



Western Digital.



Hard disk drive specifications

Ultrastar[®] DC HC590

3.5-inch Serial Attached SCSI hard disk drive

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WUH722624AL5201
WUH722624AL5204

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1 General

1.1 Introduction

This document describes the specifications of the Ultrastar® DC HC590 a Western Digital 3.5-inch 7200-rpm Serial Attached SCSI interface hard disk drive with the following model numbers:

Table 1 Type and Model#

| Capacity | Type | Interface | Format | Model# | Description | P3 Power Disable Supported |
|--------------------|---------------|----------------------|-----------------|-------------------|-------------------|----------------------------|
| 26TB ^{*2} | US7SSU260 | Serial Attached SCSI | 512 Emulation | WUH722626AL5201 | SED ^{*1} | Yes |
| 24TB | | | | WUH722626AL5204 | Base(SE) | |
| | 512 Emulation | | WUH722624AL5201 | SED ^{*1} | | |
| WUH722624AL5204 | | | Base(SE) | | | |

^{*1}TCG w/ Instant Secure Erase

^{*2}One TB equals one trillion bytes. Actual user capacity may be less due to operating environment.

How to Read Model Numbers

WUH722626AL5204 – 26TB SAS 12Gb/s 512e Base (SE) with Pin 3 support

W = Western Digital

U = Ultrastar

H = Helium

72 = 7200 RPM

26 = Max capacity (26TB)

26 = Capacity this model (26TB)

(24 = Capacity this model (24TB))

A = Generation code

L = 26.1mm z-height

52 = Interface (52 = 512e SAS 12Gb/s)

^{**} 512e models can be converted to 4Kn format and vice versa

(Note: Changing the block size does not change the HDD Model Number reported by the drive.)

0 = Power Disable Pin 3 support

4 = Data Security Mode. Base (SE)^{*} : No Encryption, Sanitize Overwrite only

1 = SED^{*} : Self-Encryption Drive

TCG-Enterprise and Sanitize Crypto Scramble / Erase

^{**} See section 8.9 Mode Select & 8.11.1 Mode Parameter List

1.2 Glossary

| | |
|------------|---------------------------------------------------|
| ADM | Automatic Drive Maintenance |
| DFT | Drive Fitness Test |
| ESD | Electrostatic Discharge |
| GB | 1,000,000,000 bytes |
| Gbps | 1,000,000,000 bits per second |
| ISE | Instant Secure Erase |
| KiB | 1,024 bytes |
| Kbpi | 1,000 bits per inch |
| Ktpi | 1,000 tracks per inch |
| MiB | 1,048,576 bytes |
| MB | 1,000,000 bytes |
| MB/s | 1,000,000 bytes per second |
| Mbps | 1,000,000 bits per second |
| MiB/s | 1,048,576 bytes per second |
| PI | Protection Information |
| PSID | Physical presence Security ID |
| S.M.A.R.T. | Self-Monitoring Analysis and Reporting Technology |
| SE | Secure Erase |
| SED | Self-Encrypting Drive |
| TB | 1,000,000,000,000 bytes |
| TCG | Trusted Computing Group |

1.3 General caution

Do not apply force to the top cover. Handle the drive by its edges or frame only.

Do not touch the interface connector pins or the surface of the print circuit board.

The drive can be damaged by shock or ESD (Electrostatic Discharge). Any damage sustained by the drive after removal from the shipping package and opening the ESD protective bag are the responsibility of the user.

1.4 References

- SAS Compliance: “Serial Attached Serial SCSI-3 (SAS-3)”
- SAS Protocol
 - This drive supports Serial SCSI Protocol (SSP)
 - STP (Tunneled SATA) and SMP (Management protocol) protocols are NOT supported

2 General features

- Data capacities of 26TB and 24TB
- Spindle speeds of 7200 RPM
- Fluid Dynamic Bearing motor
- Triple Stage Actuator
- Closed-loop actuator servo
- Load/Unload mechanism, non-head disk contact start/stop
- Automatic Actuator lock
- Write Cache
- Power saving modes/Low RPM idle mode (APM)
- S.M.A.R.T. (Self-Monitoring and Analysis Reporting Technology)
- Adaptive zone formatting
- RVS (Rotational Vibration Safeguard)
- 512MiB DDR4 Memory
- 64GB iNAND® embedded flash drive
- Segmented buffer implementation
- Automatic Error Recovery procedures for read and write commands
- Automatic defect reallocation
- PSID support
- SAS Interface 12/6/3/1.5Gbps
- dual-ported operations support
- full duplex operations support
- Variable sector size (512-528 bytes in multiples of eight)
- Back to back write
- Self-diagnostics at power on
- 64 bit addressing feature
- SAS-3 compliant
- ANSI T10 Protection Information (End-to-End)
- TCG Enterprise Encryption support (specific model only)
- FIPS 140-3, 180-4 and 197 support (specific models only)

Part 1. Functional specification

3 Fixed disk subsystem description

3.1 Control Electronics

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

- Controls and interprets all interface signals between the host controller and the drive.
 - Controls read write accessing of the disk media, including defect management and error recovery.
 - Controls starting, stopping, and monitoring of the spindle.
 - Conducts a power-up sequence and calibrates the servo.
 - Analyzes servo signals to provide closed loop control. These include position error signal and estimated velocity.
 - Monitors the actuator position and determines the target track for a seek operation.
 - Controls the voice coil motor driver to align the actuator in a desired position.
 - Constantly monitors error conditions of the servo and takes corresponding action if an error occurs.
 - Monitors various timers such as head settle and servo failure.
 - Performs self-checkout (diagnostics).
-

3.2 Head disk assembly

The head disk assembly (HDA) is assembled in a clean room environment and contains the disks and actuator assembly. Helium is constantly circulated and filtered when the drive is operational. No venting of the HDA is accomplished, as HDA is hermetically sealed.

The spindle is driven directly by an in-hub, brushless, sensor less DC drive motor. Dynamic braking is used to quickly stop the spindle.

3.3 Actuator

The read/write heads are mounted in the actuator. The actuator is a swing-arm assembly driven by a voice coil motor. A closed-loop positioning servo controls the movement of the actuator. An embedded servo pattern supplies feedback to the positioning servo to keep the read/write heads centered over the desired track.

The actuator assembly is balanced to allow vertical or horizontal mounting without adjustment.

When the drive is powered off, the actuator automatically moves the head to the actuator ramp outside of the disk where it parks.

4 Drive characteristics

This section describes the characteristics of the drive.

4.1 Default logical drive parameters

The default of the logical drive parameters in Identify Device data is as shown below.

Table 2 Formatted capacity

| Description | 26TB model | | | |
|-----------------------------------|--------------------|--------------------|--------------------|--------------------|
| Physical Layout | | | | |
| Label capacity | 26TB | | | |
| Bytes per Sector | 4,096 | 4,096+8*8PI | 4,160 | 4,224 |
| Number of Heads | 22 | 22 | 22 | 22 |
| Number of disks | 11 | 11 | 11 | 11 |
| Logical Layout¹ | | | | |
| Bytes per Sector | 512 | 512+8PI | 520 | 528 |
| Number of Sectors | 50,782,535,680 | 49,750,736,896 | 49,750,736,896 | 48,995,762,176 |
| Total Logical Data Bytes | 26,000,658,268,160 | 25,870,383,185,920 | 25,870,383,185,920 | 25,869,762,428,928 |

| Description | 26TB model | | | |
|-----------------------------------|--------------------|--------------------|--------------------|--------------------|
| Physical Layout | | | | |
| Label capacity | 26TB | | | |
| Bytes per Sector | 4,096 | 4,096 + 8PI | 4,160 | 4,224 |
| Number of Heads | 22 | 22 | 22 | 22 |
| Number of disks | 11 | 11 | 11 | 11 |
| Logical Layout¹ | | | | |
| Bytes per Sector | 4,096 | 4,096 + 8PI | 4,160 | 4,224 |
| Number of Sectors | 6,347,816,960 | 6,303,514,624 | 6,218,842,112 | 6,124,470,272 |
| Total Logical Data Bytes | 26,000,658,268,160 | 25,869,624,016,896 | 25,870,383,185,920 | 25,869,762,428,928 |

| Description | 24TB model | | | |
|-----------------------------------|--------------------|--------------------|--------------------|--------------------|
| Physical Layout | | | | |
| Label capacity | 24TB | | | |
| Bytes per Sector | 4,096 | 4,096+8*8PI | 4,160 | 4,224 |
| Number of Heads | 22 | 22 | 22 | 22 |
| Number of disks | 11 | 11 | 11 | 11 |
| Logical Layout¹ | | | | |
| Bytes per Sector | 512 | 512+8PI | 520 | 528 |
| Number of Sectors | 46,875,541,504 | 45,923,434,496 | 45,923,434,496 | 45,227,180,032 |
| Total Logical Data Bytes | 24,000,277,250,048 | 23,880,185,937,920 | 23,880,185,937,920 | 23,879,951,056,896 |

| Description | 24TB model | | | |
|-----------------------------------|--------------------|--------------------|--------------------|--------------------|
| Physical Layout | | | | |
| Label capacity | 24TB | | | |
| Bytes per Sector | 4,096 | 4,096 + 8PI | 4,160 | 4,224 |
| Number of Heads | 22 | 22 | 22 | 22 |
| Number of disks | 11 | 11 | 11 | 11 |
| Logical Layout¹ | | | | |
| Bytes per Sector | 4,096 | 4,096 + 8PI | 4,160 | 4,224 |
| Number of Sectors | 5,859,442,688 | 5,818,548,224 | 5,740,429,312 | 5,653,397,504 |
| Total Logical Data Bytes | 24,000,277,250,048 | 23,879,321,911,296 | 23,880,185,937,920 | 23,879,951,056,896 |

Notes:

¹ Logical layout: Logical layout is an imaginary drive parameter (that is, the number of heads) which is used to access the drive from the system interface. The Logical layout to Physical layout (that is, the actual Head and Sectors) translation is done automatically in the drive. The default setting can be obtained by issuing an IDENTIFY DEVICE command

4.2 Data sheet

Table 3 Data sheet

| Description | 26TB Model | 24TB Model |
|----------------------------------------------|------------|------------|
| Max Data transfer rate (Mbps) | 2690 | 2560 |
| Max Interface transfer rate (MB/s) | 1200 | 1200 |
| Max Sustained transfer rate (MB/s) *1 | 302 | 287 |
| Max Sustained transfer rate (MiB/s) *1 | 288 | 274 |
| Memory size (MiB) | 512 | 512 |
| Rotational speed (RPM) | 7,200 | 7200 |
| Recording density- max (Kbpi) | 2280 | 2170 |
| Track density (Ktpi) | 515 | 500 |
| Areal density - max (Gbits/in ²) | 1190 | 1100 |

*1 The location of the max Sustained transfer rate is at approximately 10% into the capacity of the HDD.

4.3 Worldwide Name Assignment

Table 4 World Wide Name Assignment

| Description | WWN |
|------------------------------------------|----------------------------------|
| Organizationally Unique Identifier (OUI) | 000CCAh (for WESTERN DIGITAL) |
| SHBU Block Assignment | 2F1h, 401h,405h, 413h (Thailand) |

4.4 Drive organization

4.4.1 Drive Format

Upon shipment from WESTERN DIGITAL manufacturing the drive satisfies the sector continuity in the physical format by means of the defect flagging strategy described in Section 5 on [page 28](#) to provide the maximum performance to users.

4.4.2 Cylinder allocation

Physical cylinder is calculated from the starting data track of 0. It is not relevant to logical CHS. Depending on the capacity some of the inner zone cylinders are not allocated.

Data cylinder

This cylinder contains the user data which can be sent and retrieved via read/write commands and a spare area for reassigned data.

Spare cylinder

The spare cylinder is used by WESTERN DIGITAL manufacturing and includes data sent from a defect location.

4.5 Performance characteristics

Drive performance is characterized by the following parameters:

- Command overhead
- Mechanical positioning
 - Latency
- Data transfer speed
- Buffering operation (Look ahead/Write cache)

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

The terms “Typical” and “Max” are used throughout this specification with the following meanings: Typical. The average of the drive population tested at nominal environmental and voltage conditions. Max. The maximum value measured on any one drive over the full range of the environmental and voltage conditions. (See Section 6.2, “Environment” and Section 6.3, “DC Power Requirements”)

4.5.1 Mechanical positioning

4.5.1.1 Average latency

Table 5 Latency Time

| Rotational speed | Time for a revolution (ms) | Average latency (ms) |
|------------------|----------------------------|----------------------|
| 7200 RPM | 8.3 | 4.16 |

4.5.2 Drive ready time

Table 6 Drive ready time

| Power on to ready | POR Condition | Typical (sec) | Maximum (sec) |
|-------------------|----------------------------------------------------------------------------------------|---------------|---------------|
| 11 Disk model | Controlled POR without Deferred FW Activation | 25 | 30 |
| | Controlled POR with Deferred FW Activation | N/A | 60 |
| | Uncontrolled POR (EPO) with destage to media cache and possible Deferred FW Activation | N/A | 75 |

Ready The condition in which the drive can perform a media access command (such as read, write) immediately

Power on This includes the time required for the internal self-diagnostics.

Notes: The typical and maximum drive ready times in the table are for proper power shutdown using the required power-off sequence. The actual time may vary depending on the drive pre-condition before the EPO event.

4.5.3 Operating modes

4.5.3.1 Operating mode descriptions

| Operating mode | Description |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Spin up | Period of time from 0 rpm to full rpm |
| Start up | Period of time from power on to drive ready. |
| Seek | Seek operation mode |
| Write | Write operation mode |
| Read | Read operation mode |
| Active | Drive is able to perform a media access command (such as read, write) immediately |
| Idle_0 | Drive Ready, but not performing IO, drive may power down selected electronics to reduce power without increasing response time |
| Idle_A | Drive Ready, but not performing IO, drive may power down selected electronics to reduce power without increasing response time |
| Idle_B | Spindle rotation at 7200 RPM with heads unloaded |
| Idle_C/Standby_Y | Spindle rotation at Low RPM with heads unloaded |
| Standby_Z | Actuator is unloaded and spindle motor is stopped. Commands can be received immediately |

Note: Upon power down or spindle stop a head locking mechanism will secure the heads in the OD parking position.

4.5.3.2 Mode transition times

Mode transition times are shown below

Table 7 Mode transition times

| From | To | RPM | Typical (sec) |
|-----------|--------|--------------|---------------|
| Idle_B | Active | 7200 | 1.5 |
| Idle_C | Active | 6300 -> 7200 | 4 |
| Standby_Y | Active | 6300 -> 7200 | 4 |
| Standby_Z | Active | 0 > 7200 | 15 |

Note: Maximum transition time of 30 Seconds based on drive timeout value

5 Defect flagging strategy

Media defects are remapped to the next available sector during the Format Process in manufacturing. The mapping from LBA to the physical locations is calculated by an internally maintained table.

5.1 Shipped format

- Data areas are optimally used.
 - No extra sector is wasted as a spare throughout user data areas.
 - All pushes generated by defects are absorbed by the spare tracks of the inner zone.
-

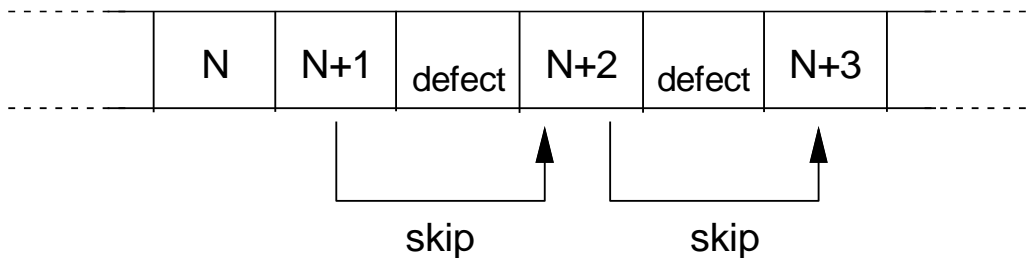


Figure 1 PList physical format

Defects are skipped without any constraint, such as track or cylinder boundary. The calculation from LBA to physical is done automatically by internal table.

6 Specification

6.1 Electrical interface

6.1.1 Connector location

Refer to the following illustration to see the location of the connectors.

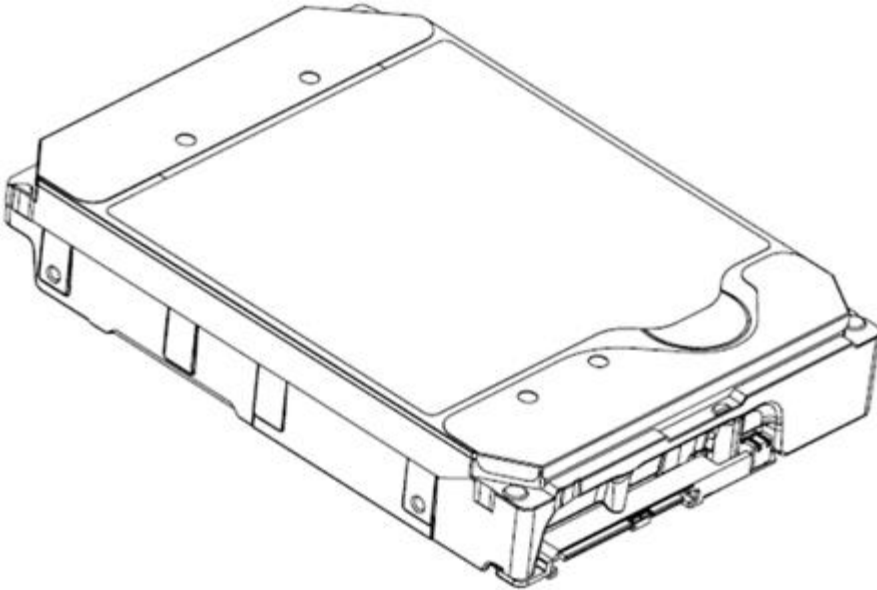


Figure 2 Connector location

6.1.1.1 Signal 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 disk 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.

6.1.2 29 pin Serial Attached SCSI (SAS) Connector Definition

Diagram of top and bottom of connector showing pin outs.

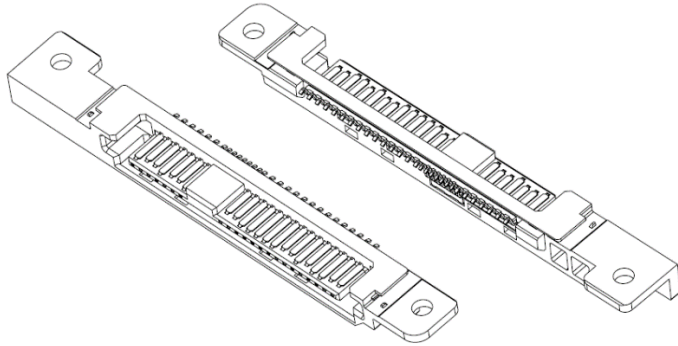


Figure 3 SAS Connector

Table 8 29-pin Connector Signal Definition

| Pin No. | 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 Transmit (Negative) signal |
| S13 | TS+ | SAS Secondary Port Transmit (Positive) signal |
| S14 | GND | GND for SAS Secondary Port |
| P1 | Reserved | NOT USED (P1 and P2 tied internally) |
| P2 | Reserved | NOT USED (P1 and P2 tied internally) |
| P3 | Power Disable | Enter/Exit Power Disable |
| 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 |
| P12 | GND | GROUND |
| P13 | +12V-Charge | Pre-charge pin for +12V |
| P14 | +12V | +12V power supply input |
| P15 | +12V | +12V power supply input |

6.1.3 Voltage and Ground Signals

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

6.1.4 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.

6.2 Environment

6.2.1 Temperature and humidity

Table 9 Temperature and humidity

| System Responsibility | |
|----------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| The system is responsible for maintaining a drive sensor temperature below 60°C. Drive sensor temperature is as reported using Log Sense page 0xD. | |
| Operating conditions | |
| Temperature | Ambient 5°C to Drive Reported 60°C |
| Relative humidity | 5 to 90% non-condensing (*1) |
| Maximum wet bulb temperature | 29.4°C non-condensing (*1) |
| Maximum temperature gradient | 20°C/Hour |
| Altitude | -300 to 3,048 m |
| Non-Operating conditions | |
| Temperature | -40 to 70°C |
| Relative humidity | 5 to 95% non-condensing (*1) |
| Maximum wet bulb temperature | 35°C non-condensing (*1) |
| Maximum temperature gradient | 20°C/Hour |
| Altitude | -300 to 12,000 m (Inside dashed-dotted line of Figure 4) |

Notes:

1. Noncondensing conditions should be maintained at any time.

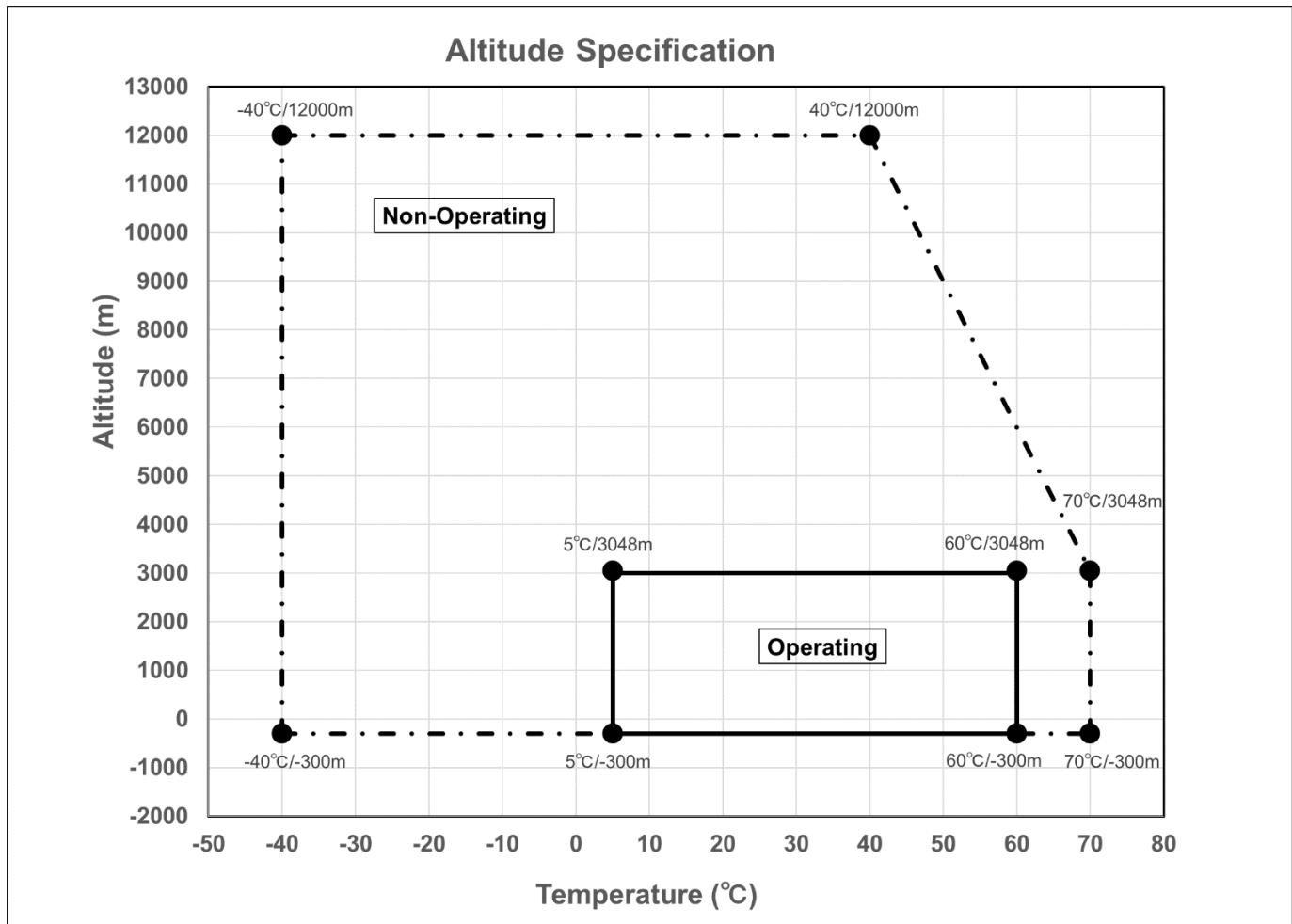


Figure 4 Limits of temperature and altitude

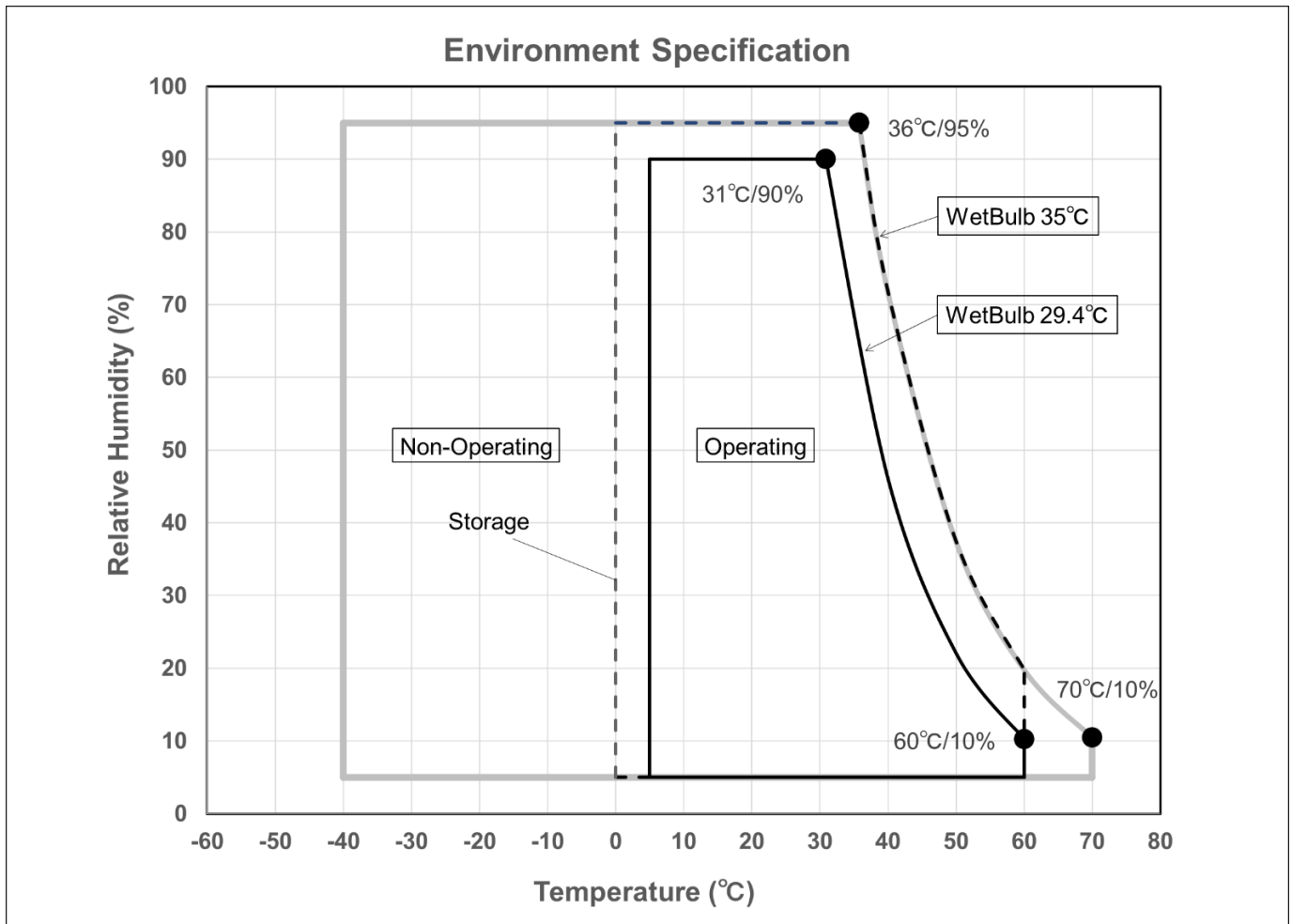


Figure 5 Limits of temperature and humidity

6.2.2 Storage Requirements

6.2.2.1 Packaging

The drive or option kit must be heat-sealed in a moisture barrier bag with bag supplied by WESTERN DIGITAL.

6.2.2.2 Storage

Maximum storage periods are 180 days within original, unopened Western Digital shipping bag or 60 days in an opened bag or outside the bag, while maintaining a temperature range of 0°C - 60°C and the specified humidity and altitude limits in the environmental section of this manual.

Storage can be extended to 1 year packaged or unpackaged under optimal environmental conditions (<25°C, <40% relative humidity non-condensing, and non-corrosive environment).

During any storage period, the drive shock, vibration, magnetic and electrical field specifications should be followed.

6.2.3 Atmospheric condition

Environments that contain elevated levels of corrosives (e.g., hydrogen sulfide, sulfur oxides, or hydrochloric acid) should be avoided. Care must be taken to avoid using any compound/material in a way that creates an elevated level of corrosive materials in the atmosphere surrounding the disk drive. Care must also be taken to avoid use of any organometallic (e.g., organosilicon, or organotin) compound/material in a way that creates elevated vapor levels of these compounds/materials in the atmosphere surrounding the disk drive.

6.3 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 values for current and power are considered 'typical' values. Typical is defined as observed average or observed maximum in a sample of 6 drives per model under voltage conditions of 5.0V and 12.0V at the drive reported temperatures as noted.

6.3.1 Input voltage

Table 10 Input voltage

| Input voltage | During run and spin up | Absolute max spike voltage | Supply rise time |
|------------------|------------------------|----------------------------|------------------|
| +5 Volts Supply | 5V \pm 5% | -0.3 to 5.5V | 0 to 200ms |
| +12 Volts Supply | 12V \pm 5% | -0.3 to 15.0V | 0 to 400ms |

Caution: To avoid damage to the drive electronics, power supply voltage spikes must not exceed specifications.

