurs.

16.62.8 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, shall be activated and no longer considered deferred.

The BUFFER ID field, the BUFFER OFFSET field, and PARAMETER LIST LENGTH field shall be ignored in this mode.

16.62.9 Enable Expander Communications Protocol (Mode 11010b)

In this mode the drive behavior is the same as Write Data to Echo Buffer (Mode 0101b).

16.63 WRITE LONG (10) - (3F)

Table 221: WRITE LONG (10) - (3F)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 3Fh							
1	COR_DIS	WR_UNCOR	PBLOCK	Reserved				Obsolete
2-5	Logical Block Address							
6	Reserved							
7-8	Byte Transfer Length							
9	Control Byte - refer to Section 16.1							

The WRITE LONG command requests the drive to write **one block** of data transferred from the Initiator.

The transfer data must include

•User Data

•4 bytes of CRC data

Parameters are

•**COR_DIS** Correction Disabled when set to 1, we mark the LBA as a pseudo unrecovered error with correction disabled. A subsequent read to this LBA would:

a) Perform no error recovery on the block;

b) Perform no automatic reallocation of the affected logical blocks, including any automatic reallocation enabled by the Read-Write Error Recovery mode page;

c) Not consider errors on the affected logical blocks to be informational exception conditions as defined in the Information Exceptions Control mode page (see SPC-4);

d) not log errors on the affected logical blocks in the Error Counter log pages

e) On a read to the LBA, return 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 when set to 1 and we receive a Write Long command, we would create a pseudo unrecovered error with correction enabled. On following read commands to the LBA, the drive will:

a) use our normal recovery procedures (which will end in a hard error);

b) perform no automatic reallocation of the affected logical blocks, including any automatic reallocation enabled by the Read-Write Error Recovery mode page;

c) consider errors on the affected logical blocks to be informational exception conditions as defined in the Information Exceptions Control mode page (see SPC-4);

d) log errors on the affected logical blocks in the Error Counter log pages

e) On a read to the LBA, return 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 same, format, write long without COR_DIS set, reassign or write verify command.

If there is more than one logical block per physical block (i.e., the LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field in the READ CAPACITY (16) parameter data (see 5.17.1) is set to a non-zero value), then the drive supports the PBLOCK bit. The PBLOCK is defined to be the physical block of data that contains the logical block specified in the CDB.

Table 222: COR_DIS bit, WR_UNCOR bit, and PBLOCK bit

COR_DIS	WR_UNCOR	PBLOCK	More than one logical block per physical block [a]	Description
0	0	0	yes or no	Write only the specified logical block using the value in the BYTE TRANSFER LENGTH field.
		1	no	Terminate the WRITE LONG command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN CDB.
			yes	Write the entire physical block containing the specified logical block using the value in the BYTE TRANSFER LENGTH field.
0	1	0	yes or no	Mark only the specified logical block as containing a pseudo unrecovered error with correction enabled (see 4.18.2) in a manner that causes the device server to perform the maximum error recovery as defined by the Read-Write Error Recovery mode page (see 6.4.8). Ignore the BYTE TRANSFER LENGTH field, and transfer no data.
		1	no	Terminate the WRITE LONG command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN CDB.
			yes	Mark the entire physical block containing the specified logical block as containing a pseudo unrecovered error with correction enabled (i.e., mark all of the logical blocks in the same physical block that contains the specified logical block as containing a pseudo unrecovered error with correction enabled) (see 4.18.2). Ignore the BYTE TRANSFER LENGTH field, and transfer no data.

[a] An entry of “yes” means that the LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field in the READ CAPACITY (16) parameter data (see 5.17.2) is set to a non-zero value. An entry of “no” means that the field is set to zero.

COR_DIS	WR_UNCOR	PBLOCK	More than one logical block per physical block [a]	Description
1	0	0	yes or no	Mark only the specified logical block as containing a pseudo unrecovered error with correction disabled (see 4.18.2) Write only the specified logical block using the value in the BYTE TRANSFER LENGTH field.
		1	no	Terminate the WRITE LONG command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN CDB.
			yes	Mark the entire physical block containing the specified logical block as containing a pseudo unrecovered error with correction disabled (i.e., mark all of the logical blocks in the same physical block that contains the specified logical block as containing a pseudo unrecovered error with correction disabled) (see 4.18.2). Write the entire physical block containing the specified logical block using the value in the BYTE TRANSFER LENGTH field.
1	1	0	yes or no	Mark only the specified logical block as containing a pseudo unrecovered error with correction disabled (see 4.18.2). Ignore the BYTE TRANSFER LENGTH field, and transfer no data.
		1	no	Terminate the WRITE LONG command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN CDB.
			yes	Mark the entire physical block containing the specified logical block as containing a pseudo unrecovered error with correction disabled (i.e., mark all of the logical blocks in the same physical block that contains the specified logical block as containing a pseudo unrecovered error with correction disabled) (see 4.18.2). Ignore the BYTE TRANSFER LENGTH field, and transfer no data.

[a] An entry of "yes" means that the LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field in the READ CAPACITY (16) parameter data (see 5.17.2) is set to a non-zero value. An entry of "no" means that the field is set to zero.

- **Logical Block Address** specifies the logical block at which the write operation shall occur.
- **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 **Check Condition** status, then the sense key is set to *Illegal Request*, and an additional sense code is set to *Invalid Field in CDB*. The valid and ILI bits are set to one 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 zero (see table above) or is calculated as follows:
transfer length = logical block size + protection information size + CRC size *(PBLOCK=0)*
*transfer length = (8 * logical block size) + (8 * protection information size) + (8 * CRC size)* *(PBLOCK=1)*
where 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:
For PBLOCK = 0:
[user data logical block] [protection data, if any] [CRC]
For PBLOCK = 1:
[user data logical block (aligned) n] [protection data, if any] [CRC]
[user data logical block n + 1] [protection data, if any] [CRC]
.
.
.
[user data logical block n + 7] [protection data, if any] [CRC]

Note: Since the ECC bytes are not included in the Read Long data, ECC correction capability cannot be tested using Read/ Write Long.

16.64 WRITE LONG (16) - (9F/11)

Table 223: WRITE LONG (16) - (9R/11)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Operation Code (9Fh)							
1	COR_DIS	WR_UNCOR	PBLOCK	Service Action (11h)				
2-9	Logical Block Address							
10-11	Reserved							
12-13	Byte Transfer Length							
14	Reserved							
15	Control							

For a description of the fields, refer to WRITE LONG (10) - (3F), page 271

16.65 WRITE SAME (10) - (41)

Table 224: WRITE SAME (10) - (41)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 41h							
1	WRPROTECT			Ancho r	Unmap	PBDA TA=0	LBDA TA=0	Obso- lete
2-5	Logical Block Address							
6	Reserved							
7-8	Number of Blocks							
9	Control Byte - refer to Section 16.1							

The WRITE SAME 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 of the data over the SCSI bus.

• See the WRITE(10) command description for the definition of the WRPROTECT field.

• **Anchor** bit is ignored

• **Unmap** when set to 1**,** the Write Same will result in one of the following:

-The LBA range (specified in the CDB) being anchored, since the drive is resource provisioned, as long as the data in the data out descriptor matches what would be expected on a subsequent read (i.e. data out buffer of all zeros for data and, if provided, all 0xFFs for the protection information)

-Normal Write Same operation (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 the number is zero, all of the remaining blocks on the specified logical unit are written.

• **RelAdr** Relative Block Address is not supported and must be set to be 0.

16.66 WRITE SAME (16) - (93)

Table 225: Write Same (16) - (93)

<table>
<tr><th rowspan="2">Byte</th><th colspan="8">Bit</th></tr>
<tr><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>0</td><td colspan="8">Command Code = 93h</td></tr>
<tr><td>1</td><td colspan="3">WRPROTECT</td><td>Anchor</td><td>Unmap</td><td>PBDATA = 0</td><td>LBDATA = 0</td><td>Obsolete</td></tr>
<tr><td>2-9</td><td colspan="8">Logical Block Address</td></tr>
<tr><td>10-13</td><td colspan="8">Number of Blocks</td></tr>
<tr><td>14</td><td colspan="8">Reserved</td></tr>
<tr><td>15</td><td colspan="8">Control Byte - refer to Section 16.1</td></tr>
</table>

SeeWRITE SAME (10) - (41), page 276 for a description of all the fields.