6.3.2 Power supply current

Table 11 SAS power consumption

| X.X.X Power supply current (typical) | | | | |
|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|--------------------|---------------|
| (SAS) | | | | |
| Serial Attached SCSI @ 12Gb/sec | | 24TB/26TB CMR Model | | |
| | IO/Sec | +5V Current (Amp) | +12V Current (Amp) | Power (Watts) |
| Max Peak Operational [1] | | 1.09 | 2.00 | |
| Start up Peak DC [2] | | 0.73 | 1.42 | |
| Start up Peak AC [3] | | 0.93 | 2.00 | |
| Idle_0 Ave. | | 0.37 | 0.34 | 5.9 |
| Idle Ripple | | 0.09 | 0.06 | |
| Random Read 4KB Qd=4 Peak [1] | | 1.02 | 1.76 | |
| Random Read 4KB Qd=4 Ave. | 122 | 0.48 | 0.57 | 9.3 |
| Random Read 4KB Qd=8 Peak [1] | | 1.04 | 1.77 | |
| Random Read 4KB Qd=8 Ave. | 147 | 0.48 | 0.60 | 9.6 |
| Random Read 4KB Qd=16 Peak [1] | | 0.99 | 1.75 | |
| Random Read 4KB Qd=16 Ave. | 175 | 0.48 | 0.55 | 9.0 |
| Random Write 4KB Qd=4 WCE=0 Peak [1] | | 0.98 | 1.65 | |
| Random Write 4KB Qd=4 WCE=0 Ave. | 556 | 0.53 | 0.34 | 6.7 |
| Random Write 4KB Qd=16 WCE=0 Peak [1] | | 0.98 | 1.66 | |
| Random Write 4KB Qd=16 WCE=0 Ave. | 551 | 0.53 | 0.34 | 6.7 |
| Random RW 50/50 4KB Qd=4 WCE=0 Peak [1] | | 0.99 | 1.74 | |
| Random RW 50/50 4KB Qd=4 WCE=0 Ave. | 218 | 0.49 | 0.52 | 8.7 |
| Random RW 70/30 4KB Qd=4 WCE=0 Peak [1] | | 1.02 | 1.73 | |
| Random RW 70/30 4KB Qd=4 WCE=0 Ave. | 160 | 0.48 | 0.50 | 8.4 |
| Random RW 50/50 4KB Qd=1 WCE=0 Peak [1] | | 0.99 | 1.72 | |
| Random RW 50/50 4KB Qd=1 WCE=0 Ave. | 150 | 0.49 | 0.52 | 8.6 |
| Max Power Workload | | | | |
| Random Read 4KB Qd=8 Peak [1] | | 1.04 | 1.77 | |
| Random Read 4KB Qd=8 Ave. | 147 | 0.48 | 0.60 | 9.6 |
| Sequential Read 64KB Qd=16 Peak [1] | MiB/s | 1.09 | | |
| Sequential Read 64KB Qd=16 Ave. [4] | 262/263 | 0.86 | 0.31 | 8.0 |
| Sequential Write 64KB Qd=16 Peak [1] | MiB/s | 1.07 | | |
| Sequential Write 64KB Qd=16 Ave. [4] | 262/263 | 0.84 | 0.31 | 7.9 |
| Power Save Mode | | +5V Current (Amp) | +12V Current (Amp) | Power (Watts) |
| Idle_A | | 0.37 | 0.34 | 5.9 |
| Idle_B | | 0.29 | 0.21 | 3.9 |
| Idle_C | | 0.29 | 0.16 | 3.4 |
| Standby_Y | | 0.29 | 0.16 | 3.4 |
| Standby_Z | | 0.28 | 0.012 | 1.5 |
| Power Saved (Watts) [5] | | | | 0.0 |
| | | | | 2.0 |
| | | | | 2.5 |
| | | | | 2.5 |
| | | | | 4.4 |
| Notes | | | | |
| Sample size | 6 HDDs per model | | | |
| Temperature | HDD reported temperature = 40degC (25degC for Start up) | | | |
| Sampling rate | 62.5K measurements/sec | | | |
| PHY | Dual port, 12Gb/s | | | |
| [1] | Peak current is established via the average current in a 16 usec moving window. The peak values of the HDDs in the population are then averaged and reported. | | | |
| [2] | Start up DC (average) current is measured within a 200ms sliding window. The peak DC values of the HDDs in the population are then averaged and reported. | | | |
| [3] | Start up AC current is sampled at 62.5kHz. The peak sample values of the HDDs in the population are then averaged and reported. | | | |
| [4] | Average measured at sustained sequential streaming rate. | | | |
| [5] | Power saved compared to Idle_0 | | | |

6.3.3 Power line noise limits

Table 12 Allowable power supply noise limits at drive power connector

| | Noise Voltage (mV pp) | Frequency Range |
|---------|-----------------------|-----------------|
| +5V DC | 250 | 100Hz-20MHz |
| +12V DC | 800 | 100Hz-8KHz |
| | 450 | 8KHz-100KHz |
| | 250 | 100KHz-20MHz |

During drive operation, both 5 and 12-volt ripple are generated by the drive due to dynamic loading of the power supply. This voltage ripple will add to existing power supply voltage ripple. The sum is the power line noise.

To prevent significant performance loss, the power line noise level when measured at the drive power connector should be kept below the limits in the above table.

6.3.4 Power Consumption Efficiency

Table 13 Power consumption efficiency

| Power Consumption Efficiency at Idle | SAS 26TB | SAS 24TB |
|--------------------------------------|----------|----------|
| W/TB | 0.227 | 0.246 |
| W/GB | 0.000227 | 0.000246 |

6.4 Workload

6.4.1 Workload

The maximum rated workload is <550TB/YR. The workload can be comprised of reads and/or writes. The maximum rated workload is specified for operating at typical temperatures. Occasional* excursions in operating conditions between the “typical AFR specification conditions” and the “maximum drive operating conditions” may occur without significant impact to reliability.

*Occasional excursions shall not exceed 2% of total run time.

6.5 Reliability

6.5.1 Annualized failure rate

This product has a 0.35% AFR specification rating based on typical workload and temperatures. The AFR specification is based on a sample population and is estimated by statistical measurements and acceleration algorithms under typical operating conditions at 40° C device reported temperature. Derating of AFR will occur above these parameters, up to 550TB/YR workload and 60° C (device reported temp). AFR ratings do not predict an individual drive's reliability and do not constitute a warranty.

6.5.2 Data integrity

OptiNAND™'s Enhance Data Safety feature allows up to full DRAM write cache of user data protection in event of Emergency Power Off event. Data is power-loss safe in both Write Cache Enabled and Write Cache Disabled modes..

No customer data is lost during power loss. As write cache is by nature power-loss safe, no further action will be performed as part of a FLUSH CACHE (E7h) or FLUSH CACHE EXT (EAh) command. This feature can be disabled to cause FLUSH CACHE commands to flush data to media instead of iNAND if desired.

6.5.3 Cable noise interference

To avoid any degradation of performance throughput or error rate when the interface cable is routed on top or comes in contact with the HDA assembly, the drive must be grounded electrically to the system frame by four screws. The common mode noise or voltage level difference between the system frame and power cable ground or AT interface cable ground should be in the allowable level specified in the power requirement section.

6.5.4 Load/Unload

The product supports a minimum of 600,000 normal load/unloads in a 40° C environment. Load/unload is invoked by transition of the HDD's power mode. (Chapter 4.5.3 Operating modes)

Idle (Idle_A) <-> unload idle (Idle_B)

Idle (Idle_A) <-> Low rpm idle (Idle_C)

6.5.5 Start/stop cycles

The drive withstands a minimum of 50,000 start/stop cycles in a 40° C environment and a minimum of 10,000 start/stop cycles in extreme temperature or humidity within the operating range.

6.5.6 Preventive maintenance

None

6.5.7 Data reliability

Probability of not recovering data is 1 in 10¹⁵ bits read.

LDPC on the fly/ offline data correction

- 4608-bit LDPC
- This implementation recovers maximum 2500 bits single burst error by on-the-fly correction and maximum 3500 bits single burst error by offline correction

6.5.8 Required Power-Off Sequence

The required sequence for removing power from the drive is as follows:

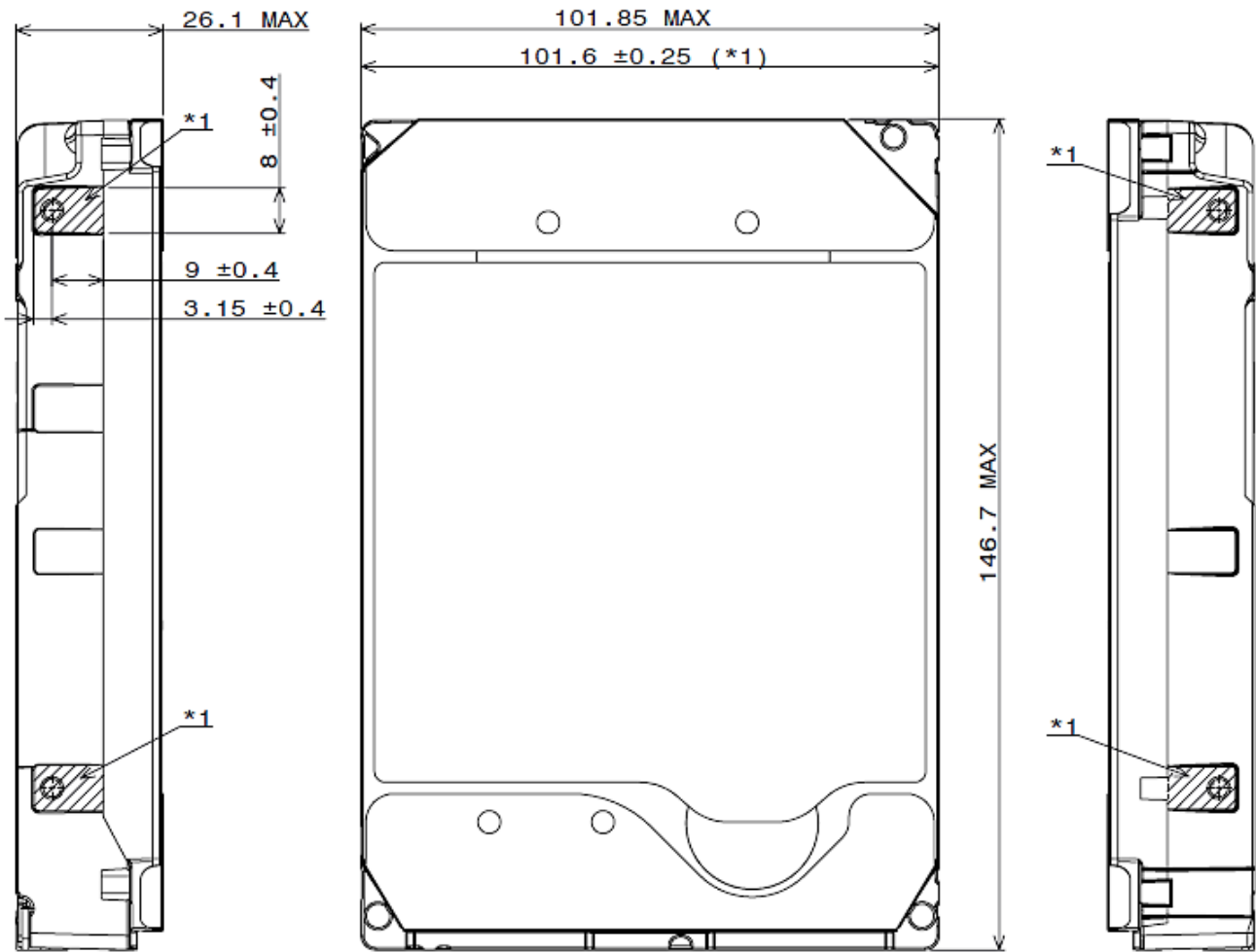
Step 1: Issue a STOP UNIT Command

Step 2: Wait until the Command Complete status is returned. However, the time out value needs to be 60 seconds considering error recovery time.

Step 3: Terminate power to HDD.

6.6 Mechanical specifications

6.6.1 Physical dimensions



*1 101.6±0.25 IS APPLIED FOR HATCHED AREA ONLY.

Figure 6 Top and side views and mechanical dimensions

All dimensions are in millimeters.

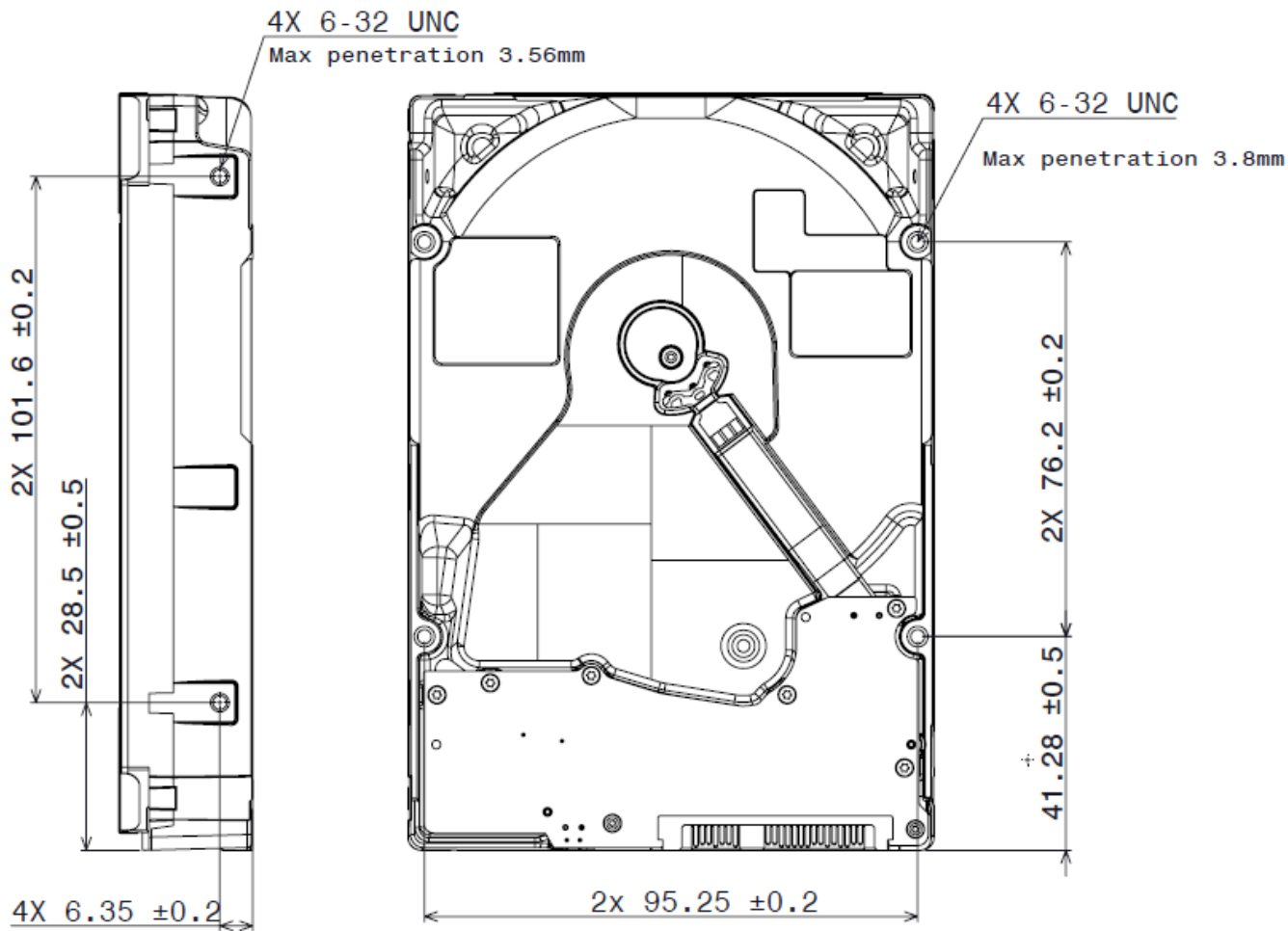


Figure 7 Bottom and side views with mounting hole locations

All dimensions in the above figure are in millimeters.

The following table shows the physical dimensions of the drive.

Table 14 Physical Dimensions

| Height (mm) | Width (mm) | Length (mm) | Weight (grams) |
|-------------|------------------|-------------|----------------|
| 26.1 MAX | 101.6 ± 0.25 | 147 MAX | 670 MAX |

6.6.2 Connector locations

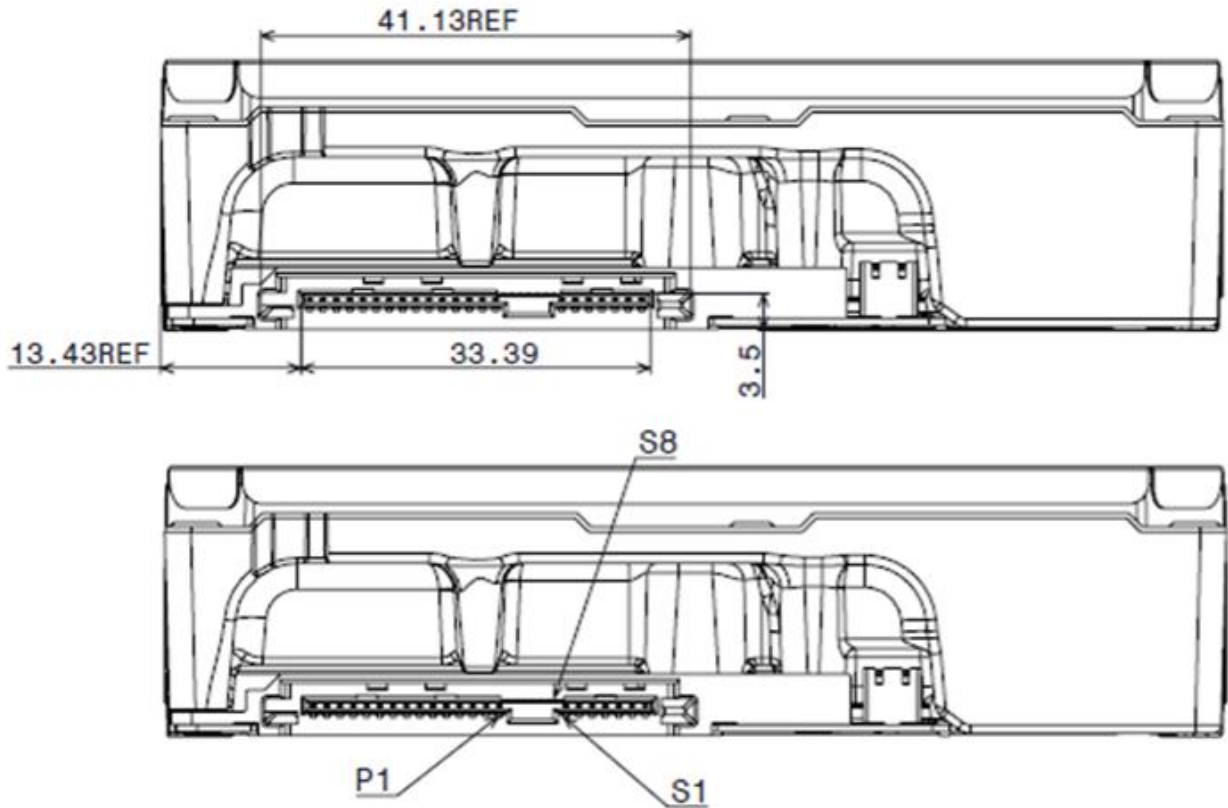


Figure 8 Connector locations

6.6.3 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 other orientations than that in which it was formatted.

For reliable operation, the drive must be mounted in the system securely enough to prevent excessive motion or vibration of the drive during seek operation or spindle rotation, using appropriate screws or equivalent mounting hardware.

The recommended mounting screw torque is 0.6 - 1.0 Nm (6-10 Kgf.cm).

The recommended mounting screw depth is 3.8 mm maximum for bottom and 3.56 mm maximum for horizontal mounting.

6.6.4 Heads unload and actuator lock

Heads are moved out from disks (unload) to protect the disk data during shipping, moving, or storage. Upon power down, the heads are automatically unloaded from disk area and the locking mechanism of the head actuator will secure the heads in unload position.

6.7 Vibration and shock

All vibration and shock measurements recorded in this section are made with a drive that has no mounting attachments for the systems. The input power for the measurements is applied to the normal drive mounting points.

6.7.1 Operating vibration

6.7.1.1 Random vibration (Linear)

The test is 30 minutes of random vibration using the power spectral density (PSD) levels shown below in each of three mutually perpendicular axes. The disk drive will operate without a hard error when subjected to the below random vibration levels.

Table 15 Random vibration PSD profile break points (operating)

| Frequency | 5 Hz | 17 Hz | 45 Hz | 48 Hz | 62 Hz | 65 Hz | 150 Hz | 200 Hz | 500 Hz | RMS (m/sec ²) |
|------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|------------|-------------|---------------------------|
| [(m/sec ²) ² /Hz] | 2.1 x 10E-3 | 1.2 x 10E-1 | 1.2 x 10E-1 | 8.4 x 10E-1 | 8.4 x 10E-1 | 1.0 x 10E-1 | 1.0 x 10E-1 | 5.2x 10E-2 | 5.2 x 10E-2 | 6.86 |

The overall RMS (root mean square) level is 6.86 m/sec² (0.7 G).

6.7.1.2 Swept sine vibration (Linear)

The drive will meet the criteria shown below while operating in the specified conditions:

- No hard error occurs with 4.9 m/sec² (0.5 G) 0 to peak, 5 to 300 to 5 Hz sine wave, 0.5 oct/min sweep rate with 3-minute dwells at two major resonances
- No hard error occurs with 9.8 m/sec² (1 G) 0 to peak, 5 to 300 to 5 Hz sine wave, 0.5 oct/min sweep rate with 3-minute dwells at two major resonances

6.7.1.3 Random vibration (Rotational)

The drive will meet the criteria shown below while operating in the specified conditions:

- Less than 10% Performance degradation
- The overall RMS (Root Mean Square) level of vibration is 12.5Rad/sec². PSD profile is shown below.

Table 16 Random vibration (Rotational) PSD profile break points

| Frequency | 20 Hz | 100 Hz | 200 Hz | 800 Hz | 1000 Hz | 1500 Hz | 1700 Hz | 2000 Hz | RMS (Rad/s ²) |
|------------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|---------------------------|
| [(Rad/s ²) ² /Hz] | 1.90E -02 | 1.90E -02 | 1.87E -01 | 1.87E -01 | 5.33E -02 | 7.70E -03 | 4.00E -03 | 4.00E -03 | 12.5 |

6.7.2 Nonoperating vibration

The drive does not sustain permanent damage or loss of previously recorded data after being subjected to the environment described below

6.7.2.1 Random vibration

The test consists of a random vibration applied for each of three mutually perpendicular axes with the time duration of 10 minutes per axis. The PSD levels for the test simulate the shipping and relocation environment shown below. The overall RMS (Root Mean Square) level of vibration is 10.2 m/sec² (1.04 G).

Table 17 Random vibration PSD profile break points (nonoperating)

| Frequency | 2 Hz | 4 Hz | 8 Hz | 40 Hz | 55 Hz | 70 Hz | 200 Hz |
|------------------------------------------|-------|------|------|-------|-------|-------|--------|
| [(m/sec ²) ² /Hz] | 0.096 | 2.89 | 2.89 | 0.289 | 0.962 | 0.962 | 0.096 |

6.7.2.2 Swept sine vibration

- 19.6 m/sec² (2 G) (Zero to peak), 5 to 500 to 5 Hz sine wave
- 0.5 oct/min sweep rate
- 3 minutes dwell at two major resonances

6.7.3 Operating shock

The drive meets the following criteria while operating in the conditions described below. The shock test consists of 10 shock inputs in each axis and direction for total of 60. There must be a delay between shock pulses long enough to allow the drive to complete all necessary error recovery procedures.

- No hard error occurs with a 98.1 m/sec² (10 G) half-sine shock pulse of 11 ms duration
- No hard error occurs with a 294 m/sec² (30 G) half-sine shock pulse of 4 ms duration.
- No hard error occurs with a 294 m/sec² (30 G) in vertical axis, 392 m/sec² (40 G) in horizontal axis half-sine shock pulse of 2 ms duration

6.7.4 Nonoperating shock

The drive will operate without non-recoverable errors after being subjected to shock pulses with the following characteristics.

6.7.4.1 Sinusoidal shock wave

The shape is approximately half-sine pulse. The figure below shows the maximum acceleration level and duration.

Table 18 Sinusoidal shock wave

| Acceleration level (m/sec ²) | Duration (ms) |
|------------------------------------------|---------------|
| 1960(200G) | 2 |
| 1470(150G) | 11 |

6.7.5 Nonoperating Rotational shock

All shock inputs shall be applied around the actuator pivot axis.

Table 19 Rotational Shock

| Duration | Rad/sec ² |
|----------|----------------------|
| 1 ms | 30,000 |
| 2 ms | 20,000 |

6.8 Acoustics

The upper limit criteria of the octave sound power levels are given in Bels relative to one picowatt and are shown in the following table. The sound power emission levels are measured in accordance with ISO 7779.

Table 20 Sound power levels

| Mode | 7200rpm (Typical / Max) |
|-----------|-------------------------|
| Idle | 2.5 / 2.8 |
| Operating | 3.2 / 3.4 |

Mode definition:

Idle mode. The drive is powered on, disks spinning, track following, unit ready to receive and respond to interface commands.

Operating mode. Continuous random cylinder selection and seek operation of the actuator with a dwell time at each cylinder. The seek rate for the drive is to be calculated as shown below:

- Dwell time = $0.5 \times 60/\text{RPM}$
- Seek rate = $0.4 / (\text{Average seek time} + \text{Dwell time})$

6.9 Identification labels

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

- A label containing the Western Digital logo and the part number
- A label containing the drive model number, the manufacturing date code, the formatted capacity, the place of manufacture, certification logos from various safety agencies (e.g., UL/CSA/CE/RCM, etc.)
- A bar code label containing the drive serial number
- A label containing the jumper pin description
- A user designed label per agreement

The above labels may be integrated with other labels.

6.10 Safety

6.10.1 UL and CSA standard conformity

The product is qualified per UL 62368-1, 3rd Edition and CAN/CSA No.62368-1, 3rd Edition for Audio/video, information and communication technology equipment Part 1: Safety requirements.

The UL recognition or the CSA certification is maintained for the product life

The UL and C-UL certification mark is on the drive.

6.10.2 EU Safety standard conformity

The product is approved by TUV complying EN 62368-1 : 2014 standard.

6.10.3 Flammability

The printed circuit boards used in this product are made of material with the UL recognized flammability rating of V-1 or better. The flammability rating is marked or etched on the board. All other parts not considered electrical components are made of material with the UL recognized flammability rating of V-2 minimum.

6.10.4 Safe handling

The product is conditioned for safe handling regarding sharp edges and corners.

6.10.5 Substance restriction requirements

The product complies with the Directive 2011/65/EU and Directive (EU) 2015/863 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), the Substances of Very High Concern (SVHC) updated candidates of European Union Regulation 1907/2006 on the Registration Evaluation Authorization and Restriction of Chemicals (REACH), China RoHS Directive, Taiwan BSMI and with Halogen free requirements based on the electronics industry standard, IEC 61249-2-21 (<http://www.iec.ch/>).

6.10.6 Secondary circuit protection

The product contains both 5V and 12V over-current protection circuitry.

6.11 Electromagnetic compatibility

When installed in a suitable enclosure and exercised with a random accessing routine at maximum data rate, the drive meets the following worldwide EMC requirements:

- United States Federal Communications Commission (FCC) Code of Federal Regulations, Part 15 (Class B)
- EN 55032: Electromagnetic compatibility of multimedia equipment - Emission Requirements
- EN 55035: Electromagnetic compatibility of multimedia equipment - Immunity requirements

6.11.1 CE Mark

The product is declared to be in conformity with requirements of the following EC directives.

EMC Directive 2014/30/EU on electromagnetic compatibility.

RoHS Directive 2011/65/EU and (EU) 2015/863 on the restriction of the use of certain hazardous substances in electrical and electronic equipment

6.11.2 RCM Mark

The product complies with the standard of Electromagnetic compatibility of multimedia equipment – Emission requirements, EN 55032, which is required by Australian Communications and Media Authority.

6.11.3 BSMI Mark

The product complies with the Taiwan's EMC standard of information technology equipment – Radio disturbance characteristics – Limits and methods of measurement, CNS 15936 Class B.

6.11.4 KC Mark

The product complies with the Korean EMC standards of KS C 9832:2019 for Emission and KS C 9835:2019 for Immunity. The product is registered under Broadcasting and Communication Equipment.

6.12 Third Party Open-Source Licenses

This product may include or use the following open source software subject to the following open source licenses. If required by the applicable open source license, Western Digital may provide the open source code to you on request either electronically or on a physical storage medium for a charge covering the cost of performing such distribution, which may include the cost of media, shipping, and handling.

Each third-party component that may be included is listed below, followed by its associated license text.

Components:

Bzip2 1.0.8 : Bzip2 License

PCRE 8.45 : BSD 3-clause "New" or "Revised" License

Licenses:

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(PCRE 8.45)

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Part 2. Interface specification

7 SAS Attachment

This section defines some basic terminology and describes the behavior of the drive when attached to a **Serial Attached SCSI** (i.e., SAS) domain.

7.1 General

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

SAS is logically a bi-directional, point to point serial data channel that leverages the SCSI protocol set. Nodes are physically connected via 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 relevant to this product.

- SCSI Application Layer - Clause 10
- SSP Transport Layer (Serial SCSI Protocol) - 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.

- T10/BSR INCITS 492, SAS Protocol Layer (SPL-3) (ISO/IEC 14776-263:201x)

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

- T10/BSR INCITS 546 Revision 8, SCSI Architecture Model - 6 (SAM-6)
- T10/BSR INCITS 566-201x, SCSI Primary Commands - 6 (SPC-6) (ISO/IEC 14776-455: 20xx)
- T10/BSR INCITS 506, SCSI Block Commands - 4 (SBC-4) (ISO/IEC 14776-324:201x)
- T10/BSR INCITS 519, Serial Attached SCSI – 3 (SAS-3) (ISO/IEC 14776-154:201x)
- T10/BSR INCITS 491, SCSI / ATA Translation - 4 (SAT-4) (at Public Review).

7.2 SAS Features

The following SAS features are supported by the Drive.

- SAS Compliance
 - "Serial Attached SCSI -3 (SAS-3)"



- SAS Protocol
 - This drive supports **Serial *SCSI* Protocol (SSP)**.
 - STP (Tunneled SATA) and SMP (Management protocol) protocols are **NOT** supported.
- SAS Dual Ported Operation
 - Single PHY ports (i.e., Narrow port. Wide Port **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
 - G1 (1.5 Gbps), G2 (3.0 Gbps) , G3 (6.0 Gbps), and G4(12 Gbps) supported
 - Largely Automated OOB and speed negotiation sequences
 - Optional Support for the hot-plug timeout in hardware
- 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**
- Power Consumer Device Support
 - Supports POWER_CAPABLE = 01b (Drive is a power consumer device)
- Interface Power Management Support
 - Supports partial/slumber low phy power condition
- Storage Element Depopulation Support
 - This feature is disabled by default. Please contact technical support personnel to request enablement of this feature via firmware
 - When enabled, this device limits the number of storage elements that may be depopulated to two
- 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

7.3 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 21 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 22 IEEE Registered Name format

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

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

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

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 23.

Table 23 Name Address Authority field

| 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 Western Digital |
| Object | Device Name/Port Identifier 00b Logical Unit Name 01b Port 1 10b Port 2 11b Target Device Name |
| S/N | Sequentially increasing drive serial number assigned at manufacturing. |

7.4 Spin up

The drive supports the Active Wait, Active, and Stopped states specified by the SAS standard. After power on, the drive enters the Active Wait state. The Drive will not spin up its spindle motor after power on until it receives a NOTIFY (Enable Spinup) primitive on either port to enter the Active state. If a NOTIFY (Enable Spinup) primitive is received prior to receiving a StartStop Unit command with the Start bit set to one, spin up will begin immediately. For SAS, this is analogous to auto-spinup function in legacy SCSI. This provision allows the system to control the power spikes typically incurred with multiple drives powering on (and spinning up) simultaneously.

If a StartStop command with the Start bit set to one is received prior to receiving a NOTIFY (Enable Spinup), the Drive will not start its spindle motor until Notify (Enable Spinup) is received on either port. Successful receipt of a NOTIFY (Enable Spinup) is a prerequisite to spin up.

If the StartStop Unit command with the Start bit set, also has the immediate bit set, status will be returned prior to actually spinning up the motor, but the actual act of spinning up the motor is deferred until receipt of the NOTIFY (Enable Spinup) primitive. If a media access command is received after sending immediate Status and prior to receiving a NOTIFY (Enable Spinup), the Drive will terminate the command with CHECK CONDITION status with a sense key of NOT READY and an additional sense code of LUN NOT READY, NOTIFY (ENABLE SPINUP) REQUIRED. If a media access command is received after receiving the NOTIFY (Enable Spinup) primitive and before the drive is finished spinning up, the Drive will terminate the command with CHECK CONDITION status with a sense key of LUN NOT READY and an addition sense code of LUN IS IN THE PROCESS of BECOMING READY.

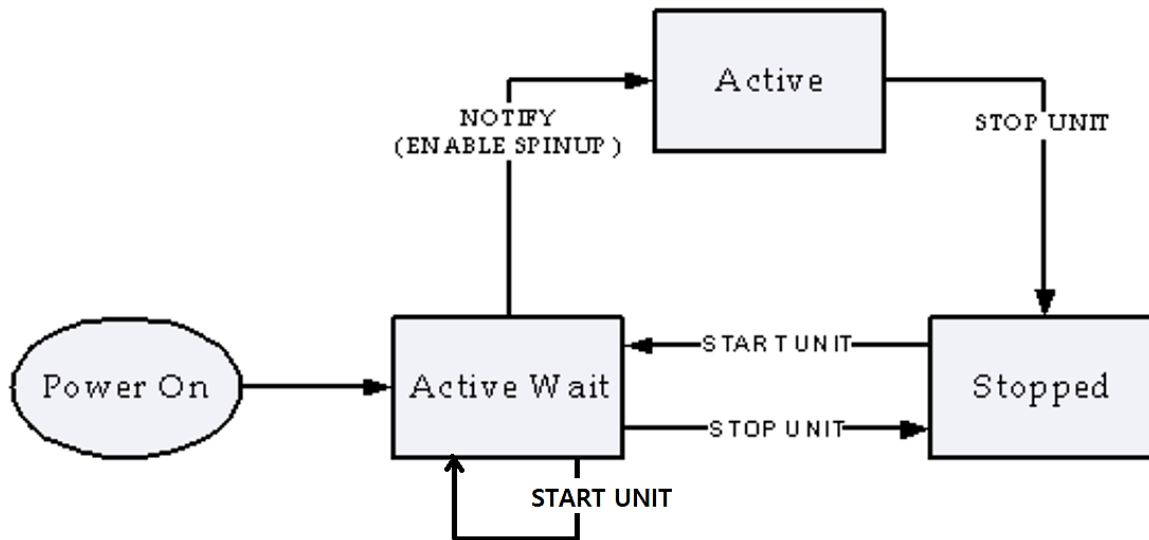


Figure 9 Spin up

7.5 PHY Layer

The Phy layer defines 8b10b coding 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-3.

7.5.1 Link Reset Sequence

The Link Reset Sequences for SAS are defined in the SPL-3 ANSI specification and shown below. As show in the diagram, a Phy Reset sequence, consists of an OOB sequence, followed by speed negotiations. 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 will be followed by Phy Reset/Identification sequences.

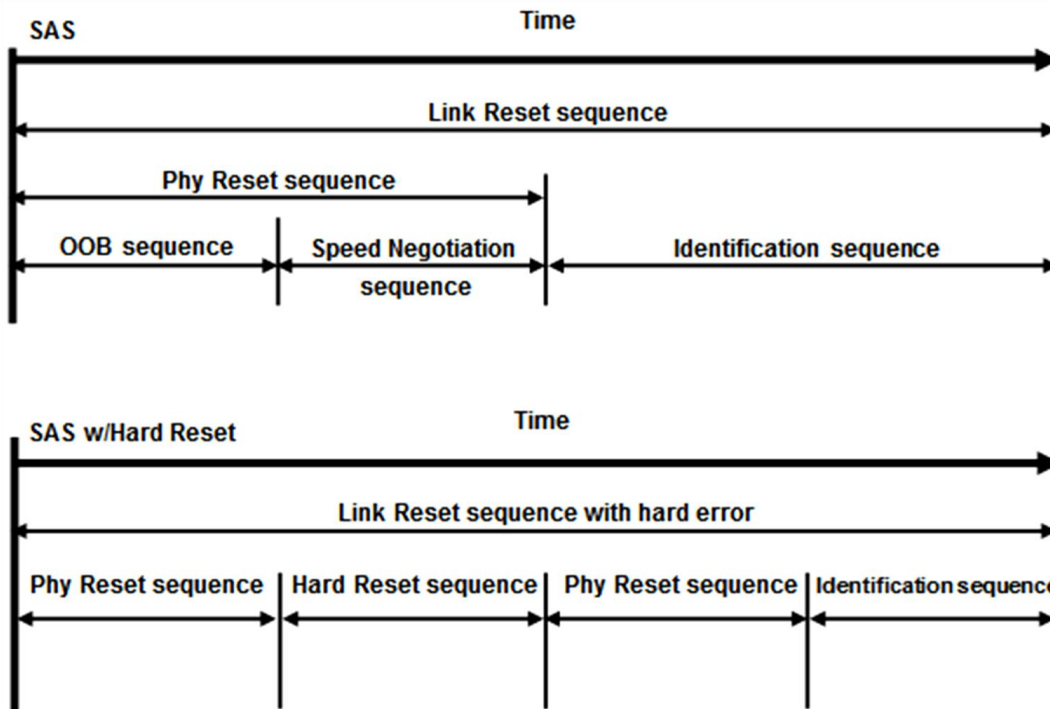


Figure 10 Link Reset Sequence

7.5.2 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.

7.5.3 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-3 specification for more details.

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

- POR
- loss of sync
- Identify timeout

7.5.4 SAS Speed Negotiation

The Drive supports G1 (1.5 Gbps), G2 (3.0 Gbps), G3 (6.0 Gbps), and G4 (12 Gbps) negotiation speeds. The default maximum negotiation rate is G3 speed (per byte 32 in the Phy Control and Discover Mode Page 19 subpage 1). Drive is SAS3 device and supports SNW-1, SNW-2, and SNW-3 speed negotiation with Phy capabilities exchange, and training (Train-SNW). Phy capabilities is defined in table below:

Phy Capabilities:

Table 24 SAS Speed Negotiation

| Byte | Bit | | | | | | | |
|------|-------------------|------------------|-------------------|----------------|----------------------------------|----------------|-------------------|----------------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Start =1b | TX SSC Type = 0b | Reserved | | Requested Logical Link Rate = 0h | | | |
| 1 | G1 Without SSC=1b | G1 With SSC=1b | G2 Without SSC=1b | G2 With SSC=1b | G3 Without SSC=1b | G3 With SSC=1b | G4 Without SSC=1b | G4 With SSC=1b |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | Parity |

- **Start** 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
- **TX SSC Type** is set to 0 to indicate that PHY's transmitter uses down-spreading-SSC when SSC is enabled
- **Requested Logical Link Rate** field is set to 0 to indicate that drive does not support multiplexing
- **G1 Without SSC** is set to 1 to indicate that drive supports 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** set to 1 to indicate that drive supports G1 (1.5 Gbps) with SSC
- **G2 With SSC** set to 1 to indicate that drive supports G2 (3.0 Gbps) with SSC
- **G3 With SSC** set to 1 to indicate that drive supports G3 (6.0 Gbps) with SSC
- **G4 With SSC** is 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. The priority of the supported settings bits are defined in the following table.

Table 25 Supported Settings Bit Priorities

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

7.5.5 PHY Error Handling

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

Table 26 PHY Layer Error Handling

| Error | Error Handling Procedure |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Link Reset | After POR or Hard Reset, the drive initiates link reset by transmitting exactly 1 COMINIT. For other resets, the drive does not initiate Link Reset. |
| COMINIT Timeout | If COMINIT or COMSAS is not received before the "Hot Plug Timeout" period expires, the drive continues to transmit DC zero and 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 |

7.6 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-3.

7.6.1 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 27 Address Frame Format

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

- The ADDRESS FRAME TYPE field indicates the type of address frame and is defined in Table 28. This field determines the definition of the frame type dependent bytes.

Table 28 Frame type:

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

7.6.1.1 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 Identify Address Frame format is defined as follows:

Table 29 Identify Address Frame

| Byte | Bit | | | | | | | | |
|-------|-----------------------|-----------------|---|--------------------|--------------------------|-------------------------------|---------------------------------|---------------------------|--|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | Reserved | Device Type = 1 | | | Address Frame Type = 0 | | | | |
| 1 | Reserved | | | | Reason | | | | |
| 2 | Reserved | | | | SSP Initiator Port=0b | STP Initiator Port=0b | SMP Initiator Port=0b | Reserved | |
| 3 | Reserved | | | | SSP Target Port=1b | STP Target Port=0b | SMP Target Port=0b | Reserved | |
| 4-11 | Device Name | | | | | | | | |
| 12-19 | SAS Address | | | | | | | | |
| 20 | PHY Identifier | | | | | | | | |
| 21 | Persistent Capable | Power Capable | | Slumber Capable | Partial Capable | Inside ZPSDS Persistent=0b | Requested Inside ZPSDS=0b | Break_Reply Capable=1b | |
| 22 | Reserved | | | | | | | Pwr_DIS Capable | |
| 23-27 | Reserved | | | | | | | | |
| 28-31 | CRC | | | | | | | | |

- **Device Type:** set to 001b to indicate that this drive is an "End Device".
- **Address Frame Type:** set to 00b to indicate that this is an IDENTIFY.
- **Reason:** field indicates the reason for link reset sequence as defined in Table 31
- **Initiator Port bits:** set to 000b since this device is a target device only
- **Target Port bits:** set to 100b since this device is a SSP target device only
- **Device Name:** field contains Target Device Identifier
- **SAS ADDRESS:** field contains the port identifier of the SAS port transmitting this frame.
- **PHY Identifier:** field contains the PHY identifier of the PHY transmitting this frame.
- **Persistent Capable** is set to 0b to indicate the drive does not support persistent connections
- **Inside ZPSDS Persistent:** set to 0b since this is an "End Device"
- **Requested Inside ZPSDS:** set to 0b since this is an "End Device"
- **Power Capable** is set to 00b to indicate drive does not issue PWR_REQ or PWR_DONE and does not respond to PWR_GRANT. Setting this field to 01b indicates that the drive is capable of requesting additional consumption of power (i.e., the drive is a power consumer device). A Power Consumer device manages the requests received from management application layer and the requests that are sent to power source device. It also processes power consumption grants received from a power source device. A power consumer device only requests additional power consumption on one phy at a time and:
 - exit any low power condition before requesting consumption of power beyond the typical peak power, and
 - disable any enabled low power phy power conditions until consumption of power beyond the typical peak power is complete and then re-enable any low phy power condition that was disabled.

The Power Capable field is defined as in Table 30.

Table 30 Power Capable field

| Code | Description |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00b | The device containing the phy: a) does not respond to PWR_GRANT with PWR_ACK, PWR_REQ with PWR_ACK, or PWR_DONE with PWR_ACK; and b) does not issue PWR_REQ or PWR_DONE. |
| 01b | The device containing the phy is capable of allowing the management of additional consumption of power by: a) Issuing PWR_REQ and PWR_DONE; and b) Responding to PWR_GRANT with PWR_ACK. |
| 10b | The device containing the phy is capable of managing the additional consumption of power by responding to: a) PWR_REQ with PWR_ACK; b) PWR_REQ with PWR_GRANT; and c) PWR_DONE with PWR_ACK |
| 11b | Reserved |

- **Slumber Capable** is set to 0b to indicate that the slumber power PHY mode is disabled. Setting it to 1b indicates that the drive is capable of supporting the slumber PHY power condition. While the drive is in slumber PHY power condition:
 - a) The phy is only capable of processing a COMINIT or COMWAKE
 - b) The phy may take more time to return to the active phy power condition than while in the partial phy power condition; and
 - c) The power consumed by the phy should be less than the power consumed while the phy is in the active phy power condition and while the phy is in the partial phy power condition.
- **Partial Capable** is set to 0b to indicate that the partial power PHY mode is disabled. Setting it to 1b indicates that the drive is capable of supporting partial PHY power condition. While the drive is in Partial power PHY condition:
 - a) The phy is only capable of processing COMINIT or COMWAKE;
 - b) The phy may take less time to return to the active phy power condition than while in the slumber phy power condition; and
 - c) The power consumed by the phy should be less than the power consumed while the phy is in the active phy power condition and may be greater than the power consumed while the phy is in slumber phy power condition.
- **Break_Reply Capable:** set to 1b to indicate that this port is capable of sending BREAK_REPLY primitive sequence in responding of receiving BREAK primitive sequences
- **Pwr_DIS Capable** is set to 1b to indicate the drive does support the PWR_DIS signal as defined in SAS-3

Table 31 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 |

7.6.1.2 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:

Table 32 OPEN Address Frame format

| 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, 9h, 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: This bit is set to zero when the Drive is the source port acting as a SAS target.
- Protocol: this field is set to 001b to indicate SSP Protocol.
- Features: this field is set to zero and ignored by the Drive per SPL-3.
- Connection Rate: field should be set to 8h (1.5Gbps), 9h (3Gbps), Ah (6Gbs), or Bh (12Gbs), 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: field contains the port identifier of the SAS port to which a connection is being requested.
- Source SAS Address: field contains the port identifier on the port that originated this frame (i.e., the drive's port address).
- Source Zone Group: This field is set to zero and ignored by the Drive per SPL-3.
- Pathway Blocked Count: this field 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: this field 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: this field is set to zero and ignored by the Drive per SPL-3.

7.6.2 Link Layer Error Handling

Table 33 Link Layer Error Handling

| 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 | <p>OPEN_REJECT – Retry able Variations</p> <p>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 (for example when it is not able to extend R-Rdy credit at this time due to lack of buffers...), so the initiator will ask us to keep "RETRY"-ing, until it becomes available at a later time. Thus, we don't consider this an error condition, but part of normal behavior for the initiator.</p> <p>OPEN_REJECT(RATE_NOT_SUPPORTED) – If this occurs, it must mean that a link between the drive and initiator renegotiated to a lower link rate after the command was received. In this case, we retry in a new connection at 1.5Gbps. If this error is received for a 1.5Gbps connection, the command is internally aborted.</p> <p>OPEN_REJECT – (PATHWAY_BLOCKED)</p> <p>OPEN_REJECT (BAD_DESTINATION), OPEN_REJECT (WRONG_DESTINATION), OPEN_REJECT (PROTOCOL_NOT_SUPPORTED) – If these OPEN_REJECTs are received, we internally abort the command.</p> |
| 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 | <p>Reserved fields in the OPEN frame are not checked.</p> <p>The Dest Address field is checked, and if it doesn't match OPEN_REJECT (WRONG_DESTINATION) is returned.</p> <p>The Protocol field is checked, if not set to SSP OPEN_REJECT (PROTOCOL_NOT_SUPPORTED) is returned.</p> <p>If the Link Rate exceeds the physical link rate on that port, OPEN_REJECT (LINK_RATE_NOT_SUPPORTED) is returned.</p> <p>The Initiator bit is not checked.</p> |
| 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. |

7.7 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, see the ANSI specification, SPL-3.

The transport layer defines the frame format as follows.

Table 34 SAS Frame Format

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

- FRAME TYPE field, which defines the format of the INFORMATION UNIT field as follows:

Table 35 FRAME TYPE field

| Code | Name of Frame | Information Unit | Originator | IU Size (bytes) |
|------------|-----------------|--------------------------|---------------------|-----------------|
| 01h | DATA | Data | Initiator or Target | 1-1024 |
| 05h | XFER_RDY | Data Transfer Ready | Target | 12 |
| 06h | COMMAND | Command | Initiator | 28-284 |
| 07h | RESPONSE | Response | Target | 24-1024 |
| 16h | TASK | Task Management Function | Initiator | 28 |
| F0-FFh | Vendor Specific | | | |
| All others | Reserved | | | |

- The HASHED DESTINATION SAS ADDRESS field contains the hashed value of the destination SAS address.
- The HASHED SOURCE SAS ADDRESS field contains the hashed value of the source SAS address.
- The TLR CONTROL field is not supported.
- The RETRY DATA FRAMES is not supported.
- The CHANGING DATA POINTER is not supported.

- The NUMBER OF FILL BYTES field 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.
- The TAG field contains a value that allows the SSP port to establish a context for commands and task management functions.
- The TARGET PORT TRANSFER TAG field is set and used by the drive. The initiator should echo this field in outbound data IU.
- The INFORMATION UNIT field 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.

7.7.1 Command Information Unit

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

Table 36 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 | | | | | | | |

- The LOGICAL UNIT NUMBER field contains the address of the logical unit. The drive only supports a LUN of 0's.
- A DISABLE FIRST BURST bit is not supported by the drive
- The TASK ATTRIBUTE field is defined as follows:

Table 37 TASK ATTRIBUTE field

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

- The ADDITIONAL CDB LENGTH field contains the length in dwords (four bytes) of the ADDITIONAL CDB field.
- The CDB and ADDITIONAL CDB BYTES fields together contain the CDB.

7.7.2 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 | | | | | | | |

- The LOGICAL UNIT NUMBER field contains the address of the logical unit. The drive only supports a LUN of 0's.
- The TASK MANAGEMENT FUNCTION field is defined as follows:

Table 39 TASK MANAGEMENT FUNCTION field

| 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 both ports. 2. Release any device reservation on either port. 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, the TAG OF TASK TO BE MANAGED field 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 40.

Table 40 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 | | | | | | | |

The UADE DEPTH is the number of pending unit attention conditions or deferred errors. It is defined as in Table 41.

The SENSE KEY field is the value of the SENSE KEY field in the highest priority pending unit attention condition or deferred error.

The ADDITIONAL SENSE CODE field is the value of the ADDITIONAL SENSE CODE field in the highest priority pending unit attention condition or deferred error.

The ADDITIONAL SENSE CODE QUALIFIER field is the value of the ADDITIONAL SENSE CODE QUALIFIER field in the highest priority pending unit attention condition or deferred error

Table 41 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 |

7.7.3 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 42 XFER_RDY Information Unit

| Byte | Bit | | | | | | | |
|------|-------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-4 | REQUESTED OFFSET | | | | | | | |
| 4-7 | WRITE DATA LENGTH | | | | | | | |
| 8-11 | Reserved | | | | | | | |

- The REQUESTED OFFSET field 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.
- The WRITE DATA LENGTH field contains the number of bytes of write data the Initiator may transmit to the Drive (using DATA frames) from the requested offset.

7.7.4 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 43 Data Information Unit

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

7.7.5 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 44 Response Information Unit

| Byte | Bit | | | | | | | | |
|-----------------|--------------------------------|---|---|---|---|---|-----------|-----|-----|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0-7 | RESERVED | | | | | | | | |
| 8-9 | RETRY DELAY TIMER | | | | | | | MSB | LSB |
| 10 | RESERVED | | | | | | Data Pres | | |
| 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 | | | | | | | | |

The RETRY DELAY TIMER field contains the retry delay timer code which is defined as follows:

Table 45 RETRY DELAY TIMER field

| 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 |
| TASK SET FULL | 0000h | Same as normal busy |
| | 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 elapsed, or b) A command addressed to the Drive completes. |
| | FFF0h-FFFFh | RESERVED |
| GOOD | 0000h-FFFFh | RESERVED |
| CHECK CONDITION | 0000h-FFFFh | RESERVED |
| CONDITION MET | 0000h-FFFFh | RESERVED |
| RESERVATION CONFLICT | 0000h-FFFFh | RESERVED |
| ACA ACTIVE | 0000h-FFFFh | RESERVED |
| TASK ABORT | 0000h-FFFFh | RESERVED |

- The DATAPRES field, which indicates the format and content of the STATUS field, SENSE DATA LENGTH field, RESPONSE DATA LENGTH field, RESPONSE DATA field, and SENSE DATA field.

Table 46 DATAPRES 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 47 RESPONSE CODE

| Byte | Bit | | | | | | | |
|------|---------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-2 | RESERVED | | | | | | | |
| 3 | RESPONSE CODE | | | | | | | |

RESPONSE CODES are defined as follows:

Table 48 RESPONSE DATA

| Value | RESPONSE Code Description |
|--------|---------------------------------------|
| 00b | Task Management Function Complete |
| 02b | Invalid Frame |
| 04b | Task Management Function No Supported |
| 05b | Task Management Function Failed |
| 08b | Task Management Function Succeeded |
| 09b | Invalid LUN |
| Others | RESERVED |

7.7.6 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.

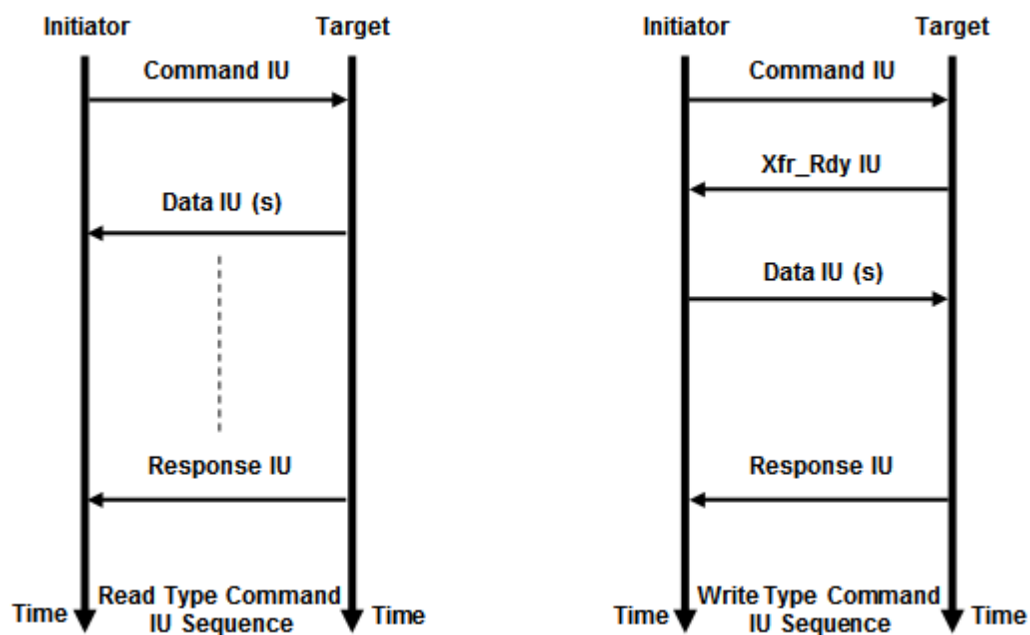


Figure 11 SSP Information Unit Sequences

7.7.7 Transport Layer Error Handling

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

Table 49 Transport Layer Error Handling

| Error | Error Handling Procedure |
|-----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SSP Header Field Checking | Reserved fields in SSP frames are not checked. |
| Data Offset Error | If a DATA frame with an invalid Data Offset is received, the command associated with the DATA frame is aborted with 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. |

8 SCSI Command Set

Summaries of the SCSI commands supported by the drive are listed below.

Table 50 SCSI Commands Supported

| Code | Description |
|---------|----------------------------------------------------|
| 04h | FORMAT UNIT (04) |
| 9Eh | GET PHYSICAL ELEMENT STATUS (9E) |
| 12h | INQUIRY (12) |
| 4Ch | LOG SELECT (4C) |
| 4Dh | LOG SENSE (4D) |
| 15h | MODE SELECT (6) - (15) |
| 55h | MODE SELECT (10) - (55) |
| 1Ah | MODE SENSE (6) - (1A) |
| 5Ah | MODE SENSE (10) - (5A) |
| 5Eh | PERSISTENT RESERVE IN (5E), |
| 5Fh | PERSISTENT RESERVE OUT (5F) |
| 34h | PRE-FETCH (10) - (34) |
| 90h | PRE-FETCH (16) - (90) |
| 08h | READ (6) - (08) |
| 28h | READ (10) - (28) |
| A8h | READ (12) - (A8) |
| 88h | READ (16) - (88) |
| 7Fh/09h | READ (32) - (7F/09) |
| 3Ch | READ BUFFER (3C) |
| 25h | READ CAPACITY (10) - (25) |
| 9Eh/10h | READ CAPACITY (16) (9E/10) |
| 37h | READ DEFECT DATA (10) - (37) |
| B7h | READ DEFECT DATA (12) - (B7) |
| 3Eh | READ LONG (10) - (3E) |
| 9Eh | READ LONG (16) - (9E) |
| 07h | REASSIGN BLOCKS (07) |
| 1Ch | RECEIVE DIAGNOSTICS RESULTS (1C) |
| 17h | RELEASE (6) - (17) |
| 57h | RELEASE (10) - (57) |
| 9E/18 | REMOVE ELEMENT AND TRUNCATE |
| A3h/05h | REPORT DEVICE IDENTIFIER (A3/05) |
| A0h | REPORT LUNS (A0) |
| A3h/0Ch | REPORT SUPPORTED OPERATION CODES (A3/0C) |
| A3h/0Dh | REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS (A3/0D) |
| A3h/0Fh | REPORT TIMESTAMP (A3/0F) |
| 03h | REQUEST SENSE (03) |
| 16h | RESERVE (6) - (16) |
| 56h | RESERVE (10) - (56) |
| 9E/19 | RESTORE ELEMENTS AND REBUILD |
| 01h | REZERO UNIT (01) |
| 48h | SANITIZE (48) |
| A2h | SECURITY PROTOCOL IN (A2h) |
| B5h | SECURITY PROTOCOL OUT (B5h) |

| Code | Description |
|-------------|---------------------------------|
| 1Dh | SEND DIAGNOSTIC (1D) |
| A4h/06h | SET DEVICE IDENTIFIER (A4/06) |
| A4h/0Fh | SET TIMESTAMP (A4/0F) |
| 1Bh | START STOP UNIT (1B) |
| 35h | SYNCHRONIZE CACHE (10) - (35) |
| 91h | SYNCHRONIZE CACHE (16) - (91) |
| 00h | TEST UNIT READY (00) |
| 2Fh | VERIFY (10) - (2F) |
| AFh | VERIFY (12) - (AF) |
| 8Fh | VERIFY (16) - (8F) |
| 7Fh/0Ah | VERIFY (32) - (7F/0A) |
| 0Ah | WRITE (6) - (0A) |
| 2Ah | WRITE (10) - (2A) |
| AAh | WRITE (12) - (AA) |
| 8Ah | WRITE (16) - (8A) |
| 7Fh/0Bh | WRITE (32) - (7F/0B) |
| 2Eh | WRITE AND VERIFY (10) - (2E) |
| A Eh | WRITE AND VERIFY (12) - (A E) |
| 8Eh | WRITE AND VERIFY (16) - (8E) |
| 7Fh/0Ch | WRITE AND VERIFY (32) - (7F/0C) |
| 3Bh | WRITE BUFFER (3B) |
| 3Fh | WRITE LONG (10) - (3F) |
| 9Fh | WRITE LONG (16) - (9F/11) |
| 41h | WRITE SAME (10) - (41) |
| 93h | WRITE SAME (16) - (93) |
| 7Fh/0Dh | WRITE SAME (32) - (7F/0D) |

8.1 SCSI Control Byte

The Control Byte is the last byte of every CDB. The format of this byte is shown below.

Table 51 SCSI Control Byte

| Bit | | | | | | | |
|--------|---|--------------|---|---|----------|---|----------|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| VU = 0 | | Reserved = 0 | | | NACA = 0 | | Obsolete |

VU = Vendor Unique.

The NACA (Normal ACA) bit specifies whether an ACA condition is established if the command terminates with CHECK CONDITION status. The NACA bit is set to zero specifying that an ACA shall not be established.

8.2 Abbreviations

These abbreviations are used throughout the following sections:

Table 52 Abbreviations

| | |
|-------------|----------------------------------------------------------------------------|
| 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 |

8.3 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.

8.4 FORMAT UNIT (04)

Table 53 FORMAT UNIT

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|---------|---------|--------------------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 04h | | | | | | | |
| 1 | FMTPINFO | | LONG LIST=0 | FMTDATA | CMPLIST | Defect List Format | | |
| 2 | VU = 0 | | | | | | | |
| 3 | Reserved = 0 | | | | | | | |
| 4 | Reserved = 0 | | | | FFMT | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA | Obsolete | |

- **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).
 - **FmtData** set to one specifies 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**
 - Set to one specifies that the Grown Defect List (GList) existing prior to the issuance of the Format Unit command be discarded. If provided, the DList then becomes the GList. Following these operations, the Drive will be formatted with the PList and GList.
 - Set to zero specifies that the GList existing prior to the issuance of the Format Unit command is retained. If provided, the DList is combined with the GList to become the new GList. Following these operations, the Drive will be formatted with the PList and GList.
- Note:** The drive manages two internal defect lists and one external. The PList is created at time of manufacture. The GList is built after manufacture by the Initiators' use of the REASSIGN BLOCK command and the Automatic Reallocate functions. The DList is an external list. It is supplied by the Initiator in the Data Out phase of the FORMAT UNIT command.
- **Defect List Format** specifies the format of the defect descriptor transferred to the Target when FmtData bit is set to one. The Target supports the following three defect descriptor formats for the FORMAT UNIT command:

Table 54 Defect descriptor format

| Format | Description |
|-------------|------------------------------|
| 000b | Block format (not supported) |
| 100b | Bytes from Index format |
| 101b | Physical Sector format |

If the FmtData bit is set to zero, this field must also be zero. Otherwise, the command will complete with a CHECK CONDITION with a sense key of *Illegal Request* and an additional sense code of *Invalid Field in CDB*.

Note: 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.

FFMT - The fast format field supports the following modes:

Table 55 FFMT field description

| Code | Description |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00b | Perform defect management and initialize media to the new format. |
| 01b | <p>Change block size only. May only be used on transitions of physically compatible size such as between 512 emulated and 4096. (Note: Formatting with Protection Information is not considered a physically compatible block size)</p> <p>For incompatible size transitions, the command will complete with a CHECK CONDITION with a sense key of Illegal Request and an additional sense code of Invalid Field in CDB.</p> <p>If the error reported is Key/code/qualifier 5/24/09, need to discard the GList beforehand.</p> <p>If the following options are enabled command shall terminate with INVALID FAST FORMAT COMBINATION. Options: CmpList, Merge GList PList, or Defect List length is non-zero,</p> <p>If the current block size is 512 and format unit (01b) is received and if there is only partial data available in a Media Block (4K) due to media errors, those LBAs in the defect sectors are marked as hard error. Any following read commands on those LBAs shall terminate with CHECK CONDITION with KCQ 03/11/00 (UEC =0xF7A7)</p> |
| 10b | Perform defect management but do not initialize the media. May result in any medium error on read before write. |
| 11b | Reserved |

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 *Task Set 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.