16.67 WRITE SAME (32) - (7F/0D)

Table 226: Write Same (32) - (7F/0D)

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Command Code = 7Fh							
1	Control Byte - refer to Section 16.1							
2-5	Reserved							
6	Reserved			Group Number = 0				
7	Additional CDB Length = 18h							
8-9	Service Action = 000Dh							
10	WRPROTECT			Anchor	Unmap	PBDATA =0	LBDATA =0	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							

The WRITE SAME command requests that the drive write a single block of data transferred from the initiator to drive for a number of sequential logical blocks. This command is useful for writing large data areas with the same data, without sending all of 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 and, if the drive is formatted with protection information enabled, protection information.

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 will be processed normally. Any other protection types will result in Check Condition status to be returned with sense key of Illegal Request and 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 one in Mode Page 0Ah, the Logical Block Application Tag Mask field contains a value that is a bit mask for enabling the checking of 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 one 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 zero, the Logical Block Application Tag Mask field and the Expected Logical Block Application Tag field are ignored.

17.0 SCSI Status Byte

Upon the completion of a command a status byte is sent to the initiator. Additional sense information may also be available depending on the contents of the status byte. The following section describes the possible values for the status byte and sense data. All Reserved fields are set to zero.

Table 227: 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 has been successfully completed.

02h 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 target's command queue 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, sense data are not valid.

18.0 Additional information

This chapter provides additional information or descriptions of various functions, features, or operating models supported by the Target that are not fully described in previous chapters.

18.1 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.

18.1.1 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:

1. Check Condition status for invalid Logical Unit Number. (See Section 18.1.2, “Invalid LUN Processing” on page 283)
2. Check Condition status for Incorrect Initiator Connection.
3. Check Condition status for Unit Attention Condition (See Section 18.1.4, “Unit Attention Condition” on page 285
4. Busy Status or Queue Full Status (See 18.1.3, “Command Processing During Execution of Active I/O Process” on page 284
5. Check Condition status for Deferred Error Condition (See Section 18.1.7, “Deferred Error Condition” on page 287)
6. Check Condition status during Startup and Format operations (See Section “18.1.5, “Command Processing During Startup, Format and Sanitize Operations” on page 287)
7. Reservation Conflict status (See Section 18.1.9, “Command Processing while Reserved” on page 295)
8. Check Condition status for invalid command opcode
9. Check Condition status for invalid command descriptor block

The highest priority internal condition that prevents command execution is reported by the Target provided there is no bus error.

For all Check Conditions 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.

18.1.2 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 16.4, “INQUIRY (12)” on page 89).

Request Sense: Execute the command, return the sense data with the Sense Key set to Illegal Request and the Additional Sense Code and Additional Sense Code Qualifier set to LOGICAL UNIT NOT SUPPORTED, and return GOOD status (see also 16.35, “REQUEST SENSE (03)” on page 227).

All Others: Do not execute the command and return CHECK CONDITION status, along with the auto-sense data with the Sense Key set to Illegal Request and the Additional Sense Code and 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.

18.1.3 Command Processing During Execution of Active I/O Process

When the target is not executing any I/O processes, a new I/O process is permitted to execute (unless execution is prevented by another internal target condition listed in 18.1.1, “Priority of SCSI Status Byte Reporting” on page 283).

If an active I/O process exists when the target receives a new command, then the target determines if:

- 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, then the target determines how the new command should be handled based on 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. See 18.1.5, “Command Processing During Startup, Format and Sanitize Operations” on page 287 for the exact conditions which cause this response.

Note: If a Unit Attention is pending when this condition exists, the sense key is set to Unit Attention rather than Logical Unit Not Ready since Unit Attention has a higher reporting priority (see 18.1.1, “Priority of SCSI Status Byte Reporting” on page 283).

- The command is permitted to execute if:
  - the command is a priority command (see 18.2, “Priority Commands” on page 295).
- the conditions to execute concurrently are met (see 18.5, “Concurrent I/O Process” on page 296).
- The command is added to the queue if:
  - any I/O process already exists at the target, and
  - this is not an incorrect initiator connection.
- Queue Full status is returned if:
  - the command would otherwise be added to the queue (according to the rules described above), but all slots in the queue are full, or
  - the command would otherwise be added to the queue (according to the rules described above), but all of the available queue slots not reserved for use by another initiator are full, or
  - a Format Unit command was previously queued but has not yet begun execution, or
  - the target is in a Degraded Mode (see 18.1.8, “Degraded Mode” on page 288) and a Start Unit command was previously queued but has not yet begun execution.
- Busy status is never returned.

18.1.4 Unit Attention Condition

The target generates 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) will cause a Unit Attention Condition Power-On Reset for that initiator with an Additional Sense Code and Additional Sense Code Qualifier reported as Power-On Reset, Power-On Reset Occurred.

- MODE SELECT command has been executed

  In this case, a unit attention condition is generated for all initiators except the one that issued the MODE SELECT command. The Additional Sense Code and Additional Sense Code Qualifier reported is MODE PARAMETERS CHANGED. The unit attention condition is 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: If the initiator issues a MODE SENSE command with a page code to report the current values followed by a MODE SELECT command with the same parameter list, a unit attention condition is generated despite the fact that the current parameters were not changed from their previous value. However, if the target detects an illegal parameter or error condition prior to modifying the current parameters, a unit attention condition is not generated since the parameters were not set. The unit attention condition is also not generated if the MODE SELECT command parameter list does not include any pages and only the header or header/block descriptor is present.

- FORMAT UNIT command has been executed

  In this case, a unit attention condition is generated for all initiators except the one that issued the FORMAT UNIT command. The Additional Sense Code and Additional Sense Code Qualifier reported is 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 command to download microcode has been executed

  In this case, a unit attention condition is generated for all initiators except the one that issued the WRITE BUFFER command. The Additional Sense Code and Additional Sense Code Qualifier reported is 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. The Additional Sense Code and Additional Sense Code Qualifier reported is COMMANDS CLEARED BY ANOTHER INITIATOR.

- LOG SELECT command with PCR bit has cleared parameters.

  In this case, a unit attention condition is generated for all initiators except the one that issued the LOG SELECT command. The additional sense code and additional sense code qualifier reported is Log Select Parameters Changed.

- The registration or reservation made by a Persistent Reserve Out command was cleared by another initiator.

  In this case, 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.

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:

Inquiry Execute the command, return GOOD status, and preserve the unit attention condition.

Report Luns Same as above

Request Sense Execute the command, return any pending sense data, return GOOD status, and preserve the unit attention condition. If there is not any 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.

18.1.5 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:

INQUIRY The drive sends inquiry data and returns 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 returns GOOD STATUS.

The Additional Sense Code Qualifier that is returned depends on type of I/O processes that are active:

For the START/UNIT STOP and the Auto-start operation, the qualifier 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. In both of these cases, the Sense key specific bytes are set to return the progress indication.

REPORT LUNS The drive sends REPORT LUNS data and appropriate status.

ALL OTHER The drive terminates the command with CHECK CONDITION status. The Sense data generated is described in Request Sense above.

18.1.6 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. These cases are also discussed.

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:

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 OTHER The drive terminates the command with a CHECK CONDITION status and clears the Internal Error condition.

18.1.7 Deferred Error Condition

Error code (71h) of sense data indicates that the Check Condition status returned is the result of an error or exception condition that occurred during execution of a previous command for which Good status has already been returned.

The drive creates an Deferred Error condition when

- Execution of a Format Unit command with the immediate bit of one ends with an error.
- Execution of a Sanitize command with the immediate bit of one ends with an error.

18.1.8 Degraded Mode

There are certain errors or conditions which may impair the ability of the drive to function normally. Rather than fail hard the drive is designed to be as responsive as possible. Also, in most cases, some action on the part of the initiator may be used to restore normal operation. This mode of limited operation is called Degraded Mode.

There are 4 Degraded drive modes:

- Media Degraded which is caused by one of the following conditions:
  - Context Load was started (by POR or Unit Start command) and the Target is under Self Configuration
  - Context Load Failure (Disable Logical)
  - Unit Stop command was issued after the Target successfully completed the Self Configuration
- Self Configuration Failure Degraded which is caused by one of the following conditions:
  - RAM Code, Read Failure
- Format Command Failure Degraded. This condition is caused when a Format Unit command failed or was interrupted abnormally (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 is caused when a sanitize command failed.

18.1.8.1 Response to SCSI Command in Degraded Mode - Becoming Ready

Table 228: Media 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 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 Status is returned with Sense Key 02h (Not Ready) ASC/ASCQ 0401h (In Process of Becoming Ready)

18.1.8.2 Response to SCSI Command in Degraded Mode - Context Load

Table 229: Media Degraded Mode - Context Load Failure

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

18.1.8.3 Response to SCSI Command in Degraded Mode - Drive issued received unit stop Command.

Table 230: 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)

18.1.8.4 Self Configuration Failure Degraded Mode

Table 231: 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)

18.1.8.5 Format Command Failure Degraded Mode

Table 232: 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)

18.1.8.6 Sanitize Command Failure Degraded Mode

Table 233: Sanitize Command Failure Degraded Mode

Command (w/Option)	Response
Request Sense	Executed. The Target will return 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)

18.1.9 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 Initiator that issued the Reserve command. The Initiator to receive the reservation may be either the same or a different Initiator (third-party reservation).

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 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 also 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 is 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, then the Target checks the next highest priority internal condition to determine whether execution is allowed. See Section 18.1.1, “Priority of SCSI Status Byte Reporting” on page 283.

18.2 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.

18.3 Command Queuing

The drive supports command queuing.

18.3.1 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 128 commands, if no other initiator has more than one command in the queue, although at times this maximum may be reduced as the drive can reserve command blocks for internal use.

18.3.2 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.

18.3.3 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 reset terminates all I/O processes from all initiators

18.4 Command Reordering

Command reordering is always enabled.

18.5 Concurrent I/O Process

Read and write commands are allowed to execute concurrently.

Priority commands are allowed 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.

18.6 Write Cache

Write caching is always enabled. PLI circuitry ensures data integrity. Errors on write commands are reported immediately. Deferred errors will not occur on write commands.

18.7 Automatic Rewrite/Reallocate

The target supports auto reallocation for all media access commands. Auto reallocation cannot be disabled, and the ARRE setting is ignored.

18.8 Multiple Initiator Support

This section describes how the target behaves in a multiple initiator system. Up to 64 initiators may be supported at any one time.

18.8.1 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.

18.8.2 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 18.1.4, “Unit Attention Condition” on page 285 for more information.

18.9 Reset

Reset actions will return the drive to a known, initialized state.

This device supports the reset sources discussed below.

18.9.1 Reset Sources

There are four sources of resets detected by the target:

Reset Name	Reset Source
Power-On Reset	This is the signal generated by the hardware at initial power-on
Self-Initiated reset	This is a software-generated reset that occurs when a catastrophic error is detected by the microcode.
OOB Hard Reset	This is an OOB Hard Reset Sequence received on the SAS interface.
LUN Reset	This is an SSP command frame with the LUN RESET TMF flag set

18.9.2 Reset Actions

The action taken by the drive following a reset is dependent on the source of the reset.

18.9.2.1 Power-On reset and Self-Initiated reset

These two reset conditions cause the following to be performed in the order shown:

- A power-up sequence
- 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 start-up sequence has not yet completed, the start-up sequence is restarted. Note: The power-up sequence is not re-run, since 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.

18.10 Diagnostics

The drive will execute Power on Diagnostics at power on time to assure the correct operation of the drive by validating components (RAM, SPI Flash, HDC, PLI Capacitor), checking stored information in the Reserved Area and SPI Flash, and verifying fault detects circuits.

Self-test can be invoked by issuing a SEND DIAGNOSTIC command.

18.10.1 Power on Diagnostics

At power on time the following tests are executed:

1. Validation of SPI Flash
2. RAM test for internal RAM
3. Test and Initialize HDC registers
4. RAM test for customer RAM
5. PLI selftest
6. 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 will be reported as 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). The INQUIRY, REPORT LUNS and REQUEST SENSE commands will always be responded with a GOOD status.

18.10.2 Self-test via SEND DIAGNOSTIC Command

18.10.2.1 Default Self-test

The default self-test is invoked by the SlfTst bit in the SEND DIAGNOSTIC command. The response is simply 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** is a drive read/write test. It writes data to a predefined location in the reserved area and then reads it back and validates the content.

18.10.2.2 Short and Extended Self-tests

There are two other types of self-tests that 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 self-test can be retrieved via the LOG SENSE command for Log Page 10.

18.10.2.3 Self-test Modes

There are two modes for short and extended self-tests: a foreground mode and a background mode. These modes are described in the following clauses.

Foreground mode

When the drive receives a SEND DIAGNOSTIC command specifying a self-test to be performed in the foreground mode, the drive will return status for that command after the self-test has been completed. While performing a self-test in the foreground mode, the drive will respond 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.

If the drive is performing a self-test in the foreground mode and a test error occurs, the drive will update the self-test results log page and report 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 will return 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 shall be 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:

a. The SlfTst bit is one
b. The Function Code field contains a value other than 000b or 100b.

When terminating the SEND DIAGNOSTIC command, the sense key shall be set to NOT READY and the additional sense code shall be 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.

Table 234: Short and Extended Self-Test Description

Segment Number	Short Self-Test	Extended Self-Test	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 18.10.2.1, “Default Self-test” on page 298
3h	PLI Test		Drain and recharge Caps
4h	SMART		Perform SMART testing and check results to ensure that SMART threshold criteria are not exceeded
5h	Low Level Format check		Check to insure that the media is currently not in the MEDIA FORMAT CORRUPTED state.
6h	Reserved Area check		Write/Read test in a predefined location in the drive's Reserved Area of the drive.
7h	- Verify First 300MB - Verify Last 100 MB	Verify all LBA’s	Sequential verify operation. Ensure that no uncorrectable errors occur within the verify range.
8h	Recheck SMART		Same as segment 4h.

18.10.2.4 Background Medium Scan

For a related function, see Mode Page 1Ch - Informational Exceptions Control, page 175

18.11 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 for the purpose of failure analysis.

18.12 Command Time out Limits

The 'Command Time-out Limits' are defined as the time period from the SCSI Arbitration phase through the SCSI Task complete message, associated with a particular command.

18.12.1 Format Time

A full Format Unit command completes in under 10 minutes. A fast Format Unit command completes in under 30 seconds.

18.12.2 Sanitize Time

Approximately 10-12 minutes should be allowed to complete a Sanitize command.

18.12.3 Start/Stop Unit Time

A Start Stop Unit command should complete in under 10 seconds..

18.12.4 Time-out Limits for Other Commands

The default timeout for all other commands is 5 seconds.

18.13 Recommended Initiator ERP

The Drive's design points for error reporting to the system assumes certain system action for the error return codes. These assumptions are:

1. SCSI protocol will be the first priority in reporting errors.
2. The system will maintain a log of all reported errors.

This section is directed toward documenting the assumptions made by the Drive that the system is expected to implement. The two error classes that the system should be concerned with are DATA and NON-DATA errors.

Data errors are those errors that deal with the handling of 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 as follows:

- 11 - Unrecovered read error
- 17 - Recovered read error

Nondata errors are those errors that do not have a direct relationship with transferring data to and from the media. Nondata errors can include data handling if the media is not associated with the error (that is, interface error).

The system action assumed for each class of error is outlined here.

18.13.1 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:

1. Back up all the customer data on this drive if possible
2. Replace the complete drive
3. Restore the customer data
4. Return the drive to customer service

18.13.2 Recommendations for System Error Log

The system error log should contain information about the Drive error that will 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)

18.13.3 Data Recovery Procedure

No action can be taken on hard or soft read errors. Block retirement happens automatically based on the block retirement policy in 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 will be reported on a read to the affected LBAs.

18.13.4 Nondata Error Recovery Procedure

The Drive will follow a logical recovery procedure for nondata errors. The initiator 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 back-up and logs errors at the system level for interrogation by service personnel.

18.13.4.1 Drive Busy

The Drive is busy performing an operation. **This is not an error condition.** The initiator can 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 *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* commands for the duration of a media access time-out or until the drive returns *Good Statu*s.
  - If the drive has been busy for longer than the limit specified in Section 18.12, “Command Time out Limits” on page 301, then service the drive using the service guidelines recommended in Section 18.13.1, “Drive Service Strategy” on page 302. Otherwise return to normal processing.
- If the *Test Unit Ready (00)* (or media access) command completes with *Good Statu*s, then return to normal processing.

18.13.4.2 Unrecovered Drive Error

The initiator should retry the failing command.

- If the retry of the failing command completes with *Good Status* or recovered Sense Key, follow the recovery procedure in Section 18.13.4.3, “Recovered Drive Error” on page 304.
- 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 *Good Status*, follow the recovery procedure in next Section 18.13.4.3, “Recovered Drive Error” on page 304.
  - If the retry of the failing command completes with Recovered sense or Hardware error sense, then service the drive using the service guideline recommended in Section 18.13.1, “Drive Service Strategy” on page 302.

18.13.4.3 Recovered Drive Error

The Initiator should log the error as soft with the recovery level.