8.4.1 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 56 Format of the Short Parameter List Header

| Byte | Bit | | | | | | | |
|-----------|-----------------------------------|------|------|---------|----|------------------------|-------|-----------------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved = 0 | | | | | Protection Field Usage | | |
| 1 | FOV | DPRY | DCRT | STPF =1 | IP | Obsolete | Immed | Vendor Specific |
| 2 -3 | (MSB) DEFECT LIST LENGTH (LSB) | | | | | | | |
| 4-n | Initialization Pattern Descriptor | | | | | | | |
| (n+1) - m | Defect Descriptor | | | | | | | |

Table 57 Format of the Long Parameter List Header

| Byte | Bit | | | | | | | |
|-----------|-----------------------------------|------|------|---------|----------------------------------|------------------------|-------|-----------------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved = 0 | | | | | Protection Field Usage | | |
| 1 | FOV | DPRY | DCRT | STPF =1 | IP | Obsolete | Immed | Vendor Specific |
| 2 | Reserved | | | | | | | |
| 3 | P_I_INFORMATION = 0 | | | | PROTECTION INTERVAL EXPONENT = 0 | | | |
| 4...7 | (MSB) DEFECT LIST LENGTH (LSB) | | | | | | | |
| 8-n | Initialization Pattern Descriptor | | | | | | | |
| (n+1) - m | Defect Descriptor | | | | | | | |

- **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.

Table 58 Format of the Long Parameter List Header

| 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 4096, then the formatted block length is 4104). 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.

Table 59 Data Format with Protection field

| 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 | | | | | | | |

- The Logical Block Guard field** contains a CRC that covers the preceding user data. This field is generated/checked per the SBC standard.

The Logical Block Application Tag field is modifiable 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 Reference Tag field** 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 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 set to zero indicates that the Target does not use portions of the medium identified as defective in the primary defect PList for Initiator addressable logical blocks. If the Target cannot locate the PList or it cannot determine whether a PList exists, the Target terminates the FORMAT UNIT command as described for STPF=1. A DPRY bit set to one indicates that the Target does not use the PList to identify defective areas of the medium. The PList is not deleted. DPRY must be set to 0 when DCRT is set to 0.
- DCRT** (Disable Certification) bit set to zero indicates that the Target performs a medium certification operation and generates a Certification List (CList) and adds the CList to the GList. DPRY must be set to 0 when DCRT is set to 0. A DCRT bit of one indicates that the Target does not generate a CList or perform a certification process.

Note: Since the DCRT bit is part of the Data Out phase that follows the FORMAT command, the FCERT bit in Mode Page 0 is provided to control certification when the FORMAT command is issued with no Data Out phase. If a FORMAT command is issued with a Data Out phase, then FCERT is ignored.
- STPF** (Stop Format) bit must be set to one. If one or both of the following conditions occurs, the Target terminates the FORMAT UNIT command with *Check Condition* status. The sense key is set to *Medium Error* and the additional sense code is set to *Defect List Not Found* if the first condition occurred or to *Defect List Error* if the second condition occurred.

- The Target cannot locate a required DList nor determine that the list exists.
- The Target encounters an unrecoverable error while accessing a required DList.
- **IP** (Initialization Pattern) bit 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.

8.4.2 Initialization Pattern

Table 60 Initialization Pattern Descriptor

| Byte | Bit | | | | | | | |
|-------|--------------------------------------|---|----|--------------|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | IP Modifier = 0 | | SI | Reserved = 0 | | | | |
| 1 | Initialization Pattern Type = 0 or 1 | | | | | | | |
| 2 - 3 | Initialization Pattern Length (n-3) | | | | | | | |
| 4 | Initialization Pattern | | | | | | | |
| ... | ... | | | | | | | |
| n | Initialization Pattern | | | | | | | |

- **IP Modifier** must be set to 0, indicating that the drive will not modify the initialization pattern.
- **SI** (Security Initialize) bit set to one specifies that all customer data sectors, including those that have been previously reassigned, will be initialized. SI set to zero specifies that only the current customer accessible sectors will be formatted.
- **Initialization Pattern Type**
 - Type of 0 will use a default initialization pattern.
 - Type of 1 specifies that the Initialization Pattern specified shall be repeated as required to fill each logical block.
- **Initialization Pattern Length** specifies the number of bytes that follow in the Initialization Pattern field and must be less than or equal to the current block size, and non-zero.
 - If Initialization Pattern Type is 0 and the Initialization Pattern Length is not set to 0, Check Condition status will be returned, with the sense key set to Illegal Request and the additional sense code set to Invalid Field in Parameter List
 - If Initialization Pattern Type is 1 and the Initialization Pattern Length is set to 0, Check Condition status will be returned, with the sense key set to Illegal Request and the additional sense code set to Invalid Field in Parameter List.
- **DSP** (Disable Saving Parameters) bit when zero indicates the target is to save all the current MODE SELECT savable parameters during the format operation. When the bit is one, the target is not to save the current MODE SELECT savable parameters.
- **Immed** (Immediate) bit set to zero requests that status be returned at the end of the format operation. An immediate bit set to one 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.
- **Defect List Length** field specifies the total length in bytes of the defect descriptors that follow (not including the Initialization Pattern Descriptor, if any). Up to 1024 defect descriptors are allowed. The Defect List Length must be equal to four times the number of defect descriptors for BLOCK format, or eight times the number of defect descriptors for BYTES FROM INDEX and PHYSICAL SECTOR formats. 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.

8.4.3 Defect Descriptor

The drive supports two of the three available defect descriptor formats. Entries are not required to be in ascending order. If an entry does not correspond to a valid user addressable media location, the command terminates with Check Condition status with the sense key set to Illegal Request and the additional sense code set to Invalid Field in Parameter List.

8.4.3.1 Block Format - 000b (not supported)

Format of the DList sent during the data out phase when DList Format is Block format (000b) and FmtData is set to one.

Table 61 Defect Descriptor - Block Format (for $n + 1$ defects)

| Byte | Bit | | | | | | | |
|----------------------------|-----------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 - 3 | (MSB) Defective Logical Block Address (LSB) | | | | | | | |
| 4n 4n+1 4n+2 4n+3 | (MSB) Defective Logical Block Address n (LSB) | | | | | | | |

The Block format of the DList is the LBA of each defective sector.

Note: If a Defective LBA entry, when converted to a physical sector, is equal to the physical sector of a PList entry and DPRY = 1, then the entry is not added to the GList.

8.4.3.2 Bytes From Index Format - 100b

Format of the DList sent during the data out phase when DList Format is Bytes from Index format (100b) and FmtData is set to one.

Table 62 Defect Descriptor - Bytes from Index Format (for $n = 1$ defects)

| Byte | Bit | | | | | | | |
|--------------------------------------|-----------------------------------|---|---|---|---|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 - 2 | (MSB) Cylinder Number of Defect | | | | | | | (LSB) |
| 3 | Head Number of Defect | | | | | | | |
| 4 - 7 | (MSB) Defect Bytes from Index | | | | | | | (LSB) |
| 8n 8n + 1 8n + 2 | (MSB) Cylinder Number of Defect n | | | | | | | (LSB) |
| 8n + 3 | Head Number of Defect n | | | | | | | |
| 8n + 4 8n + 5 8n + 6 8n + 7 | (MSB) Defect (n) Bytes from Index | | | | | | | (LSB) |

Each defect descriptor for the Bytes from Index format specifies that the sector containing this byte be marked defective. The defect descriptor is comprised of the cylinder number of the defect, the head number of the defect, and the number of the defect byte relative to index.

Note: If a Byte from Index entry, when converted to a physical sector, is equal to the physical sector of a PList entry and DPRY = 1, then the entry is not added to the GList.

8.4.3.3 Physical Sector Format - 101b

Format of the DList sent during the data out phase when DList Format is Physical Sector format (101b) and FmtData is set to one.

Table 63 Defect Descriptor - Physical Sector Format (for $n + 1$ defects)

| Byte | Bit | | | | | | | |
|--------------------------------------|-----------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-2 | (MSB) Cylinder Number of Defect (LSB) | | | | | | | |
| 3 | Head Number of Defect | | | | | | | |
| 4-7 | (MSB) Defect Sector Number (LSB) | | | | | | | |
| 8n 8n + 1 8n + 2 | (MSB) Cylinder Number of Defect n (LSB) | | | | | | | |
| 8n + 3 | Head Number of Defect n | | | | | | | |
| 8n + 4 8n + 5 8n + 6 8n + 7 | (MSB) Defect (n) Sector Number (LSB) | | | | | | | |

Each defect descriptor for the Physical Sector format specifies a defective sector. The defect descriptor is comprised of the cylinder number of the defect, the head number of the defect, and the defect's sector number.

Note: If a Physical Sector entry, when converted to a physical sector, is equal to the physical sector of a PList entry and DPRY = 1, then the entry is not added to the GList.

8.5 GET PHYSICAL ELEMENT STATUS (9E/17)

The GET PHYSICAL ELEMENT STATUS command requests that the device server return status information for physical elements within the logical unit.

Table 64 GET PHYSICAL ELEMENT STATUS (9E/17)

| Byte | Bit | | | | | | | |
|-------|-------------------------------|---|--------------|----------------------|-------------|----------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 9Eh | | | | | | | |
| 1 | Reserved = 0 | | | Service Action = 17h | | | | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6-9 | (MSB) Starting Element (LSB) | | | | | | | |
| 10-13 | (MSB) Allocation Length (LSB) | | | | | | | |
| 14 | Filter | | Reserved = 0 | | Report Type | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |

The STARTING ELEMENT field specifies the element identifier of the first physical element addressed by this command.

The ALLOCATION LENGTH field is defined in SPC-5. In response to a GET PHYSICAL ELEMENT STATUS command, the device server may send less data to the Data-In Buffer than is specified by the allocation length. If, in response to a GET PHYSICAL ELEMENT STATUS command, the device server does not send sufficient data to the Data-In Buffer to satisfy the requirement of the application client, then, to retrieve additional information, the application client may send additional GET PHYSICAL ELEMENT STATUS commands with different starting element values.

The FILTER field restricts the physical element status descriptors to return.

Table 65 FILTER field

| Code | Description |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00b | All physical status descriptors as specified by the other fields in the CDB. |
| 01b | Only physical element status descriptors for which the value of the PHYSICAL ELEMENT HEALTH field (see Section 8.5.1.1) is: <ul style="list-style-type: none"> a) greater than or equal to 65h and less than or equal to CFh (i.e., outside manufacturer's specification limit); b) equal to FDh (i.e., all operations associated with storage element depopulation have completed and one or more completed with error); c) equal to FEh (i.e., an operation associated with storage element depopulation is in progress);or a) d) equal to FFh (i.e., all operations associated with storage element depopulation have completed without error). |
| All others | Reserved |

The REPORT TYPE field specifies the type of physical element status descriptors to return as defined in Table 66.

Table 66 REPORT TYPE field

| Code | Description |
|------------|---------------------------------------------------------------------|
| 00b | Return descriptors for physical elements, based on the FILTER field |
| 01b | Return descriptors for storage elements, based on the FILTER field |
| All others | Reserved |

8.5.1 GET PHYSICAL ELEMENT STATUS parameter data

The GET PHYSICAL ELEMENT STATUS parameter data contains a 32-byte header followed by zero or more physical element status descriptors.

Table 67 GET PHYSICAL ELEMENT STATUS parameter data

| Byte | Bit | | | | | | | |
|------------|------------------------------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | (MSB) NUMBER OF DESCRIPTORS (LSB) | | | | | | | |
| 4-7 | (MSB) NUMBER OF DESCRIPTORS RETURNED (LSB) | | | | | | | |
| 8-11 | (MSB) IDENTIFIER OF ELEMENT BEING DEPOPULATED (LSB) | | | | | | | |
| 12-13 | (MSB) CURRENT MAXIMUM NUMBER OF DEPOPULATED ELEMENTS (LSB) | | | | | | | |
| 14-15 | (MSB) CURRENT NUMBER OF DEPOPULATED ELEMENTS (LSB) | | | | | | | |
| 16-31 | Reserved = 0 | | | | | | | |
| 32-63 | (MSB) Physical Element Status Descriptor (first) (LSB) | | | | | | | |
| ... | ... | | | | | | | |
| (n-32) – n | (MSB) Physical Element Status Descriptor (last) (LSB) | | | | | | | |

The NUMBER OF DESCRIPTORS field shall contain the number of descriptors in the element descriptors list. The element descriptors list is a list of physical elements that:

- meet the requirements of the REPORTING OPTIONS field;
- meet the requirements of the FILTER field; and
- have an element identifier that is greater than or equal to the element identifier specified by the STARTING ELEMENT field in the CDB.

The contents of the NUMBER OF DESCRIPTORS field are not altered based on the allocation length.

The NUMBER OF DESCRIPTORS RETURNED field contains the number of valid physical element status descriptors returned in the parameter data.

The IDENTIFIER OF ELEMENT BEING DEPOPULATED field contains the element identifier of the element that has a physical element health set to FEh (i.e., an operation associated with storage

element depopulation is in progress). If the value of this field is set to zero, then no operation associated with storage element depopulation is in progress.

The CURRENTMAXIMUM NUMBER OF DEPOPULATED ELEMENTS field indicates the limit on the number of physical elements that are able to be depopulated at the time that the device server processes the GET PHYSICAL ELEMENT STATUS command. If the CURRENT MAXIMUM NUMBER OF DEPOPULATED ELEMENTS field is set to zero, then the number of physical elements that are able to be depopulated is not reported.

The CURRENT NUMBER OF DEPOPULATED ELEMENTS field indicates the number of physical elements that are depopulated at the time that the device server processes the GET PHYSICAL ELEMENT STATUS command.

Due to processing considerations outside the scope of this standard, two GET PHYSICAL ELEMENT STATUS commands with identical values in all CDB fields may result in two different values in the NUMBER OF DESCRIPTORS field.

The physical element status descriptors shall be sorted in ascending order of the element identifier.

8.5.1.1 Physical Element Status descriptor

The Physical Element Status descriptor contains status information for a physical element.

Table 68 Physical Element Status descriptor format

| Byte | Bit | | | | | | | |
|-------|---------------------------|---|---|---|---|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | Reserved = 0 | | | | | | | |
| 4-7 | (MSB) ELEMENT IDENTIFIER | | | | | | | (LSB) |
| 8-13 | Reserved = 0 | | | | | | | RALWD |
| 14 | PHYSICAL ELEMENT TYPE | | | | | | | |
| 15 | PHYSICAL ELEMENT HEALTH | | | | | | | |
| 16-23 | (MSB) ASSOCIATED CAPACITY | | | | | | | (LSB) |
| 24-31 | Reserved = 0 | | | | | | | |

The ELEMENT IDENTIFIER field contains the non-zero identifier of the physical element (e.g., storage element) associated with this Physical Element Status descriptor. The PHYSICAL ELEMENT TYPE field indicates the type of the physical element associated with this Physical Element Status descriptor.

A restoration allowed (RALWD) bit set to one indicates that this storage element has been depopulated and is a candidate for being restored. A RALWD bit set to zero indicates that this storage element:

- a. has not been depopulated; or
- b. has been depopulated and is not a candidate for being restored

Table 69 PHYSICAL ELEMENT TYPE field

| Code | Description |
|------------|-----------------|
| 01b | Storage Element |
| All others | Reserved |

The PHYSICAL ELEMENT HEALTH field indicates the health of the physical element associated with this Physical Element Status descriptor.

Table 70 PHYSICAL ELEMENT HEALTH field

| Code | Description |
|----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| 00h | Not Reported |
| 01h to 63h ^a | Within manufacturer's specification limits |
| 64h | At manufacturer's specification limit |
| 65h to CFh | Outside manufacturer's specification limit |
| D0h to FCh | Reserved |
| FDh | All operations associated with storage element depopulation have completed and one or more completed with error. |
| FEh | An operation associated with storage element depopulation is in progress. |
| FFh | All operations associated with storage element depopulation have completed without error. |
| ^a the device may implement a subset of values | |

The ASSOCIATED CAPACITY field indicates the number of logical blocks by which the capacity of the device is reduced if the physical element associated with this Physical Element Status descriptor becomes depopulated. A value of FFFF_FFFF_FFFF_FFFFh indicates that the number of logical blocks by which the capacity is reduced is not specified.

8.6 INQUIRY (12)

Table 71 INQUIRY (12)

| Byte | Bit | | | | | | | |
|------|----------------------------|---|--------------|---|---|----------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code = 12h | | | | | | | |
| 1 | Reserved = 0 | | | | | | CmdDt=0 | EVPD |
| 2 | Page Code | | | | | | | |
| 3-4 | (MSB) Allocation Length | | | | | | | (LSB) |
| 5 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |

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

An **EVPD** bit of one 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.

The **Page Code** specifies which page of vital product data information the drive shall return.

Table 72 Page Code descriptions

| EVPD | PAGE CODE | Description |
|------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0 | 0 | The Target returns the standard INQUIRY data. |
| 0 | Non Zero | The drive returns <i>Check Condition</i> status with the sense key of <i>Illegal Request</i> and the additional sense code of <i>Invalid Field in CDB</i> . |
| 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, 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).

8.6.1 Inquiry Data

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

8.6.1.1 Inquiry Data Format - EVPD = 0, Page Code = 0

Table 73 Inquiry Data- EVPD = 0

| Byte | Bit | | | | | | | |
|---------|--------------------------------|------------|------------|-----------------------------|--------------------------|--------------|-----------|-----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Qualifier = 0 | | | Peripheral Device Type = 0h | | | | |
| 1 | RMB=0 | Reserved=0 | | | | | | |
| 2 | Version = 7 | | | | | | | |
| 3 | Obsolete | 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 = 0 | | Protect=1 |
| 6 | Obsolete | EncSer=0 | Port | MultiP=1 | Obsolete | | | Reserved |
| 7 | Obsolete | Obsolete | Reserved | Reserved | Obsolete | Obsolete | CmdQue= 1 | Reserved |
| 8-15 | Vendor ID = "WDC" (ASCII) | | | | | | | |
| 16-31 | Product ID (ASCII) | | | | | | | |
| 32-35 | Product Revision Level (ASCII) | | | | | | | |
| 36-43 | Unit Serial Number (ASCII) | | | | | | | |
| 44-95 | Reserved = 0 | | | | | | | |
| 96-145 | Copyright Notice (ASCII) | | | | | | | |
| 146-163 | Reserved=0 | | | | | | | |

8.22.2 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

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Removal Media Bit (RMB) is always set to zero to indicate no removal media exists.

8.22.2 Version indicates the level of the ANSI standard that the product supports. The drive supports SPC6r05.

8.22.2 NormACA (Normal ACA) field of 0 indicates the drive does not support setting the NACA bit to one in the Control Byte of the CDB as defined in the SAM.

8.22.2 HiSup bit of 1 indicates that the drive uses the hierarchical addressing model to assign LUNs to logical units.

8.22.2 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.

8.22.2 Additional Length indicates the number of bytes of INQUIRY information that follows.

8.22.2 SCCS bit of zero indicates that the device does not contain an embedded storage array controller component.

8.22.2 ACC bit of zero indicates that no access controls coordinator is addressed through this logical unit.

8.22.2 TGPS field of zero indicates that the device does not support asymmetric logical unit access.

8.22.2 3PC bit of zero indicates that the device does not support third-party copy commands.

8.22.2 Protect bit of one indicates that the drive supports protection information

8.22.2 EncSer (Enclosure Services) bit of 0 indicates that the Target does not contain an embedded enclosure services component.

8.22.2 Port bit of 0 indicates that the drive received the Inquiry command on port A, while a Port bit of 1 indicates

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

that the drive received the Inquiry command on port B.

8.22.2 MultiP (MultiPort) bit of 1 indicates that the Target has multiple ports and implements multi-port requirements.

8.22.2 CmdQue is set to one to indicate that the drive supports command queuing.

8.22.2 Vendor ID is WDC padded with ASCII blanks.

8.22.2 Product ID is specified

8.22.2 Product Revision Level indicates the level of microcode.

8.22.2 Unit Serial Number contains the drive serial number.

8.6.1.2 Inquiry Data Format - EVPD = 1, Page Code - 00h

Table 74 Inquiry Data - EVPD = 1 (Page Code = 00h)

| Byte | Bit | | | | | | | |
|------|---------------------------|---|---|-----------------------------|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Qualifier = 0 | | | Peripheral Device Type = 0h | | | | |
| 1 | Page Code = 00h | | | | | | | |
| 2 | Reserved = 0 | | | | | | | |
| 3 | Page Length = 10h | | | | | | | |
| 4 | Supported Page Code - 00h | | | | | | | |
| 5 | Supported Page Code - 03h | | | | | | | |
| 6 | Supported Page Code - 80h | | | | | | | |
| 7 | Supported Page Code - 83h | | | | | | | |
| 8 | Supported Page Code - 86h | | | | | | | |
| 9 | Supported Page Code - 87h | | | | | | | |
| 10 | Supported Page Code - 88h | | | | | | | |
| 11 | Supported Page Code - 8Ah | | | | | | | |
| 12 | Supported Page Code - 8Dh | | | | | | | |
| 13 | Supported Page Code - 90h | | | | | | | |
| 14 | Supported Page Code - 91h | | | | | | | |
| 15 | Supported Page Code - B0h | | | | | | | |
| 16 | Supported Page Code - B1h | | | | | | | |
| 17 | Supported Page Code - B2h | | | | | | | |
| 18 | Supported Page Code - D1h | | | | | | | |
| 19 | Supported Page Code - D2h | | | | | | | |
| 20 | Supported Page Code - D9h | | | | | | | |

8.22.2 Qualifier is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Page Code is set to 0, and this field contains the same value as in the page code field of the INQUIRY command descriptor block.

8.22.2 Page length specifies the length of the following page data.

8.22.2 Supported Page Code field contains the Page Codes supported by the Target. The list is in ascending order.

8.6.1.3 Inquiry Data Format - EVPD = 1, Page Code - 03h

Table 75 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 | | | | | | | |
| 2-3 | Page Length = 268 (10Ch) | | | | | | | |
| 4 | ASCII Fields Length = 00h | | | | | | | |
| 5-7 | Reserved = 0 | | | | | | | |
| 8-23 | Reserved = 0 | | | | | | | |
| 24-35 | ASCII uCode Identifier | | | | | | | |
| 36-39 | ASCII Servo P/N | | | | | | | |
| 40-41 | Major Version | | | | | | | |
| 42-43 | Minor Version | | | | | | | |
| 44-46 | User Count | | | | | | | |
| 47 | Version | | | | | | | |
| 48-51 | Build Number | | | | | | | |
| 52-75 | Build Date String | | | | | | | |
| 76-83 | Interface Speed | | | | | | | |
| 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 | | | | | | | |
| 188-191 | Flash Code Revision Level | | | | | | | |
| 192-195 | Compatibility Version | | | | | | | |
| 196-271 | Repository Hashes | | | | | | | |

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to 0 to indicate that the device is Direct Access.
- **Page Code** is set to the value of the page code field in the CDB.
- **Page Length** field 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).
- **ASCII Servo P/N** contains the part number of the Servo microcode installed on the drive. This field is hex numeric ASCII (i.e., the characters will be in the set 0...9, A...F).

- **Major Version** and **Minor Version** are version numbers of the code loaded on the drive.
- **User Count** is the number of times the code has been built since the master build.
- **Version** is the current version of this page's layout.
- **Interface Speed** is the current negotiated link rate on the Initiator's Port.
- **Build Number** is the master build version number.
- **Build Date String** is the date the code on the drive was built, in an extended string format.
- **Product ID** is the name of the product this code is for.
- **Interface ID** is the interface type and serial interface speed (e.g., SAS 6Gbps or FCAL 4Gbps) of the code.
- **Code Type** is the intended use of this code. (e.g., local, released, test)
- **User Name** is the username of the person who built this version of the code.
- **Machine Name** is the workstation on which this version of the code was built.
- **Directory Name** is the last 32 characters of the directory from where this code was built.
- **Operating State** is the drive operating state. The least significant bit contains the following:

Table 76 Operating State

| | |
|-----------------------|------------------------------------------------------------------------------|
| 0 = OM_BROKEN | We have detected a hardware failure. |
| 1 = OM_DEGRADED | We have a soft failure, i.e., incomplete format. Motor is still spinning. |
| 2 = OM_INACCESSIBL | Drive is good but motor is stopped. |
| 3 = OM_STARTING | Motor is starting. |
| 4 = OM_SPINNING | Motor is started but reserved area is not loaded yet. |
| 5 = OM_NORMAL | Drive is spinning and ready to read/write. |
| 6 = OM_POWERSAVE | Drive is ready but has entered power save mode. |
| 7 = OM_STOPPED | Drive has come ready but now has been stopped. |
| 8 = OM_NOTIFY | Drive is good but NOTIFY has not arrived (SAS) |
| 9 = OM_WAKEUP | Similar to OM_STARTING, but LUN BECOMING READY during spinup is not reported |
| 10 = OM_NOTIFY_WAKEUP | Similar to OM_NOTIFY, but next transition is to OM_WAKEUP |

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

Table 77 Functional Mode

| | |
|--------------------|----------------------------------|
| 0 = OM_NORMAL_MODE | Not in special or recovery mode. |
| 1 = OM_SPECIAL_CMD | Special command mode on. |

- **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 believes the hardware is broken.
- **Code Mode** is the type of code the drive is running. The least significant bit contains the following:

Table 78 Code Mode

| | |
|----------------------|--------------------------------------------------------------|
| 0 = OM_FLASH | Drive is running flash code |
| 1 = OM_FLASH_OVERLAY | Drive is running flash overlay code |
| 2 = OM_DISK | Drive is running code that has been loaded from disk |
| 3 = OM_TRANSIENT | Drive is running code that has been downloaded but not saved |

8.22.2 Flash Code Revision Level is the revision level of the code in flash.

8.22.2 Compatibility Version is a Revision that is used to enforce incompatibility limits.

8.22.2 Repository Hashes is a marker of the code used for the build.

8.6.1.4 Inquiry Data Format - EVPD = 1, Page Code - 80h

Table 79 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 = 0 | | | | | | | |
| 3 | Page Length = 16 (10h) | | | | | | | |
| 4-19 | Serial Number (ASCII) | | | | | | | |

8.22.2 Qualifier is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Page Code is set to the value of the page code field in the CDB.

8.22.2 Page Length is set to 16, and this field specifies the length of the following page data.

8.22.2 Serial Number gives the drive serial number, right aligned.

8.6.1.5 Inquiry Data Format - EVPD = 1, Page Code - 83h

Table 80 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 = 0 | | | | | | | |
| 3 | Page Length = 72 (48h) | | | | | | | |
| 4 | Protocol Identifier = 0h | | | | Code Set = 1 | | | |
| 5 | PIV=0 | RSVD | Association = 0 | | Identifier Type = 3 | | | |
| 6 | Reserved = 0 | | | | | | | |
| 7 | Identifier Length = 8 | | | | | | | |
| 8-15 | (MSB) LUN (World Wide ID) | | | | | | | (LSB) |
| 16 | Protocol Identifier = 0h | | | | Code Set = 1 | | | |
| 17 | PIV=1 | RSVD | Association = 1 | | Identifier Type = 3 | | | |
| 18 | Reserved = 0 | | | | | | | |
| 19 | Identifier Length = 8 | | | | | | | |
| 20-27 | (MSB) Target Port Identifier (World Wide ID) | | | | | | | (LSB) |
| 28 | Protocol Identifier = 6h | | | | Code Set = 1 | | | |
| 29 | PIV=1 | RSVD | Association = 1 | | Identifier Type = 4 | | | |
| 30 | Reserved = 0 | | | | | | | |
| 31 | Identifier Length = 4 | | | | | | | |
| 32-35 | (MSB) Relative Port Identifier | | | | | | | (LSB) |
| 36 | Protocol Identifier = 6h | | | | Code Set = 1 | | | |
| 37 | PIV=1 | RSVD | Association = 2 | | Identifier Type = 3 | | | |
| 38 | Reserved = 0 | | | | | | | |
| 39 | Identifier Length = 8 | | | | | | | |
| 40-47 | (MSB) Target Device Name Identifier (World Wide ID) | | | | | | | (LSB) |
| 48 | Protocol Identifier = 0h | | | | Code Set = 3 | | | |
| 49 | PIV=0 | RSVD | Association = 2 | | Identifier Type = 8 | | | |
| 50 | Reserved = 0 | | | | | | | |
| 51 | Identifier Length = 24 (18h) | | | | | | | |
| 52-55 | "naa" (ASCII) | | | | | | | |
| 56-75 | (MSB) Target Device Name Identifier (World Wide ID) in ASCII | | | | | | | (LSB) |

8.22.2 Qualifier is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Protocol Identifier is valid only when PIV=1. Protocol Identifier = 0 indicates Fibre Channel devices. Protocol Identifier = 6 specifies SAS devices

8.22.2 Code Set specifies the data type for the identifier field. Code Set = 1 indicates binary data, Code Set = 3 indicates ASCII.

- 8.22.2 PIV (Protocol Identifier Valid)** 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.
- 8.22.2 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.
- 8.22.2 Identifier 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.
- 8.22.2 Identifier** fields contain the actual Identifier Descriptor:
- The LUN, Target Port and Target Device Name Identifiers are defined in the NAA IEE 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
 - **n** is the 22-bit drive unique serial number
 - **yy** is the 2-bit port/node ID select
 - 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.

8.6.1.6 Inquiry Data Format - EVPD = 1, Page Code - 86h

Table 81 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 | (MSB) Page Length (003Ch) | | | | (LSB) | | | |
| 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 | (MSB) Extended Self-Test Completion Minutes | | | | (LSB) | | | |
| 12 | POA_SUP | HRA_SUP | VSA_SUP | Reserved | | | | |
| 13 | Maximum Supported Sense Data Length | | | | | | | |
| 14-63 | Reserved | | | | | | | |

8.22.2 Qualifier is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Activate Microcode field is set to 01b to indicate that the drive

- 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.

8.22.2 SPT (Supported Protection Type) field is set to 001b to indicate that the drive supports type 1 and type 2 protection.

8.22.2 GRD_CHK (Guard Check) is set to one to indicate that the drive checks the Logical Block Guard Tag field in the protection information, if any.

8.22.2 APP_CHK (Application Tag Check) bit is set to one to indicate that the drive checks the Logical Block Application Tag field in the protection information, if any.

8.22.2 REF_CHK (Reference Tag Check) bit is set to one to indicate that the drive checks the Logical Block Reference Tag field in the protection information, if any.

8.22.2 UASK_SUP (Unit Attention Condition Sense Key Specific Data Supported) bit is set to zero to indicate that the drive does not return sense-key specific data for the UNIT ATTENTION sense key.

8.22.2 GROUP_SUP (Group Supported) bit is set to zero to indicate that the grouping function is not supported.

8.22.2 PRIOR_SUP (Priority Supported) bit is set to zero to indicate that task priority is not supported.

8.22.2 HEADSUP (Head of Queue Supported), ORDSUP (Ordered Supported), and SIMPSUP (Simple Supported) are set to one to indicate support for Head of Queue, Ordered and Simple task attributes.