18.13.4.4 Drive Not Ready

The initiator should do the following:

1. Issue a *Start Stop Unit (1B)* command.
2. Verify that the drive comes ready within the time specified in Section Table 9: , “SSD Response time” on page 14.
3. If the drive fails to come ready within the specified time, service the drive using the service guidelines specified in Section 18.13.1, “Drive Service Strategy” on page 302.
4. Retry the failing command.
   a. If the failing command completes with *Good Status*, log the error as recovered.
   b. If the failing command completes with Not Ready sense, verify there is no outside cause (for example, the power supply). Then service the drive using the service guidelines specified in Section 18.13.1, “Drive Service Strategy” on page 302.

18.13.4.5 Degraded Mode

Refer to Section 18.1.8, “Degraded Mode” on page 288, for the definition of this 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. The initiator should issue a *Unit start (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” on page 301, service the drive using the service guideline recommended in Section 18.13.1, “Drive Service Strategy” on page 302.
2. Sense Code/Qualifier of *Diagnostic Failure*. Failure of a Send Diagnostic self test, a start up sequence, or other internal target failures.

   - Failure of a send diagnostic self test or a start up sequence.

   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. Recovery for a failed Send Diagnostic (1D) is achieved in one of the following ways:

   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” on page 302.

   Recovery for a failed power up sequence is achieved in one of the following ways:

   Issuing a Unit start (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” on page 302.

- Internal target failures

  Recovery of this condition is either a power cycle or successful completion of the Send Diagnostic (1D). Service the drive using the recommended service guidelines specified in Section 18.13.1, “Drive Service Strategy” on page 302, if the power cycle or the Send Diagnostic (1D) command fail to complete successfully.

3. Sense Code/Qualifier of **Format Command Failed** Format Unit (04).

   Recovery from a failed Format Unit (04) 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” on page 302.

4. Sense Code/Qualifier of **Sanitize Command Failed** after a Sanitize (48h).

   Recovery from a failed Sanitize (48h) is achieved by retrying the command. If the original Sanitize was issued with AUSE=1, a second Sanitize may be able to specify service action 1Fh 'Exit Failure Mode'. For for this service action the state of the media, success or not, is not guaranteed. Otherwise, the second attempt should just select any valid Sanitize service action.

If 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” on page 302, when replacing the drive.

18.13.4.6 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” on page 302.
     - *Other*, follow the recommendations for the error condition reported.

18.13.4.7 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 are initiator caused abort conditions. The initiator should correct the condition that caused the abort and retry the failing command.
- Sense Key = B (Aborted Command) with Additional Sense Code of 44 or 48 are drive caused abort conditions. The initiator should:
  1. Retry the failing command.
  2. If the retry of the failing command completes with
     - *Good Statu*s, log the error as recovered.
     - Abort Command Sense, verify there is no outside cause (e.g. power supply) for the failure.
  3. Retry the failing command.
  4. If the retry of the failing command completes with
     - *Good Statu*s, log the error as recovered.

- Abort command sense, then service the drive using the service guideline recommended in Section 18.13.1, “Drive Service Strategy” on page 302.

- Sense Key = B (Aborted Command) and an Additional Sense Code of 47 can be an initiator or Drive caused abort condition. The initiator should follow the above procedure for initiator caused abort conditions 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.

18.13.4.8 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:

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*).

Reset

Reset - This means the drive was reset by either a power-on reset, LIP Reset, Target Reset or an internal reset.

Mode Parameters Changed

A *Mode Select (15)* command successfully completed. This means that the mode parameters that are the current value may have changed. The parameters may or may not have changed but 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* will not be reported to the initiator that issued the *Mode Select (15).*

Microcode Has Changed

Write Buffer (3B) to download microcode has successfully completed. This means that 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 level code with new code.

Commands Cleared by Another Initiator

Tagged commands cleared by a clear queue message. This means that the command queue has been cleared. The *Unit Attention Condition* is not reported to the initiator that issued the clear queue message. *Unit Attention Condition* is reported to all initiators that had commands active or queued.

Reissue any outstanding command.

Log Select Parameters Changed

A Log Select (4C) command successfully completed. This means that the Log Select command cleared statistical information successfully (See Section 16.5, “LOG SELECT (4C)” on page 112). Unit Attention Condition is reported to all initiators excluding the initiator that issued the Log Select command.

Device Identifier Changed

A Set Device Identifier (A4) command successfully completed. This means that the Set Device Identifier information field has been updated. (See 16.43, “SET DEVICE IDENTIFIER (A4/06)” on page 240) A Unit Attention Condition is reported to all initiators excluding the initiator that issued the Set Device Identifier command.

Notify (Power Loss Expected) Received

The drive has received a Notify (Power Loss Expected) primitive. This will result in any outstanding commands being cleared and a Unit Attention Condition being reported to all initiators.

18.13.4.9 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:

1. Retry Power cycle
2. Check the send diagnostic end status. If the status is
   - GOOD, Return to normal processing
   - *Check Condition Statu*s, issue a *Request Sense (03)* and follow the recommendations for the sense data returned unless the sense data is for a component mismatch. If the sense data is for component mismatch, service the drive using the service guideline recommended in Section 18.13.1, "Drive Service Strategy" on page 302.

18.13.4.10 Self Initiated Reset

The Drive will initiate a self reset when the condition of the Drive cannot be determined. The internal reset will terminate any outstanding commands, release any reserved initiators, and reset the firmware. The initiator can recover by

1. Logging the error
2. Retrying the failing command. If the failing command completes with:
   - *Good Statu*s, return to normal processing
   - Self initiated reset sense, service the drive according the guidelines recommended in Section 18.13.1, "Drive Service Strategy" on page 302.
   - Other, follow the recommendations for the error reported.

18.13.4.11 Defect List Recovery

This is not an error condition.

The initiator either 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 are:

1/1F/00, the requested list(s) exceed the maximum length that can be supported. Please use the *Read Defect Data (12)* op code 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.

18.13.4.12 Miscompare Recovery

A miscompare can occur on a *Verify (2F)* command or a *Write and Verify (2E)* with the byte check (BytChk) bit active. Recovery for a miscompare error is different for the two commands.

Verify Command

The initiator should do the following:

1. Verify that the data sent to the drive is the correct data for the byte-by-byte compare.
2. 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 data are correct, this is an indication that the data may have been read from the media incorrectly without an error detected. Service the drive using the procedure specified in Section 18.13.1, “Drive Service Strategy” on page 302.
   - If all data are not correct, this is an indication that the data on the media is not the data the initiator expected. Rewrite the correct data to the media.

Write and Verify Command

The drive uses the same data in the data buffer to write then read and compare. A miscompare error on the *Write and Verify (2E)* command is an indication that the drive cannot reliably write or read the media. Service the drive using the procedures specified in Section 18.13.1, “Drive Service Strategy” on page 302.

18.13.4.13 Microcode Error

The microcode from the interface is validated before the device operates using that microcode. If this 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.

If the initiator attempted to load microcode using the *Write Buffer (3B)* retry the *Write Buffer (3B).* If the command 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” on page 302.

If the check sum 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” on page 302.

To load new microcode, the initiator should issue a Write Buffer (3B) command with the download and save option. If the Write Buffer (3B) command completes with

- Good Status, return to normal processing. Retry the failing command. If the task complete with
  - Good Status - Continue normal processing.
  - Check Condition Status for check sum error - Service the drive using the service guidelines recommended in Section 18.13.1, “Drive Service Strategy” on page 302.
  - Check Condition Status for any other error - follow the recommended recovery procedure for the error reported.
- Check Condition Status for Check sum error, service the drive using the service guidelines recommended in Section 18.13.1, “Drive Service Strategy” on page 302.
- Check Condition Status for any other error, follow the recommendations for the returned sense data.

18.13.4.14 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 device with error activity.

If this drive is the only drive attached to the initiator with error activity, service the drive using the procedures specified in Section 18.13.1, “Drive Service Strategy” on page 302.

Note: Service for this drive can be deferred. The longer service is deferred, the more probable a failure can occur that will require immediate service.

If more than this drive is experiencing error activity, the drive is probably not at fault. Locate and service the outside source causing error activity on this drive.

18.14 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 one or more physical blocks that contain user data and protection information, if any. For LBAs that are unmapped, the relationship between the LBA and a physical block is not defined. This drive uses a physical block size based on 4K. 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 4K-based block sizes.

The drive is always considered to be "resource provisioned". Because of this, 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, please refer to section 4.7 of the latest SBC-3 standard.

19.0 SCSI Sense Data

19.1 SCSI Sense Data Format

Format of the sense data returned by the drive in response to the REQUEST SENSE command.

Table 235: Format of Sense Data.

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Valid	Error Code (70h or 71h)						
1	Reserved							
2	0		ILI	0	Sense Key			
3-6	Information Bytes							
7	Additional Sense Length							
8-11	Product 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	Product Specific Information							
30-31	Reserved							

19.2 Sense Data Description

19.2.1 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.

19.2.2 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 immediate bit. Format unit (04h) command is an example of a command that may return a deferred error.

19.2.3 ILI: Incorrect Length Indicator (Bit 5 of byte 2)

The ILI bit is valid for the Read Long (3Eh) command and Write Long (3Fh) command only. ILI set to one and Valid Bit set to one indicates that the requested logical block length does not match the logical block length of the data on the medium for a Read Long or Write Long command. The Information field contains residue information about the error. ILI set to zero indicates there is no incorrect length condition.

0 No Incorrect Length condition.

1 Incorrect Length Indicated.

Valid	ILI	Command = Read Long or Write Long	Description
x	0	x	No incorrect length condition
1	1	yes	Requested Logical block Length does not match the logical block length of the data on the drive

19.2.4 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.

0h **No Sense**

There is no sense key information to be reported 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 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 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 Additional Sense Code Qualifier.

4h **Hardware Error**

The drive detected a unrecoverable hardware error while performing a command or during a diagnostic test. More detailed information is contained in the Additional Sense Code and 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, then the command is terminated without altering the medium. If an invalid parameter is found in parameters supplied as data, then the drive might have altered the medium.

6h **Unit Attention**

Indicates that the drive entered in the 'Unit Attention Condition'. (See Section 18.1.4, “Unit Attention Condition” on page 285)

7h **Data Protect**

8h **Not used**

9h **Vendor Specific**

Ah **Not used**

Bh **Aborted command**

The drive aborted the command.

Ch-Dh **Not Implemented**

Eh **Miscompare**

Fh **Reserved**

19.2.5 Information Bytes (Byte 3 through 6)

This field is only valid when Valid Bit is one.

- 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.

Valid	ILI	Description
0	x	0x00000000 - (not used/invalid)
1	0	LBA
1	1	Residue of the requested length in bytes

19.2.6 Additional Sense Length (Byte 7)

Indicates the remaining number of bytes in the sense data. (It is always set to 18h.)

19.2.7 Command Specific Information (Byte 8 through 11)

This field is unused and will be set to zero.

19.2.8 Additional Sense Code/Qualifier (Byte 12 and 13)

The following table shows the description of the combination of Sense Key / Sense Code / Qualifier.

Error				Reason Error is Reported
SCSI Sense Information			HGST UEC	
Key	Code	Qualifier		
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 70 degree C configurable) (MRIE = 5 or 6)
0x0	**0x0B**	**0x03**		**Background Selftest Failure Warning**
			0x1A03	SMART Warning: Background Selftest completed in Error (MRIE = 5 or 6)
0x0	**0x0B**	**0x04**		**Background Pre-Scan Failure Warning**
			0x1A04	SMART Warning: Background Prescan 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 70 degree C (MRIE = 5 or 6)
0x0	**0x5D**	**0x28**		**Predictive Failure Analysis Capacitor Error**
			0x1A28	SMART Pre-failure: PLI Capacitor Selftest 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 below 10% which results in performance degradation below specification (MRIE = 5 or 6)
0x0	**0x5D**	**0x54**		**Predictive Failure Analysis Remaining Reserve 2**
			0x1A54	SMART Pre-failure: Number of reserve erase blocks drops below 1% which results in severe performance degradation (MRIE = 5 or 6)
0x0	**0x5D**	**0x55**		**Predictive Failure Analysis NAND Channel Failure**
			0x1A55	SMART Pre-failure: NAND Channel failure (MRIE = 5 or 6)
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 70 degree C (MRIE = 3 or 4)

0x1	**0x0B**	**0x03**		**Background Selftest Failure Warning**
			0x2A03	SMART Warning: Background Selftest 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
			0x172D	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**
			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
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 Selftest 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 below 10% which results in performance degradation below specification (MRIE = 3 or 4)
0x1	**0x5D**	**0x54**		**Predictive Failure Analysis Remaining Reserve 2**
			0x2A54	SMART Pre-failure: Number of reserve erase blocks drops below 1% which results in severe performance degradation (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)
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 Spinup) 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	**0x10**	**0x01**		**Logical Block Guard Check Failed**
			0xF7BD	BATS2 T10 End-End Test Failed Guard Band Check
0x3	**0x10**	**0x02**		**Logical Block Application Tag Check Failed**
			0xF7BB	BATS2 T10 End-End Test Failed Application Tag Check
0x3	**0x10**	**0x03**		**Logical Block Reference Tag Check Failed**
			0xF7B9	BATS2 T10 End-End Test Failed Reference Tag Check
0x3	**0x11**	**0x00**		**Unrecovered Read Error**
			0xF72D	NAND ECC Error was uncorrectable
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**		**SanitizeCommand Failed**
			0xF50C	Sanitize command failed
0x3	**0x5D**	**0x01**		**Predictive Failure Analysis Media Error Threshold Exceeded**
			0xFA81	Self Test exceeded the SelfTest Unrecovered Error Threshold

Sense Key (0x4) = Hardware Error				
0x4	**0x3E**	**0x03**		**Logical Unit Failed Self-Test**
			0xF75D	Media Selftest Failed due to Error
0x4	**0x3E**	**0x04**		**Logical Unit Failed to Update Self-Test Log**
			0xF762	DRAM Selftest Failed due to Hard Error
0x4	**0x3E**	**0x05**		**Logical Unit Failed Self-Test Due to Recovered ECC Error**
			0xF763	DRAM Selftest Failed due to Recovered ECC Error
0x4	**0x40**	**0x80**		**Diagnostic Failure**
			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
			0xF107	Incorrect size specified during request for a reserved area file
			0xF108	Incorrect offset specified during request for a reserved area file
			0xF111	Error occurred while loading Flash or Disk Code
			0xF112	Incorrect checksum was calculated inside the Code Download File
			0xF119	BATS2 Read/Write Test Failed
			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	**0x40**	**0xA0**		**Diagnostic Failure**
			0xF11B	BATS2 CRC Test Failed
			0xF11C	BATS2 XOR Test Failed
			0xF136	Failure detected during BATS2 Test of End-End Protection HW
			0xF13E	Failure detected during BATS2 TCG encryption engine verification
0x4	**0x44**	**0x00**		**Internal Target Failure**
			0xF208	Insufficient NAND exists for the desire customer capacity
			0xF209	Mismatch between customer blocksize and NAND blocksize on system boot
			0xF20A	Unable to locate Saved Mode Parameters during system boot
			0xF401	Invalid Error reported from HW Data Path
			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
			0xF56E	Data Size Mismatch detected during read of reserved area contents
			0xF601	NAND Processor failed to complete boot
			0xF602	NAND Processor failed to load FW from NAND

			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
			0xF60E	NAND Processor failed to complete FCONFIG Update
			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
			0xF628	NAND Processor failed to find NAND Log Information
			0xF630	NAND Processor generic boot error
			0xFCxx	Drive failed to read file xx from Flash or Reserved Area
			0xF140	PLI Selftest detected Capacitor exceeded time to charge
			0xF141	PLI Selftest detected Capacitor exceeded time to discharge
			0xF142	PLI Selftest detected Capacitor discharged too quickly
			0xF143	PLI Capacitor is not in fully charged state after PLI Selftest
			0xF144	PLI Capacitor charge time exceeds 500ms
			0xF145	PLI Capacitor test start time exceeded
0x4	**0x44**	**0x31**		**Internal Target Failure**
			0xF631	NAND Processor logically disabled
0x4	**0x5D**	**0x01**		**Predictive Failure Analysis Command Timeout Error Threshold Exceeded**
			0xFA82	Self Test exceeded the SelfTest 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
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 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 chunksize 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
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 70 degree C (MRIE = 2)
0x6	**0x0B**	**0x03**		**Background Selftest Failure Warning**
			0x3A03	SMART Warning: Background Selftest 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**	**0x00**		**Power On, Reset, or Bus Device Reset Occurred**
			0xF515	Unit Attention for LIP
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**
			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 Selftest 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 below 10% which results in performance degradation below specification (MRIE = 2)
0x6	**0x5D**	**0x54**		**Predictive Failure Analysis Remaining Reserve 2**
			0x3A54	SMART Pre-failure: Number of reserve erase blocks drops below 1% which results in severe performance degradation (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
		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	**0x10**	**0x00**		**ID CRC or ECC Error**
			0xF417	HW Data-out Transfer aborted due to CRC Error
			0xF421	HW Data-in 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
			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
			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
			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
			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**
			0xF406	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
			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
			0xF428	HW Data transfer aborted due to write error
			0xF429	HW Data transfer aborted due to read error
			0xF42A	HW Data transfer aborted due to read transfer length error
			0xF526	HW Data-out Transfer aborted due to Data Path LBA Mismatch
			0xF527	HW Data-out or Data-in Transfer aborted due to Data Path Error
			0xF528	HW Data-out or Data-in Transfer aborted due to Data Path Timeout
			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
			0xF540	HW Transfer aborted due to simulated internal abort

			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
			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**	**0x01**		**Invalid Target Port Transfer Tag Received**
			0xF561	SAS Data-out Transfer aborted due to invalid frame length
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
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

19.2.9 RU: Field Replaceable Unit (Byte 14)

The FRU (Field Replaceable Unit) field value will always be zero.