8.22.2 WU_SUP is set to one as Write Long command is supported.

8.22.2 CRD_SUP is set to one as Write Long command is supported.

8.22.2 NV_SUP (Non-volatile Supported) is set to zero to indicate that non-volatile cache features are not supported.

8.22.2 V_SUP (Volatile Supported) is set to one to indicate support of a volatile cache.

- 8.22.2 P_I_I_SUP (Protection Information Interval Supported)** bit is set to zero to indicate that the logical unit does not support protection information intervals.
- 8.22.2 R_SUP (Referrals Supported)** bit is set to zero to indicate that the drive does not support referrals.
- 8.22.2 POA_SUP (Power On Activation Supported)** bit is set to zero to indicate that the drive does not support a WRITE BUFFER command with the MODE field set to 0Dh and the PO_ACT bit set to one.
- 8.22.2 HRA_SUP (Hard Reset Activation Supported)** bit is set to zero to indicate that the drive does not support a WRITE BUFFER command with the MODE field set to 0Dh and the HR_ACT bit set to one.
- 8.22.2 VRA_SUP (Vendor Specific Activation Supported)** bit is set to zero to indicate that the drive does not support a WRITE BUFFER command with the MODE field set to 0Dh and the VSE_ACT bit set to one.
- 8.22.2 Maximum Supported Sense Data Length** field indicates the maximum length in bytes of sense data that the drive is capable of returning in the same I_T_L_Q nexus transaction as the status.

8.6.1.7 Inquiry Data Format - EVPD = 1, Page Code - 87h

Table 82 Inquiry Data Format - EVPD = 1, (Page Code - 87h)

| 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 = 0 | | Policy Page Code = 3Fh | | | | | |
| 5 | Policy Subpage Code FFh | | | | | | | |
| 6 | MILUS=1 | Reserved = 0 | | | | | Mode Page Policy=0 | |
| 7 | Reserved = 0 | | | | | | | |

8.22.2 Qualifier is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Policy Page Code set to 3Fh and Policy Subpage Code set to FFh indicate that the descriptor applies to all mode pages and subpages

8.22.2 MILUS (Multiple Logical Units Share) set to one indicates the policy is shared by multiple logical units.

8.22.2 Mode Page Policy set to 00b indicates that all mode pages and subpages are shared.

8.6.1.8 Inquiry Data Format - EVPD = 1, Page Code - 88h

Table 83 Inquiry Data Format - EVPD = 1, (Page Code - 88h)

| 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 = 0 | | | | | | | |
| 6-7 | Primary Relative Port = 0001h | | | | | | | |
| 8-9 | Reserved = 0 | | | | | | | |
| 10-11 | Initiator Port Transfer ID Length = 0 | | | | | | | |
| 12-13 | Reserved = 0 | | | | | | | |
| 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 = 0 | | | | | | | |
| 19 | Identifier Length = 8 | | | | | | | |
| 20-27 | (MSB) | Primary Target Port Identifier (World Wide ID) | | | | | | (LSB) |
| 28-29 | Reserved = 0 | | | | | | | |
| 30-31 | Secondary Relative Port = 0002h | | | | | | | |
| 32-33 | Reserved = 0 | | | | | | | |
| 34-35 | Initiator Port Transfer ID Length = 0 | | | | | | | |
| 36-37 | Reserved = 0 | | | | | | | |
| 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 = 0 | | | | | | | |
| 43 | Identifier Length = 8 | | | | | | | |
| 44-51 | (MSB) | Secondary Target Port Identifier (World Wide ID) | | | | | | (LSB) |

8.22.2 Qualifier is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Protocol Identifier is valid only when PIV=1. Protocol Identifier = 0 indicates Fibre Channel devices. Protocol Identifier = 6 indicates SAS devices

8.22.2 Code Set specifies the data type for the identifier field. Code Set = 1 indicates binary data

8.22.2 PIV (Protocol Identifier Valid) set to one indicates that the Protocol Identifier field contains a valid value.

8.22.2 Association specifies the entity with which the Identifier field is associated: 1h for Target or Relative Port.

8.22.2 Identifier Type specifies the format and assignment authority for the identifier: 3h indicates NAA format of the WWID for Target Port.

8.22.2 Identifier fields contain the actual Identifier Descriptor.

- The Target Port Identifiers are defined in the NAA IEE WWID format where:

World Wide ID is a 64-bit unique identification for each drive. The format is: 5000CCAh

xxxh n yyb where xxx is the 12-bit block assignment defined for each model and manufacturing site, n is the 22-bit drive unique serial number, and yy is the 2-bit port/node ID

8.6.1.9 Inquiry Data Format - EVPD = 1, Page Code - 8Ah

Table 84 Inquiry Data Format - EVPD = 1, (Page Code - 8Ah)

| Byte | Bit | | | | | | | |
|-------|------------------------------------|---|---|----------------------------|--------|--------|-----------|-----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Qualifier = 0 | | | Peripheral Device Type = 0 | | | | |
| 1 | Page Code = 8Ah | | | | | | | |
| 2-3 | Page Length = 14 (000Eh) | | | | | | | |
| 4 | Reserved = 0 | | | | | | Standby_Y | Standby_Z |
| 5 | Reserved = 0 | | | | Idle_C | Idle_B | Idle_A | |
| 6-7 | Stopped Condition Recovery Timer | | | | | | | |
| 8-9 | Standby_Z Condition Recovery Timer | | | | | | | |
| 10-11 | Standby_Y Condition Recovery Timer | | | | | | | |
| 12-13 | Idle_A Condition Recovery Timer | | | | | | | |
| 14-15 | Idle_B Condition Recovery Timer | | | | | | | |
| 16-17 | Idle_C Condition Recovery Timer | | | | | | | |

- 8.22.2 Qualifier** field is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- 8.22.2 Peripheral Device Type** is set to 0 to indicate that the device is Direct Access.
- 8.22.2 Page Code** is set to the value of the page code field in the CDB.
- 8.22.2 Page Length** is set to 14, and this field specifies the length of the following page data.
- 8.22.2** If set to one, a power condition support bit (**STANDBY_Y, STANDBY_Z, IDLE_C, IDLE_B, IDLE_A**) indicates that the associated power condition is entered with START STOP UNIT command and the associated power condition is entered with a power condition timer if the timer is supported and enabled.
- 8.22.2 The recovery time fields** indicate the time, in one millisecond increments, that the logical unit takes to transition from the associated power condition to the active power condition. This time does not include the processing time for the command that caused this transition to occur. A value of zero indicates that the recovery time is not specified. A value of FFFFh indicates that the recovery time is more than 65.534 seconds.

8.6.1.10 Inquiry Data Format - EVPD = 1, Page Code - 8Dh

Table 85 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 = 4 | | | | | | | |
| 4 | Power Consumption Identifier (=0) | | | | | | | |
| 5 | Reserved = 0 | | | | Power Consumption Units (=4) | | | |
| 6-7 | Power Consumption Value | | | | | | | |

8.22.2 **Qualifier** field is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 **Peripheral Device Type** is set to 0 to indicate that the device is Direct Access.

8.22.2 **Page Code** is set to the value of the page code field in the CDB.

8.22.2 **Page Length** is set to 4, and this field specifies the length of the following page data.

8.22.2 **The Power Consumption Identifier** is set to 0.

8.22.2 **The Power Consumption Units** is set to 4, and this field indicates the units used for the POWER CONSUMPTION VALUE field. 4 = Milliwatts

8.22.2 **The Power Consumption Value** field indicate the maximum power consumption.

8.6.1.11 Inquiry Data Format - EVPD = 1, Page Code - 90h

Table 86 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** field is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

- **Page Code** is set to the value of the page code field in the CDB.

8.22.2 Page Length is set to 24, and this field specifies the length of the following page data.

8.22.2 Protocol-specific logical unit information descriptor 0 field is defined in Table 87

8.22.2 Protocol-specific logical unit information descriptor 1 field is defined in Table 87

Table 87 Protocol-specific logical unit information descriptor

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

8.22.2 Relative Port Identifier is set to 1 for Port A (Primary Port) or 2 for Port B (Secondary Port).

8.22.2 Protocol Identifier is set to 6 to specify that this is a SAS SSP Descriptor.

8.22.2 TLR Control Supported field 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

8.6.1.12 Inquiry Data Format - EVPD = 1, Page Code - 91h

Table 88 Protocol Specific Port Information VPD page to SAS SSP

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

- **Qualifier** field is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Page Code is set to the value of the page code field in the CDB

8.22.2 Page Length is set to 24, and this field specifies the length of the following page data

8.22.2 Port Information Descriptor 0 is defined in Table 89

8.22.2 Port Information Descriptor 1 is defined in Table 89

Table 89 Port Information Descriptor for SAS SSP

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

- **Relative Port Identifier** is set to 1 for Port A (Primary Port) or 2 for Port B (Secondary Port).
- **Protocol Identifier** is set to 6 to specify that this is a SAS SSP Descriptor.
- **PWR_D_S**, Power Disable Supported, is set to 1 to specify that the POWER DISABLE signal is supported.
- **SAS PHY Information Descriptor 0** is defined in Table 90

Table 90 SAS PHY Information Descriptor for SAS SSP

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

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

8.6.1.13 Inquiry Data Format - EVPD = 1, Page Code - B0h

Table 91 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 = 0 | | | | | | WSNZ=0 | |
| 5 | Maximum Compare and Write Length = 0 | | | | | | | |
| 6-7 | Optimal Transfer Length Granularity = 0 | | | | | | | |
| 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 = 0 | | | | | | | |
| 24-27 | Maximum Unmap Block Descriptor Count = 0 | | | | | | | |
| 28-31 | Optimal Unmap Granularity = 0 | | | | | | | |
| 32-35 | UGAVALID =0 | Unmap Granularity Alignment = 0 | | | | | | |
| 36-43 | Maximum Write Same Length = 0 | | | | | | | |
| 44-63 | Reserved = 0 | | | | | | | |

- **Qualifier:** set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to 0 to indicate that the device is Direct Access.
- **Page Code:** set to the value of the page code field in the CDB.
- **Page Length:** This field is set to 60 (3Ch) and specifies the length of the following page data.
- **WSNZ - Write Same No Zero:** set to zero which indicates the drive supports a value of zero in the NUMBER OF LOGICAL BLOCKS field in the WRITE SAME command CDB.
- **Maximum Compare and Write Length:** set to zero which indicates the drive does not support the COMPARE AND WRITE command.
- **Optimal Transfer Length Granularity:** set to zero to indicate that the drive does not report optimal transfer length granularity.
- **Maximum Transfer Length:** set to zero which indicates there is no reported limit on the maximum transfer length in logical blocks that the drive accepts for a single request using any of the following supported media access commands: PREFETCH, READ, VERIFY, WRITE, WRITE AND VERIFY.
- **Optimal Transfer Length:** set to zero 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 drive 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:** set to 0000_0000h to indicate that the drive does not implement the UNMAP command.
- **Maximum Unmap Block Descriptor Count:** set to 0000_0000h to indicate that the drive does not implement the UNMAP command.
- **Optimal Unmap Granularity:** set to 0000_0000h to indicate that the optimal unmap granularity is not specified.
- **UGAVALID - Unmap Granularity Alignment VALID:** set to 0 indicates that the UNMAP GRANULARITY ALIGNMENT field is not valid
- **Unmap Granularity Alignment:** set to zero and is not valid.
- **Maximum Write Same Length:** set to zero which indicates that there is no reported limit on the number of logical blocks that are requested for a single WRITE SAME command.

8.6.1.14 Inquiry Data Format - EVPD = 1, Page Code - B1h

Table 92 Inquiry Data - EVPD = 1 (Page Code = B1h)

| Byte | Bit | | | | | | | |
|------|-----------------------------------|---|---------|----------------------------|--------------------------|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Qualifier = 0 | | | Peripheral Device Type = 0 | | | | |
| 1 | Page Code = B1h | | | | | | | |
| 2-3 | Page Length = 60 (003Ch) | | | | | | | |
| 4-5 | Medium Rotation Rate 7200 (1C20h) | | | | | | | |
| 6 | Reserved | | | | | | | |
| 7 | Reserved = 0 | | WACEREQ | | Nominal Form Factor = 2h | | | |
| 8-63 | Reserved = 0 | | | | | | | |

- **Qualifier** field is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to 0 to indicate that the device is Direct Access.
- **Page Code** is set to the value of the page code field in the CDB.
- **Page Length** is set to 60, and this field specifies the length of the following page data.
- **Medium Rotation Rate** field is set to 7200.
- **WACEREQ** is set to 01b when Cryptographic Erase is supported, otherwise it is set to 00b
- **Nominal Form Factor** field is set to 2h.

8.6.1.15 Inquiry Data Format - EVPD = 1, Page Code - B2h

Table 93 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=0 | LBPWS=0 | LBPWS10=0 | Reserved = 0 | | LBPRZ=0 | ANC_SUP=0 | DP=0 |
| 6 | Reserved = 0 | | | | | Provisioning Type = 0 | | |
| 7 | Reserved = 0 | | | | | | | |

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported
- **Peripheral Device Type** is set to 0 to indicate that the device is Direct Access
- **Threshold Exponent:** set to zero which indicates that the logical unit does not support logical block provisioning thresholds
- **LBPU:** set to 0 to indicate that the device does not support the UNMAP command.
- **LBPWS:** set to 0 to indicate that the device does not support the WRITE SAME (16) command to unmap LBAs.
- **LBPWS10:** set to 0 to indicate that the device does not support the WRITE SAME (10) command to unmap LBAs.
- **LBPRZ:** set to 0 to indicate that, for an unmapped LBA specified by a read operation, the drive sends user data with all bits set to any value to the Data-In Buffer
- **ANC_SUP:** set to 0 to indicate that the device does not support anchored LBAs.
- **DP:** set to 0 to indicate no Provisioning Group Descriptor is present
- **Provisioning Type:** set to 0 to indicate the logical unit is fully provisioned

8.6.1.16 Inquiry Data Format - EVPD = 1, Page Code – D1h

Table 94 Inquiry Data - EVPD = 1 (Page Code = D1h)

| Byte | Bit | | | | | | | |
|-------|--------------------------------------|---|---|----------------------------|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Qualifier = 0 | | | Peripheral Device Type = 0 | | | | |
| 1 | Page Code = D1h | | | | | | | |
| 2 | Reserved = 0 | | | | | | | |
| 3 | Page Length = 80 (50h) | | | | | | | |
| 4-19 | ASCII Media Disk Definition | | | | | | | |
| 20-35 | ASCII Motor Serial Number | | | | | | | |
| 36-51 | ASCII Flex Assembly Serial Number | | | | | | | |
| 52-67 | ASCII Actuator Serial Number | | | | | | | |
| 68-83 | ASCII Device Enclosure Serial 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 0 to indicate that the device is Direct Access.
- **Page Code** is set to the value of the page code field in the CDB.
- **Page Length** is set to 80, 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).

Note: All ASCII fields are alphanumeric, left aligned, and padded on the right with ASCII blanks (20h).

8.6.1.17 Inquiry Data Format - EVPD = 1, Page Code - D2h

Table 95 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 = 52 (34h) | | | | | | | |
| 4 | HDC Version Length = 16 (10h) | | | | | | | |
| 5-20 | ASCII HDC Version | | | | | | | |
| 21 | Card Serial Number Length = 16 (10h) | | | | | | | |
| 22-37 | ASCII Card Serial Number | | | | | | | |
| 38 | Card Assembly Part Number Length = 16 (10h) | | | | | | | |
| 39-54 | ASCII Card Assembly Part Number | | | | | | | |
| 55 | Reserved = 0 | | | | | | | |

8.22.2 Qualifier is set to zero to indicate that the LUN specified in the Command Block is currently supported.

8.22.2 Peripheral Device Type is set to 0 to indicate that the device is Direct Access.

8.22.2 Page Code is set to the value of the page code field in the CDB.

8.22.2 Page Length is set to 52, 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).

Note: All ASCII fields are alphanumeric, left aligned, and padded on the right with ASCII blanks (20h).

8.6.1.18 Inquiry Data Format - EVPD = 1, Page Code – D9h

Table 96 Inquiry Data - EVPD = 1 (Page Code = D9h)

| Byte | Bit | | | | | | | |
|-------|--------------------------|---|---|----------------------------|---|---|-----|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Qualifier = 0 | | | Peripheral Device Type = 0 | | | | |
| 1 | Page Code = D9h | | | | | | | |
| 2-3 | Page Length = 28 (1Ch) | | | | | | | |
| 4-7 | Feature Flags (Reserved) | | | | | | NVC | |
| 8-15 | Reserved | | | | | | | |
| 16-31 | Firmware Version | | | | | | | |

- **Qualifier** is set to zero to indicate that the LUN specified in the Command Block is currently supported.
- **Peripheral Device Type** is set to 0 to indicate that the device is Direct Access.
- The **NVC** field (Byte 4, Bit 0) = NAND backed NVC Enabled.
- The **Firmware Version** field (Bytes 16..31) = NAND current firmware version.

Note: If the media is not available, bytes 0 through 3 are valid. All the other fields are ASCII blanks (20h).

Note: All ASCII fields are alphanumeric, left aligned, and padded on the right with ASCII blanks (20h).

8.7 LOG SELECT (4C)

Table 97 Log Select (4C)

| Byte | Bit | | | | | | | |
|------|--------------------|---------------------------|--------------|---|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 4Ch | | | | | | | |
| 1 | Reserved = 0 | | | | | | PCR | SP |
| 2 | PC | | Page Code | | | | | |
| 3 | SubPage Code = 0 | | | | | | | |
| 4-6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) | Parameter List Length = 0 | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

8.22.2 PCR The 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 are not 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.

8.22.2 SP The Save Parameters bit value of zero indicates that the page parameters are not 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*.

8.22.2 PC The Page Control field 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*.

8.22.2 Page Code field 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.

8.22.2 SubPage Code This field specifies the subpage to select.

8.22.2 Parameter List Length The Parameter List Length field 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).

8.22.2 Page 02h parameters: (Counters for write errors)

- Write errors recovered without delay
- Write errors recovered with possible delays
- LBAs with write fault error
- Reserved=0
- Total errors recovered
- Number of times recovery invoked
- Total write byte count
- LBAs with hard error

8.22.2 Page 03h parameters: (Counters for read errors)

- Read errors recovered without delay
- Read errors recovered with possible delays
- LBAs with LDPC detected error
- Reserved=0
- Total errors recovered
- Number of times recovery invoked
- Total read byte count
- LBAs with hard error

8.22.2 Page 05h parameters: (Counters for Verify Errors)

- Errors recovered without delay
- Errors recovered with possible delays
- LBAs with LDPC detected error
- Reserved=0
- Total errors recovered
- Number of times recovery invoked
- Total bytes verified
- LBAs with hard error

8.22.2 Page **06h** parameters: (Counters for non medium errors, seek and other hardware type failures)

- Non-Medium Error Counter

8.22.2 Page **15h** parameters: (Background Medium Scan information)

- BMS Status parameter
- all Medium Scan parameters

8.22.2 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

8.22.2 Page **30h** parameters:

- Zero Seeks counter
- Seeks \geq 2/3 counter
- Seeks \geq 1/3 and $<$ 2/3 counter
- Seeks \geq 1/6 and $<$ 1/3 counter
- Seeks \geq 1/12 and $<$ 1/6 counter
- Seeks $>$ 0 and $<$ 1/12 counter
- 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

8.22.2 Page **37h** parameters:

- Media EXC
- Hardware EXC
- Total Read Commands
- Total Write Commands

8.8 LOG SENSE (4D)

Table 98 Log Sense (4D)

| Byte | Bit | | | | | | | |
|------|-------------------------------|---|--------------|---|---|--------|----------|----|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 4Dh | | | | | | | |
| 1 | Reserved = 0 | | | | | | Obsolete | SP |
| 2 | PC | | Page Code | | | | | |
| 3 | SubPage Code | | | | | | | |
| 4 | Reserved = 0 | | | | | | | |
| 5-6 | (MSB) Parameter Pointer (LSB) | | | | | | | |
| 7-8 | (MSB) Allocation Length (LSB) | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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

8.22.2 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.

8.22.2 PC (Page Control) field 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*.

8.22.2 Page Code field 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*.

This field is ignored if the log page parameters are either ASCII list format or Binary list format.

8.22.2 SubPage Code This field specifies the subpage to select.

8.22.2 Parameter Pointer field specifies the beginning parameter code for the data transfer.

8.22.2 Allocation Length field 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. The Target terminates the Data in phase when all available Log Sense data has been transferred or when the number of bytes equals the allocation length, whichever is less.

8.8.1 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 does not stop incrementing. This parameter is reinitialized by a Log Select command.
 - 11b: List format binary data: No maximum values to handle.

8.8.2 Log Sense Page 0

Page 0 indicates the supported log sense pages. This page is used to determine which additional pages and Initiator can request.

Table 99 Log Sense Page 0

| Byte | Bit | | | | | | | |
|------|-------------------------------------------------|---|---------------|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 0 | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2-3 | Page Length = 0011h (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 – 08h | | | | | | | |
| 10 | Seventh Supported Page – 0Dh | | | | | | | |
| 11 | Eighth Supported Page – 0Eh | | | | | | | |
| 12 | Nineth Supported Page – 0Fh | | | | | | | |
| 13 | Tenth Supported Page – 10h | | | | | | | |
| 14 | Eleventh Supported Page – 15h | | | | | | | |
| 15 | Twelfth Supported Page – 18h | | | | | | | |
| 16 | Thirteenth Supported Page – 19h | | | | | | | |
| 17 | Fourteenth Supported Page – 1Ah | | | | | | | |
| 18 | Fifteenth Supported Page – 2Fh | | | | | | | |
| 19 | Sixteenth Supported Page – 30h | | | | | | | |
| 20 | Seventeenth Supported Page – 37h | | | | | | | |

8.8.3 Log Sense Page 2

This page contains counters for write errors.

Table 100 Log Sense Page 2

| Byte | Bit | | | | | | | |
|-------|---------------------------------------|----------|-----------------|----------|---|---|-----------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 02h | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 54h | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 7 | Parameter Length = 08h | | | | | | | |
| 8-15 | Reserved = 0 | | | | | | | |
| 16-17 | Parameter Code = 0001h | | | | | | | |
| 18 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 19 | Parameter Length = 08h | | | | | | | |
| 20-27 | Errors recovered with possible delays | | | | | | | |
| 28-29 | Parameter Code = 0002h | | | | | | | |
| 30 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 31 | Parameter Length = 08h | | | | | | | |
| 32-39 | Reserved = 0 | | | | | | | |
| 40-41 | Parameter Code = 0003h | | | | | | | |
| 42 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 43 | Parameter Length = 08h | | | | | | | |
| 44-51 | Total errors recovered | | | | | | | |
| 52-53 | Parameter Code = 0004h | | | | | | | |
| 54 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 55 | Parameter Length = 08h | | | | | | | |
| 56-63 | Times recovery invoked | | | | | | | |
| 64-65 | Parameter Code = 0005h | | | | | | | |
| 66 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 67 | Parameter Length = 08h | | | | | | | |
| 68-75 | Total bytes written | | | | | | | |
| 76-77 | Parameter Code = 0006h | | | | | | | |
| 78 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =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.

8.8.4 Log Sense Page 3

This page contains counters for read errors.

Table 101 Log Sense Page 3

| Byte | Bit | | | | | | | |
|-------|---------------------------------------|----------|-----------------|----------|---|---|-----------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 03h | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 54h | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 7 | Parameter Length = 08h | | | | | | | |
| 8-15 | Reserved = 0 | | | | | | | |
| 16-17 | Parameter Code = 0001h | | | | | | | |
| 18 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 19 | Parameter Length = 08h | | | | | | | |
| 20-27 | Errors recovered with possible delays | | | | | | | |
| 28-29 | Parameter Code = 0002h | | | | | | | |
| 30 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 31 | Parameter Length = 08h | | | | | | | |
| 32-39 | Reserved = 0 | | | | | | | |
| 40-41 | Parameter Code = 0003h | | | | | | | |
| 42 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 43 | Parameter Length = 08h | | | | | | | |
| 44-51 | Total errors recovered | | | | | | | |
| 52-53 | Parameter Code = 0004h | | | | | | | |
| 54 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 55 | Parameter Length = 08h | | | | | | | |
| 56-63 | Times recovery invoked | | | | | | | |
| 64-65 | Parameter Code = 0005h | | | | | | | |
| 66 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 67 | Parameter Length = 08h | | | | | | | |
| 68-75 | Total bytes written | | | | | | | |
| 76-77 | Parameter Code = 0006h | | | | | | | |
| 78 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =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. LDPC-on-the-fly correction is not included in any counters.

8.8.5 Log Sense Page 5

This page contains counters for verify errors.

Table 102 Log Sense Page 5

| Byte | Bit | | | | | | | |
|-------|---------------------------------------|----------|-----------------|----------|---|---|-----------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 05h | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 54h | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 7 | Parameter Length = 08h | | | | | | | |
| 8-15 | Reserved = 0 | | | | | | | |
| 16-17 | Parameter Code = 0001h | | | | | | | |
| 18 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 19 | Parameter Length = 08h | | | | | | | |
| 20-27 | Errors recovered with possible delays | | | | | | | |
| 28-29 | Parameter Code = 0002h | | | | | | | |
| 30 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 31 | Parameter Length = 08h | | | | | | | |
| 32-39 | Reserved = 0 | | | | | | | |
| 40-41 | Parameter Code = 0003h | | | | | | | |
| 42 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 43 | Parameter Length = 08h | | | | | | | |
| 44-51 | Total errors recovered | | | | | | | |
| 52-53 | Parameter Code = 0004h | | | | | | | |
| 54 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 55 | Parameter Length = 08h | | | | | | | |
| 56-63 | Times recovery invoked | | | | | | | |
| 64-65 | Parameter Code = 0005h | | | | | | | |
| 66 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 67 | Parameter Length = 08h | | | | | | | |
| 68-75 | Total bytes written | | | | | | | |
| 76-77 | Parameter Code = 0006h | | | | | | | |
| 78 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =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. LDPC-on-the-fly correction is not included in any counters.

8.8.6 Log Sense Page 6

This page contains counters for non-medium errors. This includes seek errors and other hardware type failures.

Table 103 Log Sense Page 6

| Byte | Bit | | | | | | | |
|------|------------------------|----------|-----------------|----------|---|---|-----------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 06h | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 0Ch | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 7 | Parameter Length = 08h | | | | | | | |
| 8-15 | Error Count | | | | | | | |

8.8.7 Log Sense Page 8

This page contains format status. It reports information about the most recent successful format operation and the state of the direct access block device since that operation was performed.

Table 104 Log Sense Page 8

| Byte | Bit | | | | | | | |
|-------|---------------------------------------|----------|-----------------|----------|---|---|-----------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 08h | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 40h | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 7 | Parameter Length = 08h | | | | | | | |
| 8 | Protection Field Usage | | | | | | | |
| 9 | Format Options | | | | | | | |
| 10-11 | Defect List Length | | | | | | | |
| 12-13 | Parameter Code = 0000h | | | | | | | |
| 14 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 15 | Parameter Length = 0Ch | | | | | | | |
| 16-23 | Format Data Output Values | | | | | | | |
| 24-25 | Parameter Code = 0001h | | | | | | | |
| 26 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 27 | Parameter Length = 0Ch | | | | | | | |
| 28-35 | Grown Defects during Certification | | | | | | | |
| 36-37 | Parameter Code = 0002h | | | | | | | |
| 38 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 39 | Parameter Length = 0Ch | | | | | | | |
| 40-47 | Total Blocks Reassigned during Format | | | | | | | |
| 48-49 | Parameter Code = 0003h | | | | | | | |
| 50 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 51 | Parameter Length = 0Ch | | | | | | | |
| 52-59 | Total New Blocks Reassigned | | | | | | | |
| 60-61 | Parameter Code = 0004h | | | | | | | |
| 62 | DU=0 | Obsolete | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 63 | Parameter Length = 08h | | | | | | | |
| 64-67 | Power on Minutes since Format | | | | | | | |

8.8.8 Log Sense Page D

This page contains temperature information.

Table 105 Log Sense Page D

| Byte | Bit | | | | | | | |
|-------|-----------------------------------------|------|-----------------|----------|---|---|-----------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 0Dh | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 0Ch | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU=0 | DS=1 | TSD=0 | Obsolete | | | Format & Linking =11b | |
| 7 | Parameter Length = 02h | | | | | | | |
| 8 | Reserved = 0 | | | | | | | |
| 9 | Temperature (degrees Celsius) | | | | | | | |
| 10-11 | Parameter Code = 0001h | | | | | | | |
| 12 | DU=0 | DS=1 | TSD=0 | Obsolete | | | Format & Linking =11b | |
| 13 | Parameter Length = 02h | | | | | | | |
| 14 | Reserved = 0 | | | | | | | |
| 15 | Reference Temperature (degrees Celsius) | | | | | | | |

The TEMPERATURE field indicates the temperature of the SCSI target device in degrees Celsius at the time the LOG SENSE command is performed.

The REFERENCE TEMPERATURE field indicates the maximum reported sensor temperature in degrees Celsius at which the SCSI target device is capable of operating continuously without degrading the SCSI target device's operation or reliability beyond manufacturer accepted limits.

8.8.9 Log Sense Page E

This page contains the start-stop cycle information.

Table 106 Log Sense Page E

| Byte | Bit | | | | | | | |
|-------|-------------------------------------------------------|--------|-----------------|----------|---|---|-----------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 0Eh | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 34h | | | | | | | |
| 4-5 | Parameter Code = 0001h | | | | | | | |
| 6 | DU=0 | DS=1 | TSD=0 | Obsolete | | | Format & Linking =00b | |
| 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 | Obsolete | | | Format & Linking =00b | |
| 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 | Obsolete | | | Format & Linking =00b | |
| 27 | Parameter Length = 04h | | | | | | | |
| 28-31 | Specified Cycle Count over Device Lifetime | | | | | | | |
| 32-33 | Parameter Code = 0004h | | | | | | | |
| 34 | DU = 0 | DS = 1 | TSD = 0 | Obsolete | | | Format & Linking =00b | |
| 35 | Parameter Length = 04h | | | | | | | |
| 36-39 | Accumulated Start-Stop Cycles (4 byte binary number) | | | | | | | |
| 40-41 | Parameter Code = 0005h | | | | | | | |
| 42 | DU = 0 | DS = 1 | TSD = 0 | Obsolete | | | Format & Linking =00b | |
| 43 | Parameter Length = 04h | | | | | | | |
| 44-47 | Specified Load Unload Count over Device Lifetime | | | | | | | |
| 48-49 | Parameter Code = 0006h | | | | | | | |
| 50 | DU = 0 | DS = 1 | TSD = 0 | Obsolete | | | Format & Linking =00b | |
| 51 | Parameter Length = 04h | | | | | | | |
| 52-55 | Accumulated Load Unload Cycles (4 byte binary number) | | | | | | | |

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.

8.8.10 Log Sense Page F

This page contains the Application Client Log.

Table 107 Log Sense Page F

| 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 | 1 st Application Client Log Parameter | | | | | | | |

The following table describes the application client log parameter structure.

Table 108 Log Sense Page F, Application Client Log

| Byte | Bit | | | | | | | |
|------|------------------------|----------|---------|----------|---|---|------------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | Parameter Code | | | | | | | |
| 2 | DU = 1 | Obsolete | TSD = 0 | Obsolete | | | Format & Linking = 00b | |
| 3 | Parameter Length = FCh | | | | | | | |
| 4 | First Parameter Byte | | | | | | | |
| ... | | | | | | | | |
| 255 | 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.