19.2.10 Sense Key Specific (Byte 15 through 17)

The definition of this field is determined by the value of the sense key field.

19.2.10.1 Sense Key Specific - Illegal Request (Sense Key = 5h)

Error field pointer is returned.

Table 236: Field Pointer Bytes

Byte	Bit							
	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** Indicates that the illegal parameter was in the data parameters sent by the initiator during DATA OUT phase
- **1** Indicates that the illegal parameter was 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.

19.2.10.2 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)

Actual Retry Count is reported.

Table 237: Actual Retry Count

Byte	Bit							
	7	6	5	4	3	2	1	0
15	SKSV	Reserved						
16	Reserved							
17	Actual Retry Count							

SKSV Sense-key specific valid

0 Actual Retry Count is not valid.

1 Actual Retry Count is valid.

Actual Retry Count Number of retry steps used in attempting to recover from the error condition..

19.2.10.3 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 238: Progress Indication

Byte	Bit							
	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 percent complete in which the returned value is the numerator that has 10000h as its denominator.

19.2.11 Reserved (Byte 18 through 19)

These bytes are filled with zeroes.

19.2.12 Vendor unique error information (Byte 20 through 23)

This field gives detailed information about the error. It contains a unique code which describes where the error was detected and which piece of hardware or microcode detected the error depending on current operation.

19.2.13 Physical Error Record (Byte 24 thru 29)

- ILI = 1 - This field contains zeros.
- ILI = 0 - These bytes contain the physical location of the error.

  If physical location has no relevance for the error, bytes 24 through 29 will all be set to 0FFFFFFFFFFFFh for Valid = 0 and ILI = 0. This Physical Error Record field is valid for Sense Key 1, 3, and 4 only.

19.2.14 Reserved (Byte 30 through 31)

These bytes are filled with zeroes.

20.0 Appendix. UEC list

Following is the list of Unit Error Codes and associated descriptions. The Unit Error Codes are returned by the target in sense data bytes 20-21.

Table 239: **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
0x172D	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 degree C configurable) (MRIE = 5 or 6)
0x1A03	SMART Warning: Background Selftest 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 degree C (MRIE = 5 or 6)
0x1A28	SMART Pre-failure: PLI Capacitor Selftest Failed due to Capacitor charge or discharge thresholds exceeded (MRIE = 5 or 6)
0x1A53	SMART Pre-failure: Number of reserve erase blocks drops below 10% which results in performance degradation below specification (MRIE = 5 or 6)
0x1A54	SMART Pre-failure: Number of reserve erase blocks drops below 1% which results in severe performance degradation (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)
0x1A57	SMART Pre-failure: XOR Depletion failure (MRIE = 5 or 6)
0x1A73	SMART Pre-failure: General wear failure (MRIE = 5 or 6)
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 Selftest 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 Selftest Failed due to Capacitor charge or discharge thresholds exceeded (MRIE = 3 or 4)
0x2A53	SMART Pre-failure: Number of reserve erase blocks drops below 10% which results in performance degradation below specification (MRIE = 3 or 4)
0x2A54	SMART Pre-failure: Number of reserve erase blocks drops below 1% which results in severe performance degradation (MRIE 3 or 4)
0x2A55	SMART Pre-failure: NAND Channel failure (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 degree C (MRIE = 2)
0x3A03	SMART Warning: Background Selftest 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 Selftest Failed due to Capacitor charge or discharge thresholds exceeded (MRIE = 2)
0x3A53	SMART Pre-failure: Number of reserve erase blocks drops below 10% which results in performance degradation below specification (MRIE = 2)
0x3A54	SMART Pre-failure: Number of reserve erase blocks drops below 1% which results in severe performance degradation (MRIE = 2)
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)
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
0xF107	Incorrect size specified during request for a reserved area file
0xF108	Incorrect offset specified during request for a reserved area file
0xF111	Error occurred while loading Flash or Disk Code
0xF112	Incorrect checksum was calculated inside the Code Download File
0xF119	BATS2 Read/Write Test Failed
0xF11B	BATS2 CRC Test Failed
0xF11C	BATS2 XOR Test Failed
0xF11D	Code from Reserved Area does not match Flash Code
0xF120	Single binary download is not compatible with existing code on drive
0xF123	Power transition to sleep mode requested at inappropriate time
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 chunksize detected during single binary code download
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
0xF130	Customer version of single binary download is not compatible with existing code on drive
0xF131	Timeout during write of one word to flash
0xF133	Customer mismatch detected during load of a reserved area file
0xF136	Failure detected during BATS2 Test of End-End Protection HW
0xF139	Error detected during an attempt to resize reserved area files during a code download
0xF13C	Error detected during test of reserved DRAM
0xF13D	RSA signature verification failure on download file
0xF13E	Failure detected during BATS2 TCG encryption engine verification

0xF140	PLI Selftest detected Capacitor exceeded time to charge
0xF141	PLI Selftest detected Capacitor exceeded time to discharge
0xF142	PLI Selftest detected Capacitor discharged too quickly
0xF143	PLI Capacitor is not in fully charged state after PLI Selftest
0xF144	PLI Capacitor charge time exceeds 500ms
0xF145	PLI Capacitor test start time exceeded
0xF147	Security AES verification failure
0xF148	Security RSA verification failure
0xF149	Security DRGB verification failure
0xF14A	Security SHA256 verification failure
0xF208	Insufficient NAND exists for the desire customer capacity
0xF209	Mismatch between customer blocksize and NAND blocksize on system boot
0xF20A	Unable to locate Saved Mode Parameters during system boot
0xF401	Invalid Error reported from HW Data Path
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
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
0xF418	HW Data-out Transfer aborted due to transfer error
0xF419	HW Data-out Transfer aborted due to transfer timeout
0xF420	HW Data-in Transfer aborted due to error
0xF421	HW Data-in Transfer aborted due to CRC Error
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
0xF426	HW Data-in Transfer aborted due to transfer error
0xF427	HW Data-in Transfer aborted due to transfer timeout
0xF428	HW Data transfer aborted due to write error
0xF429	HW Data transfer aborted due to read error
0xF42A	HW Data transfer aborted due to read transfer length 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
0xF50B	LUN is not ready due to in progress
0xF50C	Sanitize command failed
0xF50D	Illegal Phy Test Request
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
0xF515	Unit Attention for LIP
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
0xF526	HW Data-out Transfer aborted due to Data Path LBA Mismatch
0xF527	HW Data-out or Data-in Transfer aborted due to Data Path Error
0xF528	HW Data-out or Data-in Transfer aborted due to Data Path Timeout
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
0xF535	Miscompare detected during Verify or Write & Verify with Byte Check
0xF536	Reservation Conflict detected
0xF537	Unit Attention for Device Identifier Change
0xF53E	Data Phase error during a Data-out Transfer
0xF53F	Command was aborted due to link initialization
0xF540	HW Transfer aborted due to simulated internal abort
0xF544	DRAM Read Echo Buffer was overwritten
0xF548	Unit Attention for FCAL Device Control Hard Reset
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
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
0xF601	NAND Processor failed to complete boot
0xF602	NAND Processor failed to load FW from NAND
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
0xF60E	NAND Processor failed to complete FCONFIG Update
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
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
0xF740	Too many defects to support the capacity
0xF75C	Overall Command Timeout exceeded
0xF75D	Media Selftest Failed due to Error
0xF762	DRAM Selftest Failed due to Hard Error
0xF763	DRAM Selftest Failed due to Recovered ECC Error
0xF7B9	BATS2 T10 End-End Test Failed Reference Tag Check
0xF7BB	BATS2 T10 End-End Test Failed Application Tag Check
0xF7BD	BATS2 T10 End-End Test Failed Guard Band Check
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
0xF820	SCSI Command failed to execute due to Parameter List Length Error
0xF821	SCSI Command failed to execute due to Illegal Operation Code
0xF822	SCSI Command failed to execute due to LBA Range Error
0xF823	SCSI Command failed to execute due to Invalid Field Setting in 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
0xF828	SCSI Command failed to perform Release due to Persistent Reservation
0xFA81	Self Test exceeded the SelfTest Unrecovered Error Threshold
0xFA82	Self Test exceeded the SelfTest Command Timeout Error Threshold
0xFCxx	Drive failed to read file xx from Flash or Reserved Area

21.0 TCG SSC

This chapter provides information on HGST encryption-specific SSD firmware and features. It is assumed that the reader is familiar with the referenced specifications and industry standards.

21.1 Referenced Specifications and Standards

21.1.1 TCG Specifications

This section references 3 separate TCG specifications, which are available on the TCG website:
(**http://www.trustedcomputinggroup.org/**):

1. TCG Core Specification, Version 1.0, Revision 0.9
   - The TCG Core Specification is the general specification for trusted computing that encompasses all classes of devices, including storage
2. TCG Storage Interface Interactions Specification (SIIF), Version 1.0, 1/27/2009
   - Specifies the interaction between the SSD and the SCSI/ATA protocols
3. TCG Storage Security Subsystem Class (SSC): Enterprise, Version 1.0, rev 1.0, spec dated 1/27/09
   - A Security Subsystem Class defines minimum acceptable Core Specification capabilities of a storage device in a specific class (in our case – enterprise).
   - Storage devices in specific classes may have a subset of the capabilities that are defined in the core specification

21.1.2 Federal Information Processing Standards (FIPS)

This section references the following Federal Information Processing Standards, published by the US National Institute of Standards (NIST), which are available on the NIST website (**http://www.itl.nist.gov/fipspubs/**):

1. FIPS 197, Advanced Encryption Standard (AES), 2001 November 26. **http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf**
2. FIPS 180-3, Secure Hash Standard (SHS)
   http://csrc.nist.gov/publications/fips/fips180-3/fips180-3_final.pdf
3. FIPS 140-2, Security Requirements for Cryptographic Modules – 01 May 25
   (Supersedes FIPS PUB 140-1, 1994 January 11)
   http://csrc.nist.gov/publications/fips/fips140-2/fips1402.pdf

21.1.3 National Institute of Standards (NIST)

This section references the following NIST publications, available on the NIST website (http://www.nist.gov/index.html)

1. NIST Special Publication 800-90, Recommendation for Random Number Generation Using Deterministic Random Bit Generators (Revised), http://csrc.nist.gov/publications/nistpubs/800-90/SP800-90revised_March2007.pdf

21.1.4 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**

21.1.5 RSA Laboratories Standards

1. RSA-PSS - **http://www.rsa.com/rsalabs/node.asp?id=2146**
2. RSA PKCS #5 v2.0 Password-Based Cryptography Standard **-** **ftp://ftp.rsasecurity.com/pub/pkcs/pkcs-5v2/pkcs5v2-0.doc**

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21.1.6 Other Standards

1. T10 SCSI Standard.(T10 homepage **- (http://www.t10.org/index.html**)

21.2 Implementation Exceptions

The following is a list that describes non-compliance with the TCG Enterprise SSC specification:

- The SSC specification requires support for 1024 bands, but the implementation supports up to 4 bands.
- The K_AES_256 table was implemented with only the **UID** and **MODE** columns.
- At any given time, the implementation allows for only 1 active session. In the case when a session is active and a new session is requested, the drive answers the host with SP_BUSY, instead of NO_SESSIONS_AVAILABLE

21.3 Implementation Features and Details Outside of TCG Specifications

The following features are outside of the TCG specifications.

1. Ports
2. Firmware signing

The following implementation details are outside of the TCG SSC specification.

a. The SSC 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 we ignore it, therefore no error is generated.
b. When handling a "TCG cmd followed by a R/W cmd", all reads and writes that follow a TCG command will be processed in the normal way. No special handling or error messages will be sent to the host. It is up to the host to understand the possible outcomes of TCG commands and r/w command ordering and plan accordingly.
c. The TPer replies with SP_BUSY for requests beyond 1 session.
d. Sunset Cove drives that use TCG must have all new or erased bands initialized with write data before those ranges are read. On Sunset Cove TCG, CRC checking is enabled, so bands must be initialized with write data or CRC errors will be returned.

21.4 Encryption Algorithms

21.4.1 Advanced Encryption Standard (AES) Support

AES encryption is implemented in hardware, with support for ECB or XTS mode for 128 bit or 256 bit keys. A single key is active at any one time within the AES hardware engine. Firmware is responsible for reading the keys from the hardware and also for determining which key is attached to a given LBA range; the hardware can only detect if the LBA has been encrypted or not. The TCG protocol does not allow for a user to choose or switch between AES algorithms, so it is up to the vendor to choose which AES algorithm is used in their implementation. The HGST TCG SSC implementation in firmware supports AES 256-XTS only. Firmware does not accept external keys, and does not support the manipulation or reading of any internally generated keys it creates for AES.

21.4.2 Level 0 Discovery Vendor Specific Data

This section refers to section 10.2.14 of the TCG Storage Security Subsystem Class document (see the Specifications section of this document). Table 2 of Section 10.2.14 displays a "Vendor Specific" section in bytes 16 to 47. This Vendor Specific section is documented below.

Table 240: Persistent Reserve In (5E)

Byte	Bit							
	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
22-47	Reserved							

FDE_s/FDE_e - Full disk encryption is Supported (equivalent to Media Encryption in Locking Feature Descriptor Enterprise SSC 10.2.14) / Full disk encryption is Enabled on one or more band.

Locking_s/Locking_e - LBA band locking is supported - locking object exists in the locking SP of the device (equivalent to Locking Enabled in Locking Feature Descriptor Enterprise SSC 10.2.14) / 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/Dload_e - support for Admin SP Firmware download port / Firmware download port via Admin SP is locked.

Diag_s/Diag_e - Support for Admin SP vendor specific Diagnostic port / Diagnostics port via Admin SP is locked.

MB_s/MB_e - Multiple encrypting bands supported / Multiple encrypting bands enabled. This bit shall be set to 1 if more than one band exists in addition to the global band and is defined with at least one LBA.

21.4.2.1 T10 End-To-End Data Protection

AES encryption is performed after T10 end-to-end data protection data has been added, so that the T10 information is encrypted along with the customer data.

21.4.3 Pseudo Random Number Generation (PRNG)

Pseudo-random number generation is implemented using the NIST SP800-90 PRNG. This PRNG uses AES as a primitive both for entropy mixing and entropy output. The successive values of the state of the PRNG are kept private to the device to ensure that keys generated by the device are unpredictable. The PRNG seed is derived from an LSI Ring Oscillator that generates random numbers using hardware.

21.4.4 Key Erasure

Cryptographic erase procedure

- Erase and overwrite wrapped key material with 0x00.
- Erase and store the new wrapped key material.

21.5 TCG SSC Tables

Two copies of all TCG SCC tables and data structures are stored in the RID; 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 RID. In the case 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 reinitialized to default values automatically, and this will result in a key mismatch error when a read is attempted.

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 the time of manufacturing.

- Admin SP C_PIN table
- Locking C_PIN table
- K_AES_256 table
- Locking SP Locking Access Control table
- LockingInfo table
- Locking SP Locking table
- DataStore table

The VU entries for these tables are specified below. In addition, explanation of default values is given for non-VU entries that require it.

21.5.1 Admin SP C_PIN Table and Locking SP C_PIN Table

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 241: HGST Implementation of Admin SP_CPIN and Locking C_PIN

..	PIN	TryLimit	Tries	Persistence
..	MSID	0	0	0
..	MSID	0	0	0
..	..	..	..	..
..	MSID	0	0	0

21.5.2 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 242: HGST 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 40	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 4 entries.

21.5.3 Locking SP AccessControl Table

The TCG Enterprise SSC 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 = 4 (The implementation supports 4 bands)
- The number 7 comes from the fact that each band has 7 UID/method combinations
- 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 243: HGST Implementation of Locking SP Access Control Table

Row Number	UID	•
0	0	.
1	1	.
•	•	•
459	459	•

21.5.4 Locking Info Table

As specified in the TCG Enterprise SSC, 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) in manufacturing.

Table 244: HGST Implementation of Locking Info Table

•	NAME	Version	•	Encrypt Support	MaxRanges	MaxReEncryptions	KeysAvailable Cfg
.	0	0	.	23	0	0	0

21.5.5 Locking SP Locking Table

The "Vendor Unique" (VU) values for this table are shown below.

Table 245: 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 00 00 00 00 00h	0	0	0	0	0	0	0	0
•	•	•	•	•	•	•	•	•	•
.	00 00 00 00 00 00 00 00h	0	0	0	0	0	0	0	0

In the **ActiveKey** column, the Enterprise SCC allows for byte 3 to be defined as either 05 or 06. The HGST implementation uses 06.