8.8.11 Log Sense Page 10

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

Table 109 Log Sense Page 10

| Byte | Bit | | | | | | | |
|---------|--------------------------------------------------|---|-----------------|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 10h | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 190h | | | | | | | |
| 4-23 | 1 st Self-Test Results Log Parameter | | | | | | | |
| ... | | | | | | | | |
| 384-403 | 20 th Self-Test Results Log Parameter | | | | | | | |

The following table describes the self-test results log parameter structure

Table 110 Log Sense Page 10 Parameter Structure

| Byte | Bit | | | | | | | |
|------|---------------------------------|----------|---------|----------|-------------------------|---|------------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | Parameter Code | | | | | | | |
| 2 | DU = 0 | Obsolete | TSD = 0 | Obsolete | | | Format & Linking = 11b | |
| 3 | Parameter Length = 10h | | | | | | | |
| 4 | Function Code | | | Reserved | Self-Test Results Value | | | |
| 5 | Extended Segment Number | | | | | | | |
| 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 | | | | | | | |

8.22.2 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.

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

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

Table 111 Log Sense Page 10, Self-Test Results

| 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. |

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

Table 112 Log Sense Page 10, 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 | Physical Head Check | |
| 6h | Random Verify | |
| 7h | - Verify First 300 MB - Verify Last 100 MB | Verify all LBAs |
| 8h | Recheck SMART | |

8.22.2 Timestamp This field contains the total accumulated power-on hours of the Target at the time the self-test completed.

8.22.2 LBA of first failure This field 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.

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

See Section 8.47 SEND DIAGNOSTIC (1D), for detailed listing of operations carried out by SEND DIAGNOSTIC command and Power on Diagnostics.

8.8.12 Log Sense Page 15

This page contains information about Background Medium Scan operations.

Table 113 Log Sense Page 15

| 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.

Table 114 BMS Status Parameter Structure

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

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

8.22.2 BMS Status is described in the following table

Table 115 BMS Status

| BMS Status | Description |
|------------|---------------------------------------------------------------|
| 00h | No scans active |
| 01h | Background medium 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 |

8.22.2 The Number of Background Scans Performed field indicates the total number of background scans (i.e., total number of Background Medium Scans PLUS number of Background Prescan) that have been performed over the life of the drive.

8.22.2 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.

8.22.2 Number of Background Medium Scans Performed field indicates the number of background medium scans that have been performed over the life of the drive.

The following table describes the Medium Scan Parameter structure.

Table 116 Medium Scan Parameter Structure

| Byte | Bit | | | | | | | |
|-------|---------------------------------|----------|---------|----------|-----------|----------|------------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | Parameter Code = 0001h – 0800h | | | | | | | |
| 2 | DU = 0 | Obsolete | TSD = 0 | Obsolete | | | Format & Linking = 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 | Head | | | | (MSB) | Cylinder | | |
| 12-13 | Cylinder (LSB) | | | | | | | |
| 14 | Head | Type | | (MSB) | Sector | | | |
| 15 | Sector (LSB) | | | | | | | |

8.22.2 Power On Minutes indicates the total power on minutes at the time the error was detected.

8.22.2 Reassign Status is set as shown below. Reassignment during the background scan is not supported.

Table 117 Reassign Status

| Reassign Status | Description |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| 0h | No reassignment needed This value is not reported, if LOWIR bit is set to 1 in Background Control Mode Page. |
| 1h | Reassignment pending receipt of Reassign command or write command (if auto write reallocation is allowed) from the initiator |
| 2h-4h | Not supported |
| 5h | Error was detected by BGMS and was successfully rewritten. This value is not reported, if LOWIR bit is set to 1 in Background Control Mode Page. |
| 6h | Error was detected by BGMS and was successfully reassigned by Application Client. Contains valid data. |
| 7h – Fh | Reserved |

8.22.2 Additional Sense Code and Additional Sense Code Qualifier provide details about the error detected.

8.22.2 Type indicates the recording type(CMR, SMR).

8.8.13 Log Sense Page 18

This page contains protocol-specific log parameters.

Table 118 Log Sense Page 18

| Byte | Bit | | | | | | | |
|----------------------------------|-------------------------------------------------------|---|-----------------|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | Page Code = 18h | | | | | |
| 1 | Subpage Code = 00h | | | | | | | |
| 2-3 | (MSB) Page Length = 00D8h (LSB) | | | | | | | |
| Protocol-Specific Log Parameters | | | | | | | | |
| 4-111 | First Protocol-Specific Log Parameter – Primary Port | | | | | | | |
| 112-219 | Last Protocol-Specific Log Parameter – Secondary Port | | | | | | | |

Table 119 SAS Log Descriptor

| Byte | Bit | | | | | | | |
|-------|-------------------------------------------------------------------------------------|----------------------|---------|----------|-------------------------------|-----------------------------|-----------------------------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | (MSB) Parameter Code (0001h for Primary Port; 0002h for Secondary Port) (LSB) | | | | | | | |
| 2 | DU = 0 | Obsolete | TSD = 0 | Obsolete | | | Format and Linking | |
| 3 | Parameter Length = 68h | | | | | | | |
| 4 | Reserved = 0 | | | | Protocol Identifier = 6h | | | |
| 5 | Reserved = 0 | | | | | | | |
| 6 | Generation Code | | | | | | | |
| 7 | Number of Phys = 01h | | | | | | | |
| 8 | Reserved = 0 | | | | | | | |
| 9 | Phy Identifier = 00h | | | | | | | |
| 10 | Reserved = 0 | | | | | | | |
| 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 | (MSB) SAS Address (address of the Target Port) (LSB) | | | | | | | |
| 24-31 | (MSB) Attached SAS Address (address received in the incoming IDENTIFY) (LSB) | | | | | | | |

| Byte | Bit | | | | | | | |
|-------|-----------------------------------------------------------------------------------|-------------------------------------|---|---|---|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 32 | Attached PHY Identifier (the PHY Identifier received in the incoming IDENTIFY) | | | | | | | |
| 33-39 | Reserved = 0 | | | | | | | |
| 40-43 | (MSB) | Invalid Dword Count | | | | | | (LSB) |
| 44-47 | (MSB) | Running Disparity Error Count | | | | | | (LSB) |
| 48-51 | (MSB) | Loss of Dword Synchronization | | | | | | (LSB) |
| 53-55 | (MSB) | Phy Reset Problem | | | | | | (LSB) |
| 56-57 | Reserved = 0 | | | | | | | |
| 58 | Phy Event Descriptor Length = 0Ch | | | | | | | |
| 59 | Number of Event Descriptors = 04h | | | | | | | |
| 60-62 | Reserved = 0 | | | | | | | |
| 63 | Phy Event Source = 01h (Invalid Dword Count) | | | | | | | |
| 64-67 | (MSB) | Phy Event | | | | | | (LSB) |
| 68-71 | (MSB) | Peak Value Detector Threshold = 00h | | | | | | (LSB) |
| 72-74 | Reserved = 0 | | | | | | | |
| 75 | Phy Event Source = 02h (Running Disparity Error Count) | | | | | | | |
| 76-79 | (MSB) | Phy Event | | | | | | (LSB) |
| 80-83 | (MSB) | Peak Value Detector Threshold = 00h | | | | | | (LSB) |
| 84-86 | Reserved = 0 | | | | | | | |
| 87 | Phy Event Source = 03h (Loss of Dword Sync) | | | | | | | |
| 88-91 | (MSB) | Phy Event | | | | | | (LSB) |

| Byte | Bit | | | | | | | |
|---------|-------------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 92-95 | (MSB) Peak Value Detector Threshold = 00h (LSB) | | | | | | | |
| 96-98 | Reserved = 0 | | | | | | | |
| 99 | Phy Event Source = 04h (Phy Reset Problem) | | | | | | | |
| 100-103 | (MSB) Phy Event (LSB) | | | | | | | |
| 104-107 | (MSB) Peak Value Detector Threshold = 00h (LSB) | | | | | | | |

- **Attached Device Type:** set to the value received by this PHY during an Identify Sequence.
- **Attached Reason:** If the phy is a physical phy and a SAS phy or expander phy is attached, then the ATTACHED REASON field indicates the value of the REASON field in the last received IDENTIFY address frame (see Table 29) during the identification sequence. 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:** The REASON field indicates the reason for the last link reset sequence as reported in the last transmitted IDENTIFY address frame. (see Table 29). 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 31.
- **Negotiated PHY Link Rate:** 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
- **The GENERATION CODE** field is a one-byte counter that shall be incremented by one by the drive every time the values in this mode page or the SAS-3 Phy mode page field values are changed. A GENERATION CODE field set to 00h indicates the generation code is unknown. The drive 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 is 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:** set to the value received by this PHY during an Identify Sequence.
- **Attached Target Port:** set to the value received by this PHY during an Identify Sequence.
- **SAS ADDRESS:** field contains the SAS address *transmitted* by this PHY during an Identify Sequence.
- **Attached SAS ADDRESS:** field contains the SAS address *received* by this PHY during an Identify Sequence.
- **Attached PHY Identifier:** field 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 stops at the maximum value.
- **RUNNING DISPARITY ERROR COUNT:** 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 SYNCRONIZATION:** indicates the number of times the phy has lost dword synchronization and restarted the link reset sequence of phy reset sequences. The count stops 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 stops at the maximum value.

- **Phy Event Descriptor Length** indicate 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.

8.8.14 Log Sense Page 19h

Table 120 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 | Obsolete | | | 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 | Obsolete | | | Format and Linking = 10b | |
| 75 | Parameter Length = 08h | | | | | | | |
| 76-83 | Idle Time Intervals | | | | | | | |
| 84-85 | Parameter Code = 0003h | | | | | | | |
| 86 | DU = 0 | Obsolete | TSD = 0 | Obsolete | | | 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 121 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 (5×10^{-2} seconds).

8.8.15 Log Sense Page 1A

Table 122 Log Sense Page 1A

| Byte | Bit | | | | | | | |
|-------|-----------------------------------------|----------|-----------------|----------|---|--------------------|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved = 0 | | Page Code = 1Ah | | | | | |
| 1 | Subpage Code = 00h | | | | | | | |
| 2-3 | Page Length = 0030h | | | | | | | |
| 4-5 | Parameter Code = 0001h | | | | | | | |
| 6 | DU | Obsolete | TSD | Obsolete | | Format and Linking | | |
| 7 | Parameter Length = 04h | | | | | | | |
| 8-11 | Accumulated Transitions to Active State | | | | | | | |
| 12-13 | Parameter Code = 0002h | | | | | | | |
| 14 | DU | Obsolete | TSD | Obsolete | | Format and Linking | | |
| 15 | Parameter Length = 04h | | | | | | | |
| 16-19 | Accumulated Transitions to Idle_A | | | | | | | |
| 20-21 | Parameter Code = 0003h | | | | | | | |
| 22 | DU | Obsolete | TSD | Obsolete | | Format and Linking | | |
| 23 | Parameter Length = 04h | | | | | | | |
| 24-27 | Accumulated Transitions to Idle_B | | | | | | | |
| 28-29 | Parameter Code = 0004h | | | | | | | |
| 30 | DU | Obsolete | TSD | Obsolete | | Format and Linking | | |
| 31 | Parameter Length = 04h | | | | | | | |
| 32-35 | Accumulated Transitions to Idle_C | | | | | | | |
| 36-37 | Parameter Code = 0008h | | | | | | | |
| 38 | DU | Obsolete | TSD | Obsolete | | Format and Linking | | |
| 39 | Parameter Length = 04h | | | | | | | |
| 40-43 | Accumulated Transitions to Standby_Z | | | | | | | |
| 44-45 | Parameter Code = 0009h | | | | | | | |
| 46 | DU | Obsolete | TSD | Obsolete | | Format and Linking | | |
| 47 | Parameter Length = 04h | | | | | | | |
| 48-51 | Accumulated Transitions to Standby_Y | | | | | | | |

8.8.16 Log Sense Page 2F

This page contains SMART Status and Temperature Reading.

Table 123 Log Sense Page 2F

| Byte | Bit | | | | | | | |
|-------|---------------------------------------------|----------|-----------------|----------|---|---|--------------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved = 0 | | Page Code = 2Fh | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 000Fh | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU = 0 | Obsolete | TSD = 0 | Obsolete | | | Format and Linking = 11b | |
| 7 | Parameter Length = 04h | | | | | | | |
| 8 | SMART Sense Code Byte | | | | | | | |
| 9 | SMART Sense Qualifier | | | | | | | |
| 10 | Most Recent Temperature Reading | | | | | | | |
| 11 | Vendor HAD Temperature Trip Point | | | | | | | |
| 12-13 | Parameter Code = 0001h | | | | | | | |
| 14 | DU = 0 | Obsolete | TSD = 0 | Obsolete | | | Format and Linking = 11b | |
| 15 | Parameter Length = 03h | | | | | | | |
| 16 | Internal Environment Status Current Value | | | | | | | |
| 17 | Internal Environment Status Worst Value | | | | | | | |
| 18 | Internal Environment Status Threshold Value | | | | | | | |

8.8.17 Log Sense Page 30

This page contains Performance Counters.

Table 124 Log Sense Page 30

| Byte | Bit | | | | | | | |
|-------|--------------------------------|----------|-----------------|----------|---|---|--------------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved = 0 | | Page Code = 30h | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 0030h | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU = 0 | Obsolete | TSD = 0 | Obsolete | | | Format and Linking = 00b | |
| 7 | Parameter Length = 2Ch | | | | | | | |
| 8-9 | Zero Seeks | | | | | | | |
| 10-11 | Seeks \geq to 2/3 | | | | | | | |
| 12-13 | Seeks \geq 1/3 and $<$ 2/3 | | | | | | | |
| 14-15 | Seeks \geq 1/6 and $<$ 1/3 | | | | | | | |
| 16-17 | Seek \geq 1/12 and $<$ 1/6 | | | | | | | |
| 18-19 | Seeks $>$ 0 and $<$ 1/12 | | | | | | | |
| 20-23 | Reserved = 0 | | | | | | | |
| 24-25 | Overrun Counter | | | | | | | |
| 26-27 | Underrun Counter | | | | | | | |
| 28-31 | Device Cache Full Read Hits | | | | | | | |
| 32-35 | Device Cache Partial Read Hits | | | | | | | |
| 36-39 | Device Cache Write Hits | | | | | | | |
| 40-43 | Device Cache Fast Writes | | | | | | | |
| 44-47 | Device Cache Read Misses | | | | | | | |
| 48-51 | Reserved = 0 | | | | | | | |

Page 30h returns performance counter information. This includes seek counters and buffer overrun/under run counters.

The appropriate seek counter is incremented once during execution of Pre-Fetch, Read, Verify, Write, Write and Verify, Write Same, and Seek commands.

Buffer Overrun conditions are detected during Read commands.

Buffer Under run conditions are detected during Verify with BytChk=1, Write, Write and Verify, and Write Same commands.

Only one seek counter is incremented for each of these commands and the counter is incremented only once per command. The length of the initial seek that is required to access the first Logical Block specified for the SCSI command determines which seek counter is incremented. The Zero Seek counter is incremented if a seek is not required or if only a head switch is required to access the first Logical Block. After the initial seek, no further counter incrementing is performed for that command.

Note: *The length of a seek as reported in page 30 may differ from expected results. The reason for this is that the drive executes Idle Time Functions between operations of the drive. The seek operations that occur in Idle Time Functions are not directly entered into page 30 seek counters but they change the length of the following seek. This is because after the Idle Time Function is completed, the heads will not necessarily be in the same position as they were at the completion of the previous command.*

A buffer overrun or under run condition occurs when the Initiator does not transfer data to or from the Target data buffer fast enough to keep up with reading or writing the media. The buffer overrun counter is incremented during operations that require a Data In phase when a buffer full condition prevents the continued transfer of data from the

media to the data buffer. The buffer under run counter is incremented during operations that require a Data Out phase when a buffer empty condition prevents the start or continuation of a data transfer from the data buffer to the media (or a data transfer from the media for a Verify command with BytChk=1).

Buffer Overrun conditions are detected during the following SCSI commands:

- READ (6)
- READ (10)

Buffer Under Run conditions are detected during the following SCSI commands:

- VERIFY WITH BytChk=1
- VERIFY (16) WITH BytChk=1
- WRITE (6)
- WRITE (10)
- WRITE AND VERIFY
- WRITE AND VERIFY (16)
- WRITE SAME
- WRITE SAME (16)

- **ZERO SEEKS**

The number of times no seek was required. The operation may have resulted in a head switch.

- **SEEKS $\geq 2/3$ DISK**

The number of seeks equal to or greater than 2/3 of the disk.

- **SEEKS $\geq 1/3$ AND $< 2/3$ DISK**

The number of seeks equal to or greater than 1/3 and less than 2/3 of the disk.

- **SEEKS $\geq 1/6$ AND $< 1/3$ DISK**

The number of seeks equal to or greater than 1/6 and less than 1/3 of the disk.

- **SEEKS $\geq 1/12$ AND $< 1/6$ DISK**

The number of seeks equal to or greater than 1/12 and less than 1/6 of the disk.

- **SEEKS > 0 AND $< 1/12$ DISK**

The number of seeks less than 1/12 of the disk.

- **OVERRUN COUNTER**

The number of times that data was available to be transferred from the media but the device buffer still contained data that had not been retrieved by the Initiator. Consequently, the disk had to take additional revolutions until the buffer was available to accept data.

- **UNDER RUN COUNTER**

The number of times that the drive was ready to transfer data to its disk (on a write), but its buffer was empty (i.e., had not been filled by the Initiator), thus the disk was forced to take extra revolutions.

- **DEVICE CACHE FULL READ HITS**

The number of times that all of the data requested by the read operation was obtained from the device read or write cache.

- **DEVICE CACHE PARTIAL READ HITS**

The number of times that a portion, but not all, of the data requested by the read operation was obtained from the device read or write cache. A physical operation to the device media was required to obtain the remaining data.

- **DEVICE CACHE WRITE HITS**

The number of times that the data associated with a write operation replaces, or is combined with, existing data in the device write cache, thereby eliminating a write operation.

- **DEVICE CACHE FAST WRITES**

The number of times that space was available in the device write cache for the data associated with a write operation and a response was returned immediately.

- **DEVICE CACHE READ MISSES**

The number of times that none of the data requested by the read operation was obtained from the read cache.

The statistics reported by this page are lost on a self-initiated reset or when the Drive is powered off, even though the DS field equals zero, the parameters on this page are not savable.

8.8.18 Log Sense Page 37

This page contains a series of miscellaneous data counters including information about predictive failure analysis occurrences.

Table 125 Log Sense Page 37

| Byte | Bit | | | | | | | |
|-------|-----------------------------------------|----------|-----------------|----------|---|---|--------------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved = 0 | | Page Code = 37h | | | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | Page Length = 0040h | | | | | | | |
| 4-5 | Parameter Code = 0000h | | | | | | | |
| 6 | DU = 0 | Obsolete | TSD = 0 | Obsolete | | | Format and Linking = 00b | |
| 7 | Parameter Length = 2Ch | | | | | | | |
| 8-11 | (MSB) Power on Hours (hours only) (LSB) | | | | | | | |
| 12-19 | (MSB) Total Bytes Read (LSB) | | | | | | | |
| 20-27 | (MSB) Total Bytes Written (LSB) | | | | | | | |
| 28 | Max Drive Temperature (degrees Celsius) | | | | | | | |
| 29-30 | (MSB) GList Size (LSB) | | | | | | | |
| 31 | Number of Information Exceptions | | | | | | | |
| 32 | MED EXC | HDW EXC | Reserved = 0 | | | | | |
| 33-40 | Total Read Commands | | | | | | | |
| 41-48 | Total Write Command | | | | | | | |
| 49 | Reserved = 0 | | | | | | | |
| 52-59 | Used Spare Block Count | | | | | | | |
| 60-67 | Total Spare Block Count | | | | | | | |

The **Power on Hours** field specifies the total time the drive has been powered on in hours only.

The **Max. Drive Temperature** field specifies the maximum temperature, in degrees Celsius, the drive has ever reached.

The **GList Size** field gives the total number of LBAs that have been reassigned on the drive.

The **Number of Information Exceptions** field 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.

If set, the **Media Exception and Hardware Exception** bits 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.

Flash Correction Count is incremented each time ECC correction is applied to data stored in Flash ROM.

Used Spare Block Count is the total number of spare blocks used on the drive

Total Spare Block Count is the total number of spare blocks on the drive, both used and available.

8.9 MODE SELECT (6) - (15)

Table 126 Mode Select (6) - (15)

| Byte | Bit | | | | | | | |
|------|-----------------------|---|--------------|--------|--------------|----------|----------|----|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 15h | | | | | | | |
| 1 | Reserved = 0 | | | PF = 1 | Reserved = 0 | | | SP |
| 2-3 | Reserved = 0 | | | | | | | |
| 4 | Parameter List Length | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |

The MODE SELECT(6) - (15) command provides a means for the Initiator to specify LUN or device parameters to the Target. It also allows an Initiator to specify options the Target uses in error recovery, caching, and formatting. There is a single set of Mode Page parameters shared by all Initiators.

8.22.2 PF A 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.

8.22.2 SP (Save Pages).

8.22.2 An SP bit value of zero indicates 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.

8.22.2 An SP bit value of one indicates the drive will save the data in the reserved area of the disk. It will be used for all subsequent commands until another MODE SELECT command is issued. This information is maintained over a power cycle or reset of the drive.

8.22.2 Parameter List Length This 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 in) 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 a 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)*.

8.10 MODE SELECT (10) - (55)

Table 127 Mode Select (10) - (55)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|--------|--------------|----------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 55h | | | | | | | |
| 1 | Reserved = 0 | | | PF = 1 | Reserved = 0 | | | SP |
| 2-6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Parameter List Length | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |

The MODE SELECT (10) - (55) command provides a means for the Initiator to specify LUN or device parameters to the Target.

See the MODE SELECT (6) - (15) command for a description of the fields in this command.

8.11 MODE SENSE (6) - (1A)

Table 128 MODE SENSE (6) - (1A)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|---|-----|--------------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 1Ah | | | | | | | |
| 1 | Reserved = 0 | | | | DBD | Reserved = 0 | | |
| 2 | PCF | | Page Code | | | | | |
| 3 | Subpage Code | | | | | | | |
| 4 | Allocation Length | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |

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

If the **DBD** (Disable Block Descriptor) bit is zero, the Target will return a Block Descriptor. If the DBD bit is set to 1, the Target will not return a Block Descriptor.

Page Control Field: PCF (Page Control Field) defines the type of Page Parameter values to be returned.

PC 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: This field specifies which page or pages to return. Page code usage is defined in the figure below.

Table 129 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 CHECKCONDITION status and available sense of ILLEGAL REQUEST/INVALID FIELD IN CDB.

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

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.

8.11.1 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.

8.11.1.1 Header

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

Table 130 Mode parameter header (6)

| Byte | Bit | | | | | | | |
|------|----------------------------------|--------------|---|----------|--------------|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Mode Data Length | | | | | | | |
| 1 | Medium Type = 0 | | | | | | | |
| 2 | WP=0 | Reserved = 0 | | DPOFUA=1 | Reserved = 0 | | | |
| 3 | Block Descriptor Length = 0 or 8 | | | | | | | |

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

Table 131 Mode parameter header (10)

| Byte | Bit | | | | | | | |
|------|-------------------------------|--------------|---|----------|--------------|---|---|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | (MSB) Mode Data Length | | | | | | | (LSB) |
| 2 | Medium Type = 0 | | | | | | | |
| 3 | WP = 0 | Reserved = 0 | | DPOFUA=1 | Reserved = 0 | | | |
| 4 | Reserved = 0 | | | | | | | Long LBA |
| 5 | Reserved = 0 | | | | | | | |
| 6-7 | (MSB) Block Descriptor Length | | | | | | | (LSB) |

8.22.2 Mode Data Length. When using the MODE SENSE command, the mode data length field specifies the length in bytes of the following data that is available to be transferred. The mode data length does not include the length byte itself. When using the MODE SELECT command, this field is reserved.

8.22.2 Medium Type field is always set to zero in the drive (Default Medium Type).

8.22.2 WP. When used with the MODE SELECT command, the Write Protect (WP) bit is reserved.

When used with the MODE SENSE command, a Write Protect (WP) bit of zero indicates that the medium is write enabled.

8.22.2 DPOFUA bit value of 1 indicates that the Target supports the FUA and DPO bits in the Read and Write Commands.

8.22.2 LONGLBA bit value of 0 indicates that any following Block Descriptor uses the Short LBA Block Descriptor format. A LONGLBA bit value of 1 indicates that any following Block Descriptor uses the Long LBA Block Descriptor format

8.22.2 Block Descriptor Length specifies the length in bytes of the block descriptor. Values of 0, 8, and 16 are supported by the Target, respectively corresponding to an absent Block Descriptor, a single Short LBA Block Descriptor, and a single Long LBA Block Descriptor.

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.

8.11.1.2 Block Descriptors

Table 132 Short LBA Mode Parameter Block Descriptor

| Byte | Bit | | | | | | | |
|------|------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | (MSB) Number of Blocks (LSB) | | | | | | | |
| 4 | Reserved = 0 | | | | | | | |
| 5-7 | (MSB) Block Length (LSB) | | | | | | | |

Table 133 Long LBA Mode Parameter Block Descriptor

| Byte | Bit | | | | | | | |
|-------|------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-7 | (MSB) Number of Blocks (LSB) | | | | | | | |
| 8-11 | Reserved = 0 | | | | | | | |
| 12-15 | (MSB) Block Length (LSB) | | | | | | | |

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

8.22.2 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 (Short LBA) or 0xFFFFFFFFFFFFFFFF (Long LBA) to indicate all available blocks
- 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 returned by the MODE SENSE command, the field contains the exact number of blocks.

8.22.2 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 a value which is 4096, 4096 + 8PI, 4112, 4160, 4224 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.

8.11.1.3 Page Descriptor

Table 134 Mode Parameter Page Format

| | | | |
|----------|-----------------|-----|-----------|
| Byte 0 | PS | SPF | Page Code |
| Byte 1 | Page Length | | |
| Byte 2-n | Mode Parameters | | |

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

When using the MODE SENSE command, a Parameter Savable (PS) bit of one 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 135 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 |

The page length field 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.

8.11.2 Mode Page 00 (Vendor Unique Parameters)

Table 136 Vendor Unique Parameters - Page 00

| Byte | Bit | | | | | | | | Default |
|------|----------------------------------|----------|----------------|---------|---------------------|---------|----------|---------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 00 | | | | | | 80h |
| 1 | Page Length = 0Eh | | | | | | | | 0Eh |
| 2 | Reserved | | | MRG | Reserved | | | Ignored | 00h |
| 3 | Reserved | VGMDE | Reserved | | | RRNDE | Reserved | 00h | |
| 4 | Reserved = 0 | | | | | | | | 00h |
| 5 | Reserved | | | FDD | WCEDS | RDPE | CAEN | Ignored | 0Ah |
| 6 | IGRA | AVERP | Reserved | | OCT (high nibble) | | | 00h | |
| 7 | Overall Command Timer (low byte) | | | | | | | | 00h |
| 8 | Reserved | | | | | | | | 00h |
| 9 | Temperature Threshold | | | | | | | | 00h |
| 10 | Command Aging Limit (high byte) | | | | | | | | 00h |
| 11 | Command Aging Limit (low byte) | | | | | | | | 30h |
| 12 | Read Reporting Threshold | | | | | | | | 16h |
| 13 | Write Reporting Threshold | | | | | | | | 14h |
| 14 | DRRT | Ignored | | | FFMT | Ignored | | | 00h |
| 15 | Ignored | Reserved | FCERT | Ignored | CERTIFY _RDP BIT | Ignored | Reserved | | 00h |

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.

8.22.2 MRG (Merge GList into PList) bit is set to 1 for merging the GList entries into the PList during FORMAT UNIT command.

8.22.2 VGMDE (Veggie Mode) bit set to 1 will cause the drive to execute random self-seeks. To enable this mode, the initiator must perform the mode select to set the bit while the drive is spinning, then Stop Unit, then Start Unit. VGMDE set to 0 disables the self-seeks (normal operation).

8.22.2 RRNDE (Report Recovered Non Data Errors) bit controls the reporting of recovered Non Data Errors when the PER bit is set. If RRNDE is set, recovered Non Data Errors are reported. If the RRNDE bit is not set, then recovered Non Data Errors are not reported.

8.22.2 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.

8.22.2 WCEDS (Write Cache Enabled Data Safety) bit set to 1, and the WCE (Write Cache Enabled) bit (Mode Page 08h, byte 2, bit 2) is set to 1, the device will preserve data in write cache if a power loss occurs. If Write Cache is disabled, enabling this bit is not necessary and has no additional effect.

- **RDPE** (Repurposing Depopulation Enable) bit set to 1 enables Repurposing Depopulation command support. See GET PHYSICAL ELEMENT STATUS (9E/17), REMOVE ELEMENT AND TRUNCATE (9E/18), and RESTORE ELEMENTS AND REBUILD (9E/19) commands for usage.

8.22.2 CAEN (Command Aging Enable) When set this bit 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.

- 8.22.2 IGRA** (Ignore Reassigned LBA) bit works in conjunction with the RC bit (Mode Page 01h, byte 2, bit 4).The main purpose of this bit is to avoid undesirable read processing time delays due to reassigned LBA processing for continuous data availability requirements such as Audio Visual applications. If IGRA is set to one and RC is set to one, out-of-line reassigned LBAs will not be processed. If IGRA is set to one and RC is set to zero, or if IGRA is set to zero, reassigned LBAs will be processed normally.
- 8.22.2 AVERP** (AV ERP Mode) bit is set to one in order to specify maximum retry counts during Read DRP. When AVERP bit is set to one, the maximum retry counts for read operations is specified by Read Retry Count (Mode Page 1 Byte 3). AVERP bit is set to zero to specify that the drive shall process read DRP up to the default maximum retry count when Read Retry Count is set to a non-zero value.
- 8.22.2 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 disables the feature. OCT might not work if command exceeds time but data is available for cache transfer
- 8.22.2 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 (85 degrees Celsius).
- 8.22.2 Command Aging Limit** This value controls the maximum time a command should wait in the command queue when the CAEN bit is set. Each unit of this timer is 50ms.
- 8.22.2 Read Reporting Threshold** specifies the recovery step that must be exceeded to report recovered data errors during read operations when PER=1.For example, if the Read Reporting Threshold is set to 22, recovered read errors will be reported starting at recovery step 23
- 8.22.2 Write Reporting Threshold** specifies the recovery step that must be exceeded to report recovered data errors during write operations when PER=1.For example, if the Write Reporting Threshold is set to 20, recovered write errors will be reported starting at recovery step 21.
- 8.22.2 DRRT** (Disable Restore Reassign Target) bit which disables the reading and restoration of the target LBA during a Reassign Blocks command. If the DRRT bit is zero, the reassign command attempts to restore the target LBA's data. If the data cannot be restored, the target LBA is reassigned and written with a data pattern of all 00s. If the DRRT bit is one, no attempt is made to restore the target LBA.
- 8.22.2 FFMT** (Fast Format Enable) bit allows the formatting of the drive without any writes to the customer media. (See Table 55 for the supported fast format modes). All format operations are allowed including changing block sizes and manipulating defects. The drive will operate normally after a fast format with the following caveat: since no data is written to any customer data blocks as a result of a Fast Format operation, there is a possibility that a read attempt to any particular block (without having previously written to that block) will result in an unrecoverable data error. This will most likely happen if the block size is changed, including when formatting with protection information, as every LBA will contain data of an incorrect length and apparently an incorrect starting point. It is also possible to generate an uncorrectable data error without changing block sizes if the defect list is shortened and previously bad blocks become visible in the customer address space. Of course, ALL DATA ON THE DRIVE WILL BE LOST as the result of any format operation and so any attempt to read blocks which have not been written to will result in unpredictable behavior.
- 8.22.2 FCERT** (Format Certification) bit determines whether the certification step will be performed during a Format Unit command. FCERT bit set to 0 disables certification. FCERT bit set to 1 enables the certification step.
- 8.22.2 CERTIFY_RDP_BIT** (RDP Certification) bit allows certification after execute RDP command. When set to 0 RDP certification is disabled, when set to 1 RDP certification is enabled.

8.11.3 Mode Page 01 (Read/Write Error Recovery Parameters)

Table 137 Mode Page 01 (Read/Write Error Recovery Parameters)

| Byte | Bit | | | | | | | | Default |
|-------|-------------------|---------------------|-----------------|----|----------|-----|-----|----------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 01h | | | | | | 81h |
| 1 | Page Length = 0Ah | | | | | | | | 0Ah |
| 2 | AWRE | ARRE | TB | RC | Obsolete | PER | DTE | Obsolete | C0h |
| 3 | Read Retry Count | | | | | | | | 01h |
| 4 | Obsolete | | | | | | | | 00h |
| 5 | Obsolete | | | | | | | | 00h |
| 6 | Obsolete | | | | | | | | 00h |
| 7 | Reserved | | | | | | | | 00h |
| 8 | Write Retry Count | | | | | | | | 01h |
| 9 | Reserved | | | | | | | | 00h |
| 10-11 | (MSB) | Recovery Time Limit | | | | | | (LSB) | 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:

8.22.2 AWRE Automatic Write Reallocation Enabled bit, set to zero indicates that the drive shall not perform automatic reallocation of defective data blocks during write operations. An AWRE bit set to one indicates that the drive shall perform automatic reallocation of defective data blocks during write operations.

8.22.2 ARRE Automatic Read Reallocation Enabled bit, set to zero indicates that the drive shall not perform automatic reallocation of defective data blocks during read operations. ARRE bit set to one indicates that the drive shall perform automatic reallocation of defective data blocks during read operations.

8.22.2 TB Transfer Block bit, set to one indicates that a data block that is not recovered within the recovery limits specified shall be transferred to the Initiator before *Check Condition* status is returned. A TB bit set to zero indicates that such a data block shall not be transferred to the Initiator. Data blocks that can be recovered within the recovery limits are always transferred regardless of the value of the bit.

8.22.2 RC Read Continuous bit. An RC bit set to one specifies the device server shall transfer the entire requested length of data without adding delays during the data transfer to perform error recovery procedures. The device server may transfer pseudo read data in order to maintain a continuous flow of data. The device server shall assign priority to the RC bit over conflicting bits within this byte (PER, DTE, DCR, TB). A read continuous (RC) bit set to zero specifies that error recovery operations that cause delays during the data transfer are acceptable. RC set to zero indicates normal interpretation of PER, DTE, DCR, and TB values. The RC bit setting is used by the Target when reporting errors associated with the transfer of the Initiator's data for the Read commands. The RC bit applies only to READ commands.

Note: The Target implementation of the RC option is to disable error detection of the data fields but continue normal error detection and recovery for errors occurring in the servo field. If a servo field failure occurs, normal DRP could result in considerable recovery action, including proceeding through all levels of DRP.

8.22.2 PER Post Error bit, is set to one to indicate that the drive reports recovered errors.

8.22.2 DTE (Data Terminate on Error) bit set to one specifies that data transfer will be halted when the first recovered error is encountered. PER must be set to one when DTE is set to one. DTE set to zero will cause data transfer to continue when recovered errors are encountered.

8.22.2 Read Retry Count sets a limit on the number of DRP passes in which the Target attempts to recover read errors. A value of zero disables all data recovery procedures. When AVERP bit (Mode Page 0 Byte 6 Bit 6) is zero, a value of non-zero in Read Retry Count enables all steps of DRP. When AVERP bit is one, the number in Read Retry Count sets the maximum retry count of DRP.

8.22.2 Write Retry Count sets a limit on the number of DRP passes in which the Target attempts to recover write errors. A value of zero disables all data recovery procedures.

8.22.2 Recovery Time Limit indicates the period in 1 millisecond increments for the maximum recovery time of a single LBA. The value must be from 40 ms to 65535 ms (65.5 seconds). The granularity of the timer is 50ms. If an LBA is not able to be recovered within the limit, a Check Condition will be returned. The Recovery Time Limit will not be applied to Writes when WCE=1. A value of zero disables the timer.

The following summarizes valid modes of operation. If an illegal mode is set, the MODE SELECT command will complete successfully but the action of the drive when an error occurs is undefined.

Table 138 Error Recovery Bit Combinations (PER/DTE/TB)

| PER | DTE | TB | DESCRIPTION | |
|-----|-----|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0 | 0 | 0 | Retries and Error Correction are attempted. Recovered or corrected data (if any) or both are transferred with no <i>Check Condition</i> status at the end of the transfer. | |
| | | | no err | The transfer length is exhausted. |
| | | | soft err | The transfer length is exhausted. Transferred data includes blocks containing recovered errors. |
| | | | hard err | Data transfer stops when an unrecoverable error is encountered. The unrecoverable block is not transferred to the Initiator. The drive then creates the <i>Check Condition</i> status with the appropriate sense key. |
| 0 | 0 | 1 | Retries and Error Correction are attempted. Recovered or corrected data (if any) or both are transferred with no <i>Check Condition</i> status at the end of the transfer. | |
| | | | no err | The transfer length is exhausted. |
| | | | soft err | The transfer length is exhausted. Transferred data includes blocks containing recovered errors. |
| | | | hard err | Data transfer stops when an unrecoverable error is encountered. The unrecoverable block is transferred to the Initiator. The drive then creates the <i>Check Condition</i> status with the appropriate sense key. |
| 0 | 1 | 0 | Illegal Request-DTE must be zero when PER is zero. | |
| 0 | 1 | 1 | Illegal Request-DTE must be zero when PER is zero. | |
| 1 | 0 | 0 | The highest level error is reported at the end of transfer. Retries and error correction are attempted. Recovered or corrected data (if any) or both are transferred with <i>Check Condition</i> status and <i>Recovered Error</i> sense key set at the end of the transfer. | |
| | | | no err | The transfer length is exhausted. |
| | | | soft err | The transfer length is exhausted. Transferred data includes blocks containing recovered errors. The information byte in the sense data will contain the LBA of the last recovered error. |
| | | | hard err | Data transfer stops when an unrecoverable error is encountered. The unrecoverable block is not transferred to the Initiator. The drive then creates the <i>Check Condition</i> status with the appropriate sense key. |
| 1 | 0 | 1 | The highest level error is reported at the end of transfer. Retries and error correction are attempted. Recovered or corrected data (if any) or both are transferred with <i>Check Condition</i> status and <i>Recovered Error</i> sense key set at the end of the transfer. | |
| | | | no err | The transfer length is exhausted. |
| | | | soft err | The transfer length is exhausted. Transferred data includes blocks containing recovered errors. The information byte in the sense data will contain the LBA of the last recovered error. |
| | | | hard err | Data transfer stops when an unrecoverable error is encountered. The unrecoverable block is not transferred to the Initiator. The drive then creates the <i>Check Condition</i> status with the appropriate sense key. |
| 1 | 1 | 0 | The highest level error is reported at the end of transfer. Retries and error correction are attempted. Recovered or corrected data (if any) or both are transferred with <i>Check Condition</i> status and <i>Recovered Error</i> sense key set at the end of the transfer. | |
| | | | no err | The transfer length is exhausted. |

| PER DTE TB | DESCRIPTION | |
|------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | soft err | The transfer stops on the first soft error detected. The information in the sense data shall contain the LBA of the block in error. |
| | hard err | Data transfer stops on the unrecoverable error. The unrecoverable error block is not returned to the Initiator. The drive then creates the <i>Check Condition</i> status with the appropriate sense key. |

8.11.4 Mode Page 02 (Disconnect/Reconnect Parameters)

Table 139 Mode Page 02 (Disconnect/Reconnect Parameters)

| Byte | Bit | | | | | | | | Default |
|-------|---------------------------|----------------------------|----------------|---|---|---|---|-------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 02 | | | | | | 82h |
| 1 | Page Length = 0Eh | | | | | | | | 0Eh |
| 2 | Read Buffer Full Ratio | | | | | | | | 00h |
| 3 | Write Buffer Empty Ratio | | | | | | | | 00h |
| 4-5 | (MSB) | Bus Inactivity Time Limit | | | | | | (LSB) | 00h |
| 6-7 | Disconnect Time Limit = 0 | | | | | | | | 00h |
| 8-9 | (MSB) | Maximum Connect Time Limit | | | | | | (LSB) | 00h |
| 10-11 | (MSB) | Maximum Burst Size | | | | | | (LSB) | 00h |
| 12-13 | Reserved | | | | | | | | 00h |
| 14-15 | (MSB) | First Burst Size | | | | | | (LSB) | 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).

8.22.2 Read Buffer Full Ratio is the numerator of a fraction whose denominator is 256. The fraction indicates how full the drive data buffer should be before attempting to re-arbitrate for the link. If the ratio is set to 0h, the target will calculate and use an optimal ratio based on the negotiated transfer rate.

8.22.2 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.

8.22.2 Disconnect Time Limit is not supported.

8.22.2 Write Buffer Empty Ratio is the numerator of a fraction whose denominator is 256. The fraction indicates how empty the drive data buffer should be before attempting to re-arbitrate for the link. If the ratio is set to 0h, the target will calculate and use an optimal ratio based on the negotiated transfer rate. Both the Read Buffer Full Ratio and the Write Buffer Empty Ratio pertain to the current active notch. For each active notch as defined in page 0Ch there are separate Read Buffer Full Ratios and Write Buffer Empty Ratios. When the active notch is set to zero, the values are applied in mode page 0Ch across all notches.

8.22.2 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.

8.22.2 Maximum Burst Size field indicates the maximum amount of data that the target port shall transfer during a single data transfer operation. This value is expressed in increments of 512 bytes. A value of zero specifies there is no limit on the amount of data transferred per data transfer operation.

8.22.2 First Burst Size is not supported.

8.11.5 Mode Page 03 (Format Device Parameters)

Table 140 Mode Page 03 (Format Device Parameters)

| Byte | Bit | | | | | | | | Default |
|-------|-------------------|---------------------------------------|----------------|------|--------------|---|---|-------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 03 | | | | | | 83h |
| 1 | Page Length = 16h | | | | | | | | 16h |
| 2-3 | (MSB) | Tracks per Zone | | | | | | (LSB) | xxxxh |
| 4-5 | (MSB) | Alternate Sectors per Zone = 0 | | | | | | (LSB) | 0000h |
| 6-7 | (MSB) | Alternate Sectors per Track = 0 | | | | | | (LSB) | 0000h |
| 8-9 | (MSB) | Alternate Tracks per Logical Unit = 0 | | | | | | (LSB) | 0000h |
| 10-11 | (MSB) | Sectors per Track | | | | | | (LSB) | xxxxh |
| 12-13 | (MSB) | Data Bytes per Physical Sector | | | | | | (LSB) | xxxxh |
| 14-15 | (MSB) | Interleave = 0001h or 0000h | | | | | | (LSB) | 0001h |
| 16-17 | (MSB) | Track Skew Factor | | | | | | (LSB) | xxxxh |
| 18-19 | (MSB) | Cylinder Skew Factor | | | | | | (LSB) | xxxxh |
| 20 | SSEC | HSEC | RMB | SURF | Reserved = 0 | | | | 40h |
| 21-23 | Reserved = 0 | | | | | | | | 00h |

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

8.22.2 Tracks per Zone specifies the number of tracks within the zone. This field is a function of the active notch.

8.22.2 Sectors per Track specifies the number of physical sectors within each track. This field is a function of the active notch.

8.22.2 Data Bytes per Physical Sector specifies the number of user data bytes per physical sector. The value depends upon the current formatted Block Length.

8.22.2 Interleave value of 1 or 0 is valid. However, the drive will ignore this.

8.22.2 Track Skew Factor indicates the number of physical sectors between the last block of one track and the first block on the next sequential track of the same cylinder. This field is a function of the active notch.

8.22.2 Cylinder Skew Factor indicates the number of physical sectors between the last block of one cylinder and

the first block on the next sequential cylinder. This field is a function of the active notch.

8.22.2 SSEC = Zero indicates that the drive does not support soft sector formatting.

8.22.2 HSEC = One indicates that the drive supports hard sector formatting.

8.22.2 RMB = Zero indicates that the media does not support removable Fixed Disk.

8.22.2 SURF = Zero indicates that progressive addresses are assigned to all logical blocks in a cylinder prior to allocating addresses within the next cylinder.

8.11.6 Mode Page 04 (Rigid Disk Drive Geometry Parameters)

Table 141 Mode Page 04 (Rigid Disk Drive Geometry Parameters)

| Byte | Bit | | | | | | | | Default |
|-------|----------------------------------|-----------------------------------------------|----------------|---|---|---------|---|-------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 04 | | | | | | 84h |
| 1 | Page Length = 16h | | | | | | | | 16h |
| 2-4 | (MSB) | Number of Cylinders | | | | | | (LSB) | xxxxh |
| 5 | Number of Heads | | | | | | | | xxh |
| 6-8 | (MSB) | Starting Cylinder – Write Precompensation = 0 | | | | | | (LSB) | 0000h |
| 9-11 | (MSB) | Starting Cylinder – Reduced Write Current = 0 | | | | | | (LSB) | 0000h |
| 12-13 | (MSB) | Drive Step Rate = 0 (Not used) | | | | | | (LSB) | 0000h |
| 14-16 | (MSB) | Landing Zone Cylinder = 0 (Not used) | | | | | | (LSB) | 0000h |
| 17 | Reserved = 0 | | | | | RPL = 0 | | 00h | |
| 18 | Rotational Offset = 0 (not used) | | | | | | | | 00h |
| 19 | Reserved = 0 | | | | | | | | 00h |
| 20-21 | (MSB) | Medium Rotation Rate in RPM | | | | | | (LSB) | 1C20h |
| 22-23 | Reserved = 0 | | | | | | | | 00h |

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

8.22.2 RPL = 0, Indicates that the drive does not support spindle synchronization.

8.11.7 Mode Page 07 (Verify Error Recovery Parameters)

Table 142 Mode Page 07 (Verify Error Recovery Parameters)

| Byte | Bit | | | | | | | | Default |
|-------|--------------------|----------------------------|-----------------|----------|-----|-----|----------|-------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 07h | | | | | | 87h |
| 1 | Page Length = 0Ah | | | | | | | | 0Ah |
| 2 | Reserved = 0 | | | Obsolete | PER | DTE | Obsolete | | 00h |
| 3 | Verify Retry Count | | | | | | | | 01h |
| 4 | Obsolete | | | | | | | | 00h |
| 5-9 | Reserved = 0 | | | | | | | | 00h |
| 10-11 | (MSB) | Verify Recovery Time Limit | | | | | | (LSB) | 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 VERIFY commands and the Verify portion of WRITE AND VERIFY commands.

8.22.2 PER (post error) bit is set to one to indicate that the drive reports recovered errors. The PER and DTE bit settings in mode page 7 override those of mode page 1 during VERIFY and the Verify portion of WRITE AND VERIFY.

8.22.2 DTE (Data Terminate on Error) bit set to one specifies that data transfer will be halted when the first recovered error is encountered. PER must be set to one when DTE is set to one. DTE set to zero will cause data transfer to continue when recovered errors are encountered.

8.22.2 Verify Retry Count sets a limit on the number of verify recovery procedure (VRP) passes the Target attempts when recovering verify errors. The Verify Retry Count of one causes the Target to attempt up to one VRP pass per command when a medium error occurs during a verify operation. Only values of 0h and 01h are valid. The value of 0h disables all recovery.

8.22.2 Verify Recovery Time Limit indicates the period in 1 millisecond increments for the maximum recovery time of a single LBA during the verify operation. The value must be from 40 ms to 65535 ms (65.5 seconds). The granularity of the timer is 50ms. If an LBA is not able to be recovered within the limit, a Check Condition will be returned.

8.11.8 Mode Page 08 (Caching Parameters)

Table 143 Page 08 (Caching Parameters)

| Byte | Bit | | | | | | | | Default |
|-------|-----------------------------------------------|-------|-----------------|--------------|------------------------|-----|----|-----|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 08h | | | | | | 88h |
| 1 | Page Length = 12h | | | | | | | | 12h |
| 2 | IC | ABPF | CAP | DISC | SIZE | WCE | MF | RCD | 04h |
| 3 | Demand Read Retention Policy | | | | Write Retention Policy | | | | 00h |
| 4-5 | (MSB) Disable Pre-fetch Transfer Length (LSB) | | | | | | | | FFFFh |
| 6-7 | (MSB) Minimum Pre-fetch (LSB) | | | | | | | | 0000h |
| 8-9 | (MSB) Maximum Pre-fetch (LSB) | | | | | | | | FFFFh |
| 10-11 | (MSB) Maximum Pre-fetch Ceiling (LSB) | | | | | | | | FFFFh |
| 12 | FSW | LBCSS | DRA | Reserved = 0 | | | | | 00h |
| 13 | Number of Cache Segments | | | | | | | | 08h |
| 14-15 | (MSB) Cache Segment Size (LSB) | | | | | | | | 00h |
| 16 | Reserved = 0 | | | | | | | | 00h |
| 17-19 | (MSB) Non Cache Segment Size (LSB) | | | | | | | | 00h |

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

8.22.2 IC (Initiator Control) bit of one specifies that the drive will honor the following parameters to control cache segmentation and pre-fetch: SIZE, FSW, LBCSS, Number of Cache Segments, Cache Segment Size. The drive will never pre-fetch less data than specified by ABPF, MF, Demand Read Retention Priority, Write Retention Priority, Disable Pre-fetch Transfer Length, Minimum Pre-fetch, Maximum Pre-fetch, and Maximum Pre-fetch Ceiling, but may pre-fetch more based on internal cache algorithms. When the IC bit is set to zero, all the parameters listed above are ignored, and an internal caching algorithm is used.

8.22.2 ABPF (Abort Pre-fetch) bit of one, with DRA set to zero, causes the drive to abort the pre-fetch upon receipt of a new command. ABPF set to one takes precedence over Minimum Pre-fetch. When ABPF is zero, with DRA set to zero, the termination of any active pre-fetch is dependent upon the other parameters in this page.

8.22.2 CAP (Caching Analysis Permitted) is not supported and is ignored. The IC bit can be used to enable or disable adaptive caching.

8.22.2 DISC (Discontinuity) is not supported and is ignored. Pre-fetch operations will continue across cylinders, within the limits of other caching parameters on this page.

8.22.2 SIZE (Size Enable) bit when set to one indicates that the Cache Segment Size is to be used to control caching segmentation. When SIZE is set to zero, the Initiator requests that the Number of Cache Segments is to be used to control caching segmentation.

8.22.2 WCE (Write Cache Enable) bit when set at zero indicates that the drive must issue *Good* status for WRITE

(6) or WRITE (10) command only after successfully writing the data to the media. When the WCE bit is set to one, the drive may issue *Good* status for a WRITE (6) or WRITE (10) command after successfully receiving the data but before writing it to the media. When WCE = 1, the drive operates as if AWRE = 1.

Note: When WCE = 1, a SYNCHRONIZE CACHE command must be done to ensure data are written to the media before powering down the Target.

- 8.22.2 **MF** (Multiplication Factor) bit determines how the Maximum and Minimum Pre-fetch parameters are interpreted. If this bit is set to zero, the parameters are used as is. If the bit is set to one, the parameters are multiplied by the number of blocks requested in the Read Command.
- 8.22.2 **RCD** (Read Cache Disable) bit set at zero indicates that the drive may return some or all of the data requested by a READ (6) or READ (10) command by accessing the data buffer, not the media. An RCD bit set at one indicates that the Target does not return any of the data requested by a READ (6) or READ (10) command by accessing the data buffer. All data requested is read from the media instead.
- 8.22.2 **Demand Read Retention Priority** is not supported.
- 8.22.2 **Write Retention Priority** is not supported.
- 8.22.2 **Disable Pre-fetch Transfer Length** is used to prevent read-ahead after Read commands that are longer than the specified number of blocks. If this parameter is set to zero, a read-ahead is not performed.
- 8.22.2 **Minimum Pre-fetch** specifies the minimum number of LBAs that the drive should after each READ command. A value of zero indicates that read ahead should be terminated immediately after a new command arrives, except when the new command is on the current head and track.
- 8.22.2 **Maximum Pre-fetch** specifies the maximum number of LBAs to read ahead after a Read command.
- 8.22.2 **Maximum Pre-fetch Ceiling** specifies the maximum number of blocks the drive should attempt to read ahead. This field is ignored.
- 8.22.2 **FSW** (Force Sequential Write) is not supported and is ignored. All logical blocks will be written in sequential order.
- 8.22.2 **LBCSS** (Logical Block Cache Segment Size) bit when set to one indicates that the Cache Segment Size field units shall be interpreted as logical blocks. When it is set to zero, the Cache Segment Size field units shall be interpreted as bytes.
- 8.22.2 **DRA** (Disable Read Ahead) bit when set to one request that the Target not read into the buffer any logical block beyond the addressed logical block(s). When it is set at zero, the Target may continue to read logical blocks into the buffer beyond the addressed logical block(s).
- 8.22.2 **Number of Cache Segments** field is used to select the number of data buffer cache segments. This parameter is valid only when the SIZE bit is set at zero. It is ignored when SIZE is set at one.
- 8.22.2 **Cache Segment Size** field indicates the requested segment size in Bytes or Blocks, depending upon the value of the LBCSS bit. The Cache Segment Size field is valid only when the SIZE bit is one. It is ignored when SIZE is set at zero.
- 8.22.2 **Non Cache Segment Size** is not supported and is ignored.

8.11.9 Mode Page 0A (Control Mode Page Parameters)

Table 144 Page 0A (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 | GLTSD=0 | RLEC=0 | 04h | | |
| 3 | Queue Algorithm Modifier | | | | Reserved | QErr | | Obsolete | 00h | | |
| 4 | Reserved | RAC=0 | UA_INTLCK_CTRL=0 | SWP=0 | Obsolete | | | | 00h | | |
| 5 | ATO | TAS=0 | ATMPE | RWWP | SBPL | Reserved | | | 00h | | |
| 6-7 | Obsolete | | | | | | | | 00h | | |
| 8-9 | (MSB) | Busy Timeout Period | | | | | | | (LSB) | 00h | |
| 10-11 | (MSB) | Extended Self-Test Routine Completion Time | | | | | | | | (LSB) | Xxh |

Following are parameter options for Page 0A.

- **DPICZ** (Disable Protection Information Check if protect field is 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-4) set to zero;
 - b) The VRPROTECT field (see SBC-4) set to zero; or
 - c) The ORPROTECT field (see SBC-4) set to zero.
- **D_Sense** (Descriptor Sense Data) bit controls the format in which the drive returns sense data for CHECK_CONDITION status:
 - Setting the D_SENSE bit to 0 specifies that the drive shall return fixed format sense data for CHECK_CONDITION.
 - Setting the D_SENSE bit to 1 specifies that the drive shall return descriptor format sense data for CHECK_CONDITION
- **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
 - 8h Command reordering is disabled
 - 9h-Fh RESERVED
- **QErr** (Queue Error Management) The queue error management (QERR) field specifies how the drive shall handle blocked tasks when another task receives a *Check Condition* status.

Table 145 Queue Error Management (QERR) field

| QERR | Description |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00b | Specifies that all tasks from all Initiators are blocked from execution when a Continent 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 <i>Check Condition</i> status. A unit attention condition will be generated for each Initiator that had commands in the queue except for the Initiator that received the <i>Check Condition</i> status. The sense key will be set to <i>Unit Attention</i> and the additional sense code will be set to <i>Commands Cleared by Another Initiator</i> . |
| 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 |

8.22.2 ATO (Application Tag Owner) bit 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.

8.22.2 ATMPE (Application Tag Mode Page Enabled) bit set to zero specifies that the Application Tag mode page (see SBC-4) is disabled and the contents of logical block application tags are not defined by this specification. 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.

8.22.2 RWWP (Reject Write Without Protection) bit set to zero specifies that write commands without protection information (see SBC-4) shall be processed. A RWWP bit set to one specifies that write commands without protection information received by a drive that has been formatted with protection information 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

8.22.2 SBLP (Supported block lengths and protection information) bit set to one specifies that the device server shall return the Supported Block Lengths and Protection Types VPD page and shall set the SPT field to 110b in the Extended INQUIRY Data VPD page. An SBLP bit set to zero specifies that the device server shall not return the Supported Block Lengths and Protection Types VPD page and shall not set the SPT field to 110b in the Extended INQUIRY Data VPD page. Changing the value of the SBLP bit results in the establishment of a unit attention condition.

8.22.2 Busy Timeout Period is ignored

8.22.2 Extended Self-test Routine Completion Time specifies the time in seconds that the device server requires to complete an extended self-test provided the device server is not interrupted by subsequent commands and no errors occur during processing of the self-test. A value of FFFFh indicates that the extended self-test takes 65,535 seconds or longer. See also the EXTENDED SELF-TEST COMPLETION MINUTES field in Table 81.

8.11.9.1 Control Extension Subpage 01h

Table 146 Control Extension Subpage

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

8.22.2 TCMOS (Timestamp Changeable by Methods Outside This Specification): set to zero to specify that the timestamp shall not be changed by any method except those defined by this specification.

8.22.2 SCSIP (SCSI Precedence): set to one to specify that the timestamp changed using a SET TIMESTAMP command shall take precedence over any other methods.

8.22.2 IALUAE (Implicit Asymmetric Logical Unit Access Enabled): set to zero 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.

8.22.2 Initial Command Priority: set to zero to indicate that the drive does not support priorities with the SET PRIORITY command.

8.22.2 Maximum Sense Data Length: specifies the maximum number of bytes of sense data the drive 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 drive 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.

8.11.9.2 Control Extension Subpage 02h

Table 147 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-4 | | | | | | | |
| 4-15 | Reserved = 0 | | | | | | | |
| 16-39 | Application Tag Descriptor [first] | | | | | | | |
| ... | ... | | | | | | | |
| (n-24)-n | Application Tag Descriptor [last] | | | | | | | |

Table 148 Application Tag descriptor format

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

8.22.2 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.

8.22.2 The **LOGICAL BLOCK APPLICATION TAG** field specifies the value to be compared with the **LOGICAL LOCK APPLICATION TAG** field associated with data read or written to the LBA.

8.22.2 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 (see Section 8.24).

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 drive shall terminate the **MODE SELECT** command (see Section 8.9) with **CHECK CONDITION** status with the sense key set to **ILLEGAL REQUEST** and the additional sense code set to **INVALID FIELD IN PARAMETER LIST**.

8.22.2 The **LOGICAL BLOCK COUNT** field specifies the number of logical blocks to which this Application Tag descriptor applies.

8.22.2 A **LOGICAL BLOCK COUNT** field set to 0000_0000_0000_0000h specifies that this Application Tag descriptors shall be ignored.

8.11.9.3 Command Duration Limit T2A Subpage 07h

Table 149 Command Duration Limit T2A mode page

| Byte | Bit | | | | | | | | Default |
|---------|------------------------------------------------|---------|-----------------|---|--------------|---|---|---|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | SPF = 1 | Page Code = 0Ah | | | | | | CAh |
| 1 | Subpage Code 07h | | | | | | | | 07h |
| 2-3 | Page Length = 00E4h | | | | | | | | 00E4h |
| 4-6 | Reserved = 0 | | | | | | | | 00h |
| 7 | Performance Versus Command Duration Guidelines | | | | Reserved = 0 | | | | 00h |
| 8-39 | T2 Command Duration Limit Descriptor (first) | | | | | | | | 00h |
| 40-71 | T2 Command Duration Limit Descriptor (second) | | | | | | | | 00h |
| 72-103 | T2 Command Duration Limit Descriptor (third) | | | | | | | | 00h |
| 104-135 | T2 Command Duration Limit Descriptor (fourth) | | | | | | | | 00h |
| 136-167 | T2 Command Duration Limit Descriptor (fifth) | | | | | | | | 00h |
| 168-199 | T2 Command Duration Limit Descriptor (sixth) | | | | | | | | 00h |
| 200-231 | T2 Command Duration Limit Descriptor (seventh) | | | | | | | | 00h |

Performance Versus Command Duration Guidelines: The Performance Versus Command Duration Guidelines field specifies the maximum percentage increase in average command completion times that are caused by actions that the device server performs based on the contents of the Command Duration Guideline field in every T2 command duration limit descriptor in the Command Duration Limit T2A mode page and every T2 command duration limit descriptor in the Command Duration Limit T2B mode page.

Table 150 Performance Versus Command Duration Guidelines field

| Code | Maximum Percentage Increase in Average Command Completion Times |
|----------|-----------------------------------------------------------------|
| 0h | 0% |
| 1h | 0.5% |
| 2h | 1.0% |
| 3h | 1.5% |
| 4h | 2.0% |
| 5h | 2.5% |
| 6h | 3% |
| 7h | 4% |
| 8h | 5% |
| 9h | 8% |
| Ah | 10% |
| Bh | 15% |
| Ch | 20% |
| Dh to Fh | Reserved |

T2 Command Duration Limit Descriptor: The T2 command duration limit descriptor describes the command duration limit information that corresponds to the duration limit descriptor index in the CDB if the Command Duration

Limit T2A mode page is indicated.

Table 151 T2 Command Duration Limit Descriptor format

| Byte | Bit | | | | | | | |
|-------|----------------------------|---|---|---|-----------------------------------|---|---|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | | | | T2CDLUNITS | | | |
| 1 | Reserved | | | | | | | |
| 2-3 | MAX INACTIVE TIME | | | | | | | |
| 4-5 | MAX ACTIVE TIME | | | | | | | |
| 6 | MAX INACTIVE TIME POLICY | | | | MAX ACTIVE TIME POLICY | | | |
| 7-9 | Reserved | | | | | | | |
| 10-11 | COMMAND DURATION GUIDELINE | | | | | | | |
| 12-13 | Reserved | | | | | | | |
| 14 | Reserved | | | | COMMAND DURATION GUIDELINE POLICY | | | |
| 15 | Reserved | | | | | | | BYP_SEQ |
| 16-31 | Reserved | | | | | | | |

T2CDLUNITS: The T2CDLUNITS field specifies the time units for the MAX INACTIVE TIME field, the MAX ACTIVE TIME field, the REQUESTED LATENCY TARGET field, and the ACHIEVABLE LATENCY TARGET field.

Table 152 T2CDLUNITS field

| Code | Description |
|--------|--------------------|
| 0h | No value specified |
| 6h | 500 nanoseconds |
| 8h | 1 microsecond |
| Ah | 10 milliseconds |
| Eh | 500 milliseconds |
| Others | Reserved |

MAX INACTIVE TIME: The MAX INACTIVE TIME field specifies an upper limit on the time that elapses from the time at which the SCSI Command Received transport protocol service indication is invoked until the time at which the device server initiates actions to access, transfer, or act upon the specified data. A MAX INACTIVE TIME field set to a non-zero value specifies the time upper limit in units indicated by the T2CDLUNITS field. A MAX INACTIVE TIME field set to zero specifies that no time upper limit is specified by this T2 command duration limit descriptor. If the T2CDLUNITS field is set to 0h, the MAX INACTIVE TIME field is ignored.

MAX ACTIVE TIME: The MAX ACTIVE TIME field specifies an upper limit on the time that elapses from the time at which the device server initiates actions to access, transfer, or act upon the specified data until the time the device server returns status for the command. A MAX ACTIVE TIME field set to a non-zero value specifies the time upper limit in units specified by the T2CDLUNITS field. A MAX ACTIVE TIME field set to zero specifies that no time upper limit is specified by this T2 command duration limit descriptor. If the T2CDLUNITS field is set to 0h, the MAX ACTIVE TIME field is ignored.

MAX INACTIVE TIME POLICY: The MAX INACTIVE TIME POLICY field specifies the policy action taken if the max inactive limit is not met (i.e., the time used to cause a command to become an enabled command exceeds the time specified by the MAX INACTIVE TIME field and the T2CDLUNITS field).

Table 153 MAX INACTIVE TIME POLICY field

| Code | Description |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0h | The device server completes the command at the earliest possible time (i.e, do nothing based on the max time limit not being met). |
| 1h to Ch | Reserved |
| Dh | The device server completes the command with GOOD status, with the sense key set to COMPLETED and the sense code set to DATA CURRENTLY UNAVAILABLE. |
| Eh | Reserved |
| Fh | The device server terminates the command with CHECK CONDITION status, with the sense key set to ABORTED COMMAND and the additional sense code set to COMMAND TIMEOUT BEFORE PROCESSING. |

MAX ACTIVE TIME POLICY: The MAX ACTIVE TIME POLICY field specifies the policy action taken if the max active time limit is not met (i.e., the time used to process a command exceeds the time specified by the MAX ACTIVE TIME field and the T2CDLUNITS field).

Table 154 MAX ACTIVE TIME POLICY field

| Code | Description |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0h | The device server completes the command at the earliest possible time (i.e, do nothing based on the max time limit not being met). |
| 1h to Ch | Reserved |
| Dh | The device server completes the command with GOOD status, with the sense key set to COMPLETED and the sense code set to DATA CURRENTLY UNAVAILABLE. |
| Eh | The device server terminates the command with CHECK CONDITION status, with the sense key set to ABORTED COMMAND and the additional sense code set to COMMAND TIMEOUT DURING PROCESSING or COMMAND TIMEOUT DURING PROCESSING DUE TO ERROR RECOVERY. If the starting LBA contents have been transferred to the application client, then the device server may indicate the largest LBA for which a contiguous range of LBAs have been transferred to the application client starting with the starting LBA of the read command. |
| Fh | The device server terminates the command with CHECK CONDITION status, with the sense key set to ABORTED COMMAND and the additional sense code set to COMMAND TIMEOUT DURING PROCESSING. |

COMMAND DURATION GUIDELINE: The COMMAND DURATION GUIDELINE field specifies the preferred length of time for the completion of a command. The device server processes this preferred length of time based on comparisons to the preferred length of time for commands that select other Command Duration Limits Descriptors in which the COMMAND DURATION GUIDELINE field is not set to zero.

The preferred length of time for the command completion is specified as the non-zero time in units indicated by the T2CDLUNITS field to be added to fastest time for completion of a read command for which the device server is able to return the requested data only by accessing the media. If the T2CDLUNITS field is set to 0h, the COMMAND DURATION GUIDELINE field is ignored.

Although a time is specified by the COMMAND DURATION GUIDELINE field and the T2CDLUNITS field (i.e., the command duration guideline), the values are interpreted such that:

- a) the length of time with which the device server completes commands that select a T2 command duration limits descriptor is:
 - A) faster for smaller command duration guideline values; and
 - B) slower for larger command duration guideline values, in comparison to the command duration guideline values specified by other Command Duration Limits Descriptors; and

- b) larger magnitudes of the difference between the command duration guideline values in two different T2 command duration limits descriptors result in larger probabilities of differences between the length of time of command completions for commands that select those descriptors.

A COMMAND DURATION GUIDELINE field set to zero indicates that no command completion guidance is provided by this T2 command duration limits descriptor.

COMMAND DURATION GUIDELINE POLICY: The COMMAND DURATION GUIDELINE POLICY field specifies the policy action taken if a non-zero COMMAND DURATION GUIDELINE field specifies a command duration guideline that the device is unable to achieve for a command.

Table 155 COMMAND DURATION GUIDELINE POLICY field

| Code | Description |
|----------|---------------------------------------------------------------------------------------------------------------------------------------|
| 0h | The device server shall complete that command at the earliest possible time consistent with the specified command duration guideline. |
| 1h to Fh | Reserved |

BYPASS SEQUESTRATION (BYP_SEQ): A bypass sequestration (BYP_SEQ) bit set to zero specifies that the device server processes a command associated with this T2 command duration limit descriptor as a non-sequestered command or a sequestered command. A BYP_SEQ bit set to one specifies that the device server processes a command associated with this T2 command duration limit descriptor as a non-sequestered command.

8.11.9.4 Command Duration Limit T2B Subpage 08h

Table 156 Command Duration Limit T2A mode page

| Byte | Bit | | | | | | | | Default |
|---------|------------------------------------------------|---------|-----------------|---|-----------------------------------------|---|---|---|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | SPF = 1 | Page Code = 0Ah | | | | | | CAh |
| 1 | Subpage Code 08h | | | | | | | | 08h |
| 2-3 | Page Length = 00E4h | | | | | | | | 00E4h |
| 4-6 | Reserved = 0 | | | | | | | | 00h |
| 7 | Reserved = 0 | | | | Performance Versus Latency Controls = 0 | | | | 00h |
| 8-39 | T2 Command Duration Limit Descriptor (first) | | | | | | | | 00h |
| 40-71 | T2 Command Duration Limit Descriptor (second) | | | | | | | | 00h |
| 72-103 | T2 Command Duration Limit Descriptor (third) | | | | | | | | 00h |
| 104-135 | T2 Command Duration Limit Descriptor (fourth) | | | | | | | | 00h |
| 136-167 | T2 Command Duration Limit Descriptor (fifth) | | | | | | | | 00h |
| 168-199 | T2 Command Duration Limit Descriptor (sixth) | | | | | | | | 00h |
| 200-231 | T2 Command Duration Limit Descriptor (seventh) | | | | | | | | 00h |

The T2 command duration limit descriptor (see Table 151) describes the command duration limit information that corresponds to the duration limit descriptor index in the CDB if the Command Duration Limit T2B mode page is indicated.

8.11.10 Mode Page 0C (Notch Parameters)

Table 157 Page 0C (Notch Parameters)

| Byte | Bit | | | | | | | | Default |
|-------|-------------------|---------------------------|-----------------|---|---|---|---|-------|----------------------------------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 0Ch | | | | | | 8Ch |
| 1 | Page Length = 16h | | | | | | | | 16h |
| 2 | ND=1 | LPN=0 | Reserved = 0 | | | | | | 80h |
| 3 | Reserved = 0 | | | | | | | | 00h |
| 4-5 | (MSB) | Maximum Number of Notches | | | | | | (LSB) | Xxxxh |
| 6-7 | (MSB) | Active Notch | | | | | | (LSB) | 0000h |
| 8-11 | (MSB) | Starting Boundary | | | | | | (LSB) | Xxxxh Xxxxh |
| 12-15 | (MSB) | Ending Boundary | | | | | | (LSB) | Xxxxh xxxxh |
| 16-23 | (MSB) | Pages Notched | | | | | | (LSB) | 0000h 0000h 0000h 100Ch |

The notch page contains parameters for direct-access devices that implement a variable number of blocks per cylinder. Each section of the logical unit with a different number of blocks per cylinder is referred as a notch. The only field that is changeable is the **Active Notch** field.

8.22.2 ND = One meaning that this device is a notched drive.

8.22.2 LPN = Zero meaning that the notches are based upon physical parameters of the drive (cylinder #), not logical parameters.

8.22.2 Maximum Number of Notches is the number of notches the drive can support. This value is drive model dependent.

8.22.2 Active Notch indicates to which notch subsequent MODE SELECT/SENSE command parameters pertain. A value of 0 is used for parameter values which apply to all notches. Values from 1 to the maximum value depending on the model specify the notch number, where notch 1 is the outermost notch. Following mode parameters are based on the current active notch:

8.22.2 Mode Page 2

- Read Buffer Full Ratio
- Write Buffer Empty Ratio

8.22.2 Mode Page 3

- Alternate Sector per Zone
- Alternate Track per Zone
- Alternate Track per Logical Unit
- Sector per Track
- Track Skew Factor
- Cylinder Skew Factor

8.22.2 Starting Boundary contains the first physical location of the active notch. The first three bytes are the cylinder number and the last byte is the head. The value sent in this field is ignored.

8.22.2 Ending Boundary contains the last physical location of the active notch. The first three bytes are the cylinder number and the last byte is the head. The value sent in this field is ignored.

8.22.2 Pages Notched is a bit map of the mode page codes that indicates which pages contain parameters that may be different for different notches. The most significant bit of this field corresponds to page code 3Fh and the least significant bit corresponds to page code 00h. If a bit is one, then the corresponding mode page contains parameters that may be different for different notches. If a bit is zero, then the corresponding mode page contains parameters that are constant for all notches.

8.11.11 Mode Page 18h

Table 158 Page 18h (Protocol-Specific Logical Unit mode page)

| Byte | Bit | | | | | | | | Default | |
|------|-------------------|-------|---------------------------|---|---|--------------------------|---|---|---------|-----|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |
| 0 | PS=0 | SPF=0 | Page Code = 18h | | | | | | | 18h |
| 1 | Page Length = 06h | | | | | | | | 06h | |
| 2 | Reserved = 0 | | Transport Layer Retries=0 | | | Protocol Identifier = 6h | | | 06h | |
| 3 | Reserved = 0 | | | | | | | | 00h | |
| 4-7 | Reserved = 0 | | | | | | | | 00h | |

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

8.22.2 Transport Layer Retries is unchangeable and set to zero. The drive does not support Transport Layer Retries as defined in T10 Standard SAS Protocol Layer-3 (SPL-3r07).

8.11.12 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.

8.11.12.1 Short Format of Port Control Page

Table 159 Short (Port Control Parameters) Format

| Byte | Bit | | | | | | | | Default |
|-------|-------------------|----------------------------|------------------------------|-------------------|--------------------------|---|---|-------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 19h | | | | | | 99h |
| 1 | Page Length = 0Eh | | | | | | | | 0Eh |
| 2 | Reserved | Continue AWT | Broadcast Asynchronous Event | Ready LED Meaning | Protocol Identifier = 6h | | | | 06h |
| 3 | Reserved = 0 | | | | | | | | 00h |
| 4 | Reserved | RAC=0 | UA_INTLCK_CTRL=0 | SWP=0 | Obsolete | | | | 00h |
| 4-5 | (MSB) | I_T Nexus Loss Timer | | | | | | (LSB) | 07D0h |
| 6-7 | (MSB) | Initiator Response Timeout | | | | | | (LSB) | 07D0h |
| 8-9 | (MSB) | Reject to Open Limit | | | | | | (LSB) | 0000h |
| 10-15 | Reserved = 0 | | | | | | | | 00h |

- The Parameters Savable (PS) bit is set to one, indicating the parameters are savable.
- The **SPF** field shall be set to zero for access to the short format mode page.
- A **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).
- A **BROADCAST ASYNCHRONOUS EVENT** bit set to one specifies that the drive shall enable origination of Broadcast (Asynchronous Event). A BROADCAST ASYNCHRONOUS EVENT bit set to zero specifies that the drive shall disable origination of Broadcast (Asynchronous Event).

8.22.2 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 3 standard.

8.22.2 Protocol Identifier has a value of 6h indicating this is a SAS SSP specific mode page

- The **I_T NEXUS LOSS TIME** field 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** field 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.

- **The REJECT TO OPEN LIMIT** field contains the minimum time in 10 μ s 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.

8.11.12.2 Long Format of Port Control Page

Table 160 Long Format of Port Control Page

| Byte | Bit | | | | | | | | Default |
|------|-----------------------------------|-------------------|-----------------|---|--------------------------|---|---|-------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | SPF=1 | Page Code = 19h | | | | | | 99h |
| 1 | Subpage Code | | | | | | | | ... |
| 2-3 | (MSB) | Page Length (n-3) | | | | | | (LSB) | xxxxh |
| 4 | Reserved = 0 | | | | | | | | 00h |
| 5 | Reserved = 0 | | | | 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.

- The **SPF** field shall be set to one for access to the long format mode page.

8.22.2 Subpage Code indicates which subpage is being accessed. The drive supports 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.

8.11.12.3 PHY Control and Discover (Subpage 1)

Table 161 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 | (MSB) | Page Length = 0064h | | | | | | (LSB) | 0064h |
| 4 | Reserved = 0 | | | | | | | | 00h |
| 5 | Reserved = 0 | | | | 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.
- **The GENERATION CODE field** is a one-byte counter that shall be incremented by one by the drive every time the values in this mode page or the SAS-3 Phy mode page field values are changed. A GENERATION CODE field set to 00h indicates the generation code is unknown. The drive 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** field is set to 2, to represent the dual ported drive (one PHY per port)
- The **SAS PHY Mode Descriptor** Fields are defined in Table 162. There are two SAS PHY Mode Descriptor fields, one per port.

Table 162 SAS PHY Mode Descriptor

| Byte | Bit | | | | | | | |
|-------|----------------------------------------|------------------------|---|--------------------------|-------------------------------------|----------------------------------|---------------------------------|------------------------------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved = 0 | | | | | | | |
| 1 | PHY Identifier | | | | | | | |
| 2-3 | (MSB) Reserved (LSB) | | | | | | | |
| 4 | Reserved | Attached Device Type | | | Attached Reason | | | |
| 5 | Reason | | | | Negotiated Logical Link Rate | | | |
| 6 | Reserved | | | | Attached SSP Initiator Port | Attached STP Initiator Port | Attached SMP Initiator Port | Reserved |
| 7 | Reserved | | | | Attached SSP Target Port | Attached STP Target Port | Attached SMP Target Port | Reserved |
| 8-15 | (MSB) SAS Address (LSB) | | | | | | | |
| 16-23 | (MSB) Attached SAS Address (LSB) | | | | | | | |
| 24 | Attached Phy Identifier | | | | | | | |
| 25 | Attached Persistent Capable | Attached Power Capable | | Attached Slumber Capable | Attached Partial Capable | Attached Inside ZPSDS Persistent | Attached Requested Inside ZPSDS | Attached Break_Reply Capable |
| 26-31 | Reserved = 0 | | | | | | | |
| 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 = 0 | | | | | | | |
| 42-43 | Vendor Specific | | | | | | | |
| 44-47 | Reserved = 0 | | | | | | | |

- **PHY Identifier:** 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.
- **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.
- **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.
- **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.
- **SAS Address:** Unique Port Identifier for the Port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor
- **Hardware Minimum Physical Link Rate:** Minimum link rate supported by the Port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.

- **Hardware Maximum Physical Link Rate:** Maximum link rate supported by the Port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.
- **Programmed Minimum Physical Link Rate:** 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:** Current maximum link rate used during speed negotiation by the Port associated with the PHY Identifier listed in this SAS PHY Mode Descriptor.
- **Attached Persistent Capable** indicates the value of the PERSISTENT CAPABLE field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor. See Table 29.
- **Attached Power Capable** indicates the value of the POWER CAPABLE field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor. See Table 29.
- **Attached Slumber Capable** indicates the value of the SLUMBER CAPABLE field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor. See Table 29.
- **Attached Partial Capable** indicates the value of the PARTIAL CAPABLE field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor. See Table 29.
- **Attached Inside ZPSDS Persistent** indicates the value of the INSIDE ZPSDS PERSISTENT field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor. See Table 29.
- **Attached Requested Inside ZPSDS** indicates the value of the REQUESTED INSIDE ZPSDS field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor. See Table 29.
- **Attached Break_Reply Capable** indicates the value of the BREAK_REPLY CAPABLE field in the last received IDENTIFY address frame associated with the PHY Identifier listed in this SAS PHY Mode Descriptor. See Table 29.

8.11.12.4 Shared Port Control (Subpage 2)

Table 163 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 (MSB) (LSB) | | | | | | | | 000Ch |
| 4 | Reserved = 0 | | | | | | | | 00h |
| 5 | Reserved = 0 | | | | Protocol Identifier = 6h | | | | 06h |
| 6-7 | Power Loss Timeout | | | | | | | | 0000h |
| 8 | Reserved = 0 | | | | | | | | 00h |
| 9 | Power Grant Timeout | | | | | | | | 00h |
| 10 | Reserved = 0 | | | | Port Mode Bitmap | | | | 01h |
| 11 | Port Mode Change Delay | | | | | | | | 00h |
| 12-15 | Reserved = 0 | | | | | | | | |

- **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.
- **Power Grant Timeout** is the minimum time, in one second increments, that the drive shall wait to receive a PWR_GRANT from a power source device. A POWER GRANT TIMEOUT field set to 0000h specifies that the minimum time limit is vendor-specific and defaults to 75 seconds.

- **Port Mode** is a bitmap comprised of the FOURPHYS bit (3), the TWOPHYS bit (2), and the ONEPHY bit (1) which specifies the number of phys per port. Only the default ONEPHY mode is supported.
- **Port Mode Change Delay** specifies the minimum time in seconds that the phys shall be disabled when a bit in the port mode bitmap is changed from 0b to 1b.

8.11.12.5 Enhanced PHY Control Mode Page (Subpage 3)

Table 164 Subpage 3

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

- **The GENERATION CODE field** 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 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 165 PHY Mode Descriptor (0 and 1)

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

- Phy Capabilities are defined under the “SAS Speed Negotiation”

8.11.13 Mode Page 1A (Power Control)

Table 166 Page 1A (Power Control)

| Byte | Bit | | | | | | | | Default |
|-------|---------------------------|--------------|-----------------|--------------|--------|--------|--------|-----------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | SPF=0 | Page Code = 1Ah | | | | | | 9Ah |
| 1 | Page Length = 26h | | | | | | | | 26h |
| 2 | PM_BG_Precedence | Reserved = 0 | | | | | | Standby_Y | 00h |
| 3 | Reserved = 0 | | | | Idle_C | Idle_B | Idle_A | Standby_Z | 06h |
| 4-7 | Idle_A condition Timer | | | | | | | | 14h |
| 8-11 | Standby_Z condition Timer | | | | | | | | 00h |
| 12-15 | Idle_B condition Timer | | | | | | | | 1770h |
| 16-19 | Idle_C condition Timer | | | | | | | | 00h |
| 20-23 | Standby_Y condition Timer | | | | | | | | 00h |
| 24-38 | Reserved = 0 | | | | | | | | 00h |
| 39 | CCF_Idle | CCF_Standby | CCF_Stopped | Reserved = 0 | | | | 58h | |

8.22.2 If the **STANDBY_Y** bit is 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.

8.22.2 If the **IDLE_C** bit is 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.

8.22.2 If the **IDLE_B** bit is 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.

8.22.2 If the **IDLE_A** bit is 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_A condition timer.

8.22.2 If the **STANDBY_Z** bit is 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.

8.22.2 The **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.

8.22.2 The **STANDBY_Z Condition Timer** field 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.

8.22.2 The **IDLE_B Condition Timer** field 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.

8.22.2 The **IDLE_C Condition Timer** field 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.

8.22.2 The **STANDBY_Y Condition Timer** field 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 limit60 timer initiated head unloads per 24-hour period is enforced.

8.22.2 The **PM_BG_PRECEDENCE** field (see Table 167) specifies the interactions between background functions and power management

- 8.22.2 CCF Idle** CHECK CONDITION if from idle, 00b: restricted. 01b: Returning CHECK CONDITION status if transition was from an idle power condition is disabled. 10b: Returning CHECK CONDITION status if transition was from an idle power condition is enable, 11b: reserved.
- 8.22.2 CCF Standby** CHECK CONDITION if standby, 00b: restricted. 01b: Returning CHECK CONDITION status if transition was from a standby power condition is disabled. 10b: Returning CHECK CONDITION status if transition was from a standby power condition is enabled, 11b: reserved
- 8.22.2 CCF Stopped** CHECK CONDITION if stopped, 00b: restricted. 01b: Returning CHECK CONDITION status if transition was from a stopped power condition is disabled. 10b: Returning CHECK CONDITION status if transition was from a stopped power condition is enabled, 11b: reserved

Table 167 PM_BG_PRECEDENCE field

| Code | Vendor Specific |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h | Vendor Specific – Background operations take precedence over maintaining low power conditions (same as 01b) |
| 01b | <p>Performing background functions take precedence over maintaining low power conditions as follows:</p> <ul style="list-style-type: none"> a) if the logical unit is in a low power condition as the result of a power condition timer associated with that condition expiring, then: <ul style="list-style-type: none"> 1) the logical unit shall change from that power condition, if necessary, to the power condition required to perform the background function, when: <ul style="list-style-type: none"> a) a timer associated with a background scan operation expires, and that function is enabled or b) an event occurs to initiate a device specific background function, and that function is enabled; 2) the logical unit shall perform the background function(s) based on the definitions in this specification and other command standards (e.g., if the drive receives a command while performing a background function, then the logical unit shall suspend the function to process the command); 3) if more than one condition is met to initiate a background function, then: <ul style="list-style-type: none"> a) all initiated background functions shall be performed; and b) the order of performing the functions is vendor specific; and 4) when all initiated background functions have been completed, the drive shall check to see if any power condition timers have expired. If any power condition timer has expired, then the logical unit shall change to the power condition associated with the highest priority timer that has expired; <p>or</p> <ul style="list-style-type: none"> b) if the logical unit is performing a background function, and a power condition timer expires, then the logical unit shall perform all initiated background functions before the logical unit changes to a power condition associated with a timer has expired |
| 10b | <p>Maintaining low power conditions take precedence over performing background functions as follows:</p> <ul style="list-style-type: none"> a) if the logical unit is in a low power condition, then the logical unit shall not change from that power condition to perform a background function; b) the drive may perform any initiated and enabled background function based on the definitions in this specification or other command standards, if all the following are true: <ul style="list-style-type: none"> A) a condition is met to initiate a background function; B) that background function is enabled; C) the logical unit changes to a power condition in which the background function may be performed (e.g., the drive processes a medium access command causing the logical unit to change its power condition to continue processing that command); and D) all outstanding application client requests have been completed; <p>or</p> <ul style="list-style-type: none"> c) if the logical unit is performing a background function, and a power condition timer expires that causes a change to a power condition in which the logical unit is unable to continue performing the background function, then the logical unit shall: <ul style="list-style-type: none"> A) suspend the background function; and B) change to the power condition associated with the timer that expired. |
| 11b | Reserved = 0 |

8.11.14 Power Consumption Subpage 01h

Table 168 Power Consumption Subpage

| Byte | Bit | | | | | | | | Default |
|------|------------------------------|-------|-----------------|---|---|--------------|---|---|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | SPF=1 | Page Code = 1Ah | | | | | | DAh |
| 1 | Subpage Code = 1 | | | | | | | | 01h |
| 2-3 | Page Length = 000Ch | | | | | | | | 000Ch |
| 4-5 | Reserved = 0 | | | | | | | | 0000h |
| 6 | Reserved = 0 | | | | | Active Level | | | 00h |
| 7 | Power Consumption Identifier | | | | | | | | 00h |
| 8-15 | Reserved = 0 | | | | | | | | 00h |

The Power Consumption mode page provides a method to set the power consumption level while in the active power condition to:

- a) a relative power consumption level; or
- b) a maximum power consumption level that is based on the contents of the power consumption descriptors in the Power Consumption VPD page.

Active Level: The Active Level field specifies the relative active power consumption level, in any.

Table 169 Active Level field

| Code | Description |
|------|--------------------------------------------------------------------------------------------|
| 00h | The active power consumption level is specified by the POWER CONSUMPTION IDENTIFIER field. |
| 01b | Highest relative active power consumption level |
| 10b | Intermediate relative active power consumption level |
| 11b | Lowest relative active power consumption level |

Power Consumption Identifier: If the Active Level field is set to zero, the Power Consumption Identifier field specifies the power consumption identifier from one of the power consumption descriptors in the Power Consumption VPD page that the device server is to use.

8.11.15 Mode Page 1C (Informational Exceptions Control)

Table 170 Page 1C (Informational Exceptions Control)

| Byte | Bit | | | | | | | | Default |
|------|----------------------------|----------|-----------------|-------|---------------------|------|----------|--------|----------------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | 0 | Page Code = 1Ch | | | | | | 9Ch |
| 1 | Page Length = 0Ah | | | | | | | | 0Ah |
| 2 | PERF | Reserved | EBF | EWASC | DEXCPT | TEST | EBACKERR | LOGERR | 10h |
| 3 | Reserved = 0 | | | | Method of Reporting | | | | 03h |
| 4-7 | (MSB) Interval Timer (LSB) | | | | | | | | 0000h 0000h |
| 8-11 | (MSB) Report Count (LSB) | | | | | | | | 0000h 0000h |

- **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 zero indicates that Temperature Warnings will not be reported. An EWASC bit of one allows Temperature Warnings to be reported, if the temperature inside the disk enclosure exceeds the threshold set in Mode Page 00h. The Method of Reporting field controls the reporting method. EWASC is independent of DEXCPT.
- **DEXCPT** (Disable Exception Control) bit of zero 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 one 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.
- **Enable Background Error (EBACKERR)** bit of zero 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.

Table 171 Method of Reporting Informational Exception Condition

| 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 <i>Check Condition</i> status on any command. The sense key is set to <i>Unit Attention</i> and the additional sense code indicates the cause of the informational exception condition. The command that has the <i>Check Condition</i> 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 <i>Check Condition</i> status on any command. The sense key is set to <i>Recovered Error</i> and the additional sense code indicates the cause of the informational exception condition. The command that has the <i>Check Condition</i> 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 <i>Check Condition</i> status on any command. The sense key is set to <i>Recovered Error</i> and the additional sense code indicates the cause of the informational exception condition. The command that has the <i>Check Condition</i> 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 <i>Check Condition</i> status on any command. The sense key is set to <i>No Sense</i> and the additional sense code indicates the cause of the informational exception condition. The command that has the <i>Check Condition</i> 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 <i>Request Sense</i> command. The sense key is set to <i>No Sense</i> and the additional sense code indicates the cause of the informational exception condition. |
| 7h-Fh | Reserved. |

8.22.2 Interval Timer field 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.

8.22.2 Report Count Field 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.

8.11.15.1 Background Control (Subpage 01h)

Table 172 Background Control (Subpage 01h)

| Byte | Bit | | | | | | | | Default |
|-------|---------------------------------------------------|-------|-----------------|---|---|----------|-------|--------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | PS | SPF=1 | Page Code = 1Ch | | | | | | DCh |
| 1 | Subpage Code = 01h | | | | | | | | 01h |
| 2-3 | Page Length = 000Ch | | | | | | | | 000Ch |
| 4 | Reserved = 0 | | | | | S_L_Full | LOWIR | EN_BMS | 01h |
| 5 | Reserved = 0 | | | | | | | EN_PS | 00h |
| 6-7 | Background Medium Scan Interval Time | | | | | | | | 03F0h |
| 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 = 0 | | | | | | | | 0000h |

8.22.2 Suspend On Log Full (S_L_FULL) bit set to zero allows 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.

8.22.2 Log Only When Intervention Required (LOWIR) bit set to zero 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.

8.22.2 EN_BMS (Enable Background Medium Scan) bit set to zero 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.

8.22.2 EN_PS (Enable Pre-Scan) bit set to zero 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.

8.22.2 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. The drive will limit the value to E904h (59,652 hours or about 6.8 years).

8.22.2 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.

8.22.2 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.

8.22.2 Maximum Time to Suspend Background Scan (Ignored).

8.12 MODE SENSE (10) - (5A)

Table 173 MODE SENSE (10) - (5A)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|-------|-----|--------------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 5Ah | | | | | | | |
| 1 | Reserved = 0 | | | LLBAA | DBD | Reserved = 0 | | |
| 2 | PC | | Page Code | | | | | |
| 3 | Subpage Code | | | | | | | |
| 4-6 | Reserved = 0 | | | | | | | |
| 7-8 | Allocation Length | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |

The MODE SENSE (10) - (5A) command provides a means for the drive to report various device parameters to the initiator. See the MODE SENSE (6) - (1A) command for a description of the fields in this command.

8.22.2 Long LBA Accepted (LLBAA) bit set to zero ensures that if a Block Descriptor is present it must be a Short LBA Block Descriptor. If the LLBAA bit is set to one, the Long LBA Block Descriptor may be used.

8.13 PERSISTENT RESERVE IN (5E)

Table 174 Persistent Reserve In (5E)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|----------------|---|----------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 5Eh | | | | | | | |
| 1 | Reserved = 0 | | | Service Action | | | | |
| 2-6 | Reserved = 0 | | | | | | | |
| 7-8 | Allocation Length | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |

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).

The **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.

8.13.1 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 175 PERSISTENT RESERVE IN, Service Action Codes

| Code | Name | Description |
|---------|---------------------|-------------------------------------------------------------------------------------------|
| 00h | Read Keys | Read all registered Reservation Keys |
| 01h | Read Reservations | Reads all current persistent reservations |
| 02h | Report Capabilities | Returns capabilities information |
| 03h | Read Full Status | Reads complete information about all registrations and the persistent reservation, if any |
| 04h-1Fh | Reserved | Reserved |

8.13.2 Parameter data for Read Keys

Table 176 PERSISTENT RESERVE IN, parameter data for Read Keys

| Byte | Bit | | | | | | | |
|-----------|-------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | (MSB) Generation (LSB) | | | | | | | |
| 4-7 | (MSB) Additional Length = n-7 (LSB) | | | | | | | |
| 8-15 | (MSB) First Reservation Key (LSB) | | | | | | | |
| | : | | | | | | | |
| (n-7) - n | (MSB) Last Reservation Key (LSB) | | | | | | | |

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.

The **Generation** field contains a 32-bit counter that the Target shall increment every time a PERSISTENT RESERVE OUT command requests a Register, a Clear, a Preempt, a Preempt and Abort service, or a Register and Ignore existing key 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.

The **Additional Length** field indicate 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.

The **Reservation Key** list contains the 8-byte reservation keys for all Initiators that have registered through all ports with the Target.

8.13.3 Parameter Data for Read Reservations

Table 177 PERSISTENT RESERVE IN, parameter data for Read Reservations

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

The **Generation** field 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).

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 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.

The format of the **Reservation Descriptors** 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 178 PERSISTENT RESERVE IN