21.5.6 DataStore Table

TCG SSC Enterprise requires storage devices to contain a DataStore table. The DataStore table provides 1024 bytes of non-volatile storage for host access and modification. TCG allows all authenticated BandMaster authorities to write to the DataStore table. However, TCG SSC Enterprise specifies that there is "unconstrained read access." This means that the Anybody authority is allowed to read information from the DataStore table.

NOTE: Bandmasters should not save sensitive data to the DataStore table because any connecting individual is allowed to read the data via the unauthenticated Anybody authority.

21.6 Firmware Download and Signing

The HGST Firmware signing and download for encryption drives is meant to provide a mechanism for secure updates through the Host interface. Firmware is downloaded to the drive through the host interface, and the signature is verified using a public key installed in the reserved area during manufacturing, before it is loaded to RAM or installed in the reserved area on the SSD.

Signature verification uses the RSA-PSS (Probabilistic Signature Scheme) signature verification algorithm with EMSA-SHA256 as padding function. The firmware was designed and implemented with the intention of meeting the signing requirements under FIPS 140-2.

All HGST firmware packages will be signed, but only encryption enabled drives will verify the signature. If the signature cannot be successfully verified on encryption drives, the firmware cannot be downloaded onto the HGST encryption drives. Failures to authenticate the firmware image will result **in Check Condition with KCQ 5/26/9a (FRU 0)**. The act of issuing a firmware download to the drive will result in an implicit close of all open sessions at the security layer.

21.7 Ports

The ports capability is an HGST feature which is not a requirement under TCG Enterprise SSC. In order to use the ports capabilities on encryption drives, the user must successfully authenticate. Once a user successfully authenticates, they may change the state of any of the ports at any time during an active session to either the locked or unlocked state. The functionality and definition of these ports is shown below in a table.

The feature does make use of the TCG structures and tables. An additional table, the ports table, has been implemented, and additional entries were made to the Admin SP ACE table and the Admin SP AccessControl Table. The ports table and the modified TCG SSC tables are shown below

Table 246: **Ports Functionality**

Port Name	Description
Firmware Download	This port has 2 valid states: locked and unlocked. On encryption drives, the download port is unlocked initially, LockOnReset is "Null". Code can be downloaded onto the drive after the signature is successfully verified. If the signature cannot be verified successfully, no firmware can be downloaded to the drive. The user can change the state of the firmware download port only after authentication. On non-encryption drives, this port will be set to unlocked at the factory, and the state cannot be changed by the user. Firmware will be downloaded to the non-encryption drive through this port without verification of the signature.
Diagnostics	This port has 2 valid states: locked and unlocked. This port allows HGST access to modify any TCG table or key. In order to open this port both the SID and the Maker authorities need to be authenticated. The purpose of this port is to aid HGST in debugging

Table 247: **Ports Table**

UID	Name	LocOnReset	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 248: Modified Admin SP ACE Table

UID	Name	Cmn 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	“”	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	“”	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”

The last 2 lines of the table are the additional entries required to implement the firmware download port.

Table 249: Modified Admin SP AccessControl Table

Row Number	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)	AnybodyAuthenti-cateAdminSP	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 Author-ity object)	00 00 00 06 00 00 00 06 (Get)	Anyboby-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 Author-ity object)	00 00 00 06 00 00 00 06 (Get)	Anyboby-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 object)	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 Author-ity object)	00 00 00 06 00 00 00 07 (Set)	SID_SetMakers-Set-Makers Author-ity 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)

The last 2 lines of the table are the additional entries required to implement the firmware download port.

21.8 MSID

The MSID is set for each drive at the time of manufacturing to the serial number concatenated 4 times, to create a 32 byte password. Thus, as an example, if the serial number of a drive is abcd1234, the MSID would then be set to abcd1234abcd1234abcd1234abcd1234. In TCG use cases such as “erase” or “repurpose”, this will be the MSID that is restored to the drive.

HGST serial numbers are unique and are generated according to the following general rules:

- Maximum length of the serial number is 8 characters
- Serial numbers do not contain the characters “I”or “O”.

21.9 Logging

HGST logging functions will not record any sensitive data such as customer plain text data, passwords, encryption keys or wrapping keys.

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21.10 Number of Sessions

The HGST implementation supports 1 active session at a time. In the case when a session is active and a new session is requested, the drive answers the host with SP_BUSY. This covers the following 2 scenarios.

- If an SP is in session and an attempt is made to start a second session with the same SP.
- If an SP is in session and an attempt is made to start a second session with a different SP.

21.11 Number of Bands

The Enterprise SSC specification calls for support of up to 1024 bands. The HGST implementation supports a maximum of 4 bands.

21.12 Number of COMIDs

The HGST Enterprise SSC implementation supports 2 COMIDs, the minimum requirement in the Enterprise SSC specification. Only 1 comid can be in use at any time.

21.13 Locked and Unlocked Behavior

21.13.1 T10 SCSI Commands

The table below describes how basic T10 SCSI commands behave on encryption drives in the locked and unlocked states.

Table 250: T10 SCSI Commands Behavior Table

Command	Unlocked	Locked
FORMAT UNIT (04)	OEM	Command can't be executed when locked. Must unlock with MSID or password, before formatting.
INQUIRY (12)	OEM	OEM
LOG SELECT (4C)	OEM	OEM
LOG SENSE (4D)	OEM	OEM-no access to customer data, will get some log information.
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. Sensitive data cannot be snapshotted 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
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
SANITIZE (48)	OEM	OEM
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

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 still do ECC checking, and is 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 still do ECC checking, and is 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 still do ECC checking, and is 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 still do ECC checking, and is 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 (write DRAM onto drive)	OEM.
WRITE BUFFER (3B) (For FW download)	FW is signed and downloaded.	OEM. The write buffer command only functions to write 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.

21.13.2 TCG SSC Commands

The table below describes how the required TCG Enterprise SSC commands behave on encryption drives in the locked and unlocked states. The TCG SSC requires the implementation of the Base, Admin, Locking, and Crypto Templates. As noted, the Crypto template was not implemented. In addition the SSC does not require any Admin Template tables or methods, so they are not mentioned in the table below.

Table 251: TCG Enterprise SSC Commands Behavior

Command	Description	unlocked	Locked
Session Management	**There are two types of sessions: 1) Read-Only session 2) Read-Write session. The SSC requires us to support Read-Write sessions. Read-Only session is not allowed. A session is always initiated by the host. See the "Write" parameter in the StartSession method description @ TCG Core 5.2.3.1, and see SSC requirement in SSC 6.2.1.2.**		
Properties	Returns session properties to host.	N/A	N/A
StartSession	Start a session	N/A	N/A
SycSession	Response to say session successfully started.	N/A	N/A
CloseSession	End (Close) a session	N/A	N/A

Command	Description	unlocked	Locked
Discovery	**Allows the host to discover a TCG drive, its properties, and table values.**		
Level 0	Discovery request sent by host as IF-RCV command. Security Protocol = 0x01, COMID=0x0001	N/A	N/A
Level 1	Request basic TPER capabilities via properties using host messaging.	Uses properties method.	Uses properties method.
Level 2	TCG methods retrieve table cell values.	See methods below.	See methods below.

Command	Description	unlocked	Locked
Cryptographic Template	**Random function is only function required under SSC**		
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.

Command	Description	unlocked	Locked
Base Template	**Mandatory**		
Set	Sets a value in a table	N/A - table operations. Not related to bands/data on drive.	N/A - table operations. Not related to bands/data on drive.
Get	Gets (reads) a value in a table	N/A - table operations. Not related to bands/data on drive.	N/A - table operations. Not related to bands/data on drive.
ParamCheck LRC	TPer implements param check LRC (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 - table operations. Not related to bands/data on drive.	N/A – table operations. Not related to bands/data on drive.
Authenticate	Authenticate an authority within a session (session must have successfully begun).	Must be authorized.	Must be authorized.
GatACL	Returns contents of access controls association's ACL stored in Method Table. The result is a list of uidrefs to ACE objects.	N/A - table operations. Not to do with bands/data on drive.	N/A – table operations. Not related to bands/data on drive.

Command	Description	unlocked	Locked
Locking Template	Mandatory		
Erase	Cryptographically erases user data in a specified LBA range and resets the access control (locking) of that LBA	Can erase if authorized.	Generates error.

21.14 Error Codes

All error codes are compliant with the TCG Core specification and SIIF, except in the following case:

- The maximum sessions allowed at any single time is 1. When a session is active and a new session is requested, the drive answers the host with SP_BUSY, instead of NO_SESSIONS_AVAILABLE.

22.0 Customer Specific Requirements

This specification does not cover customer-specific requirements. Customer-specific requirements are submitted by the customer to HGST in the form of a customer-specification document.

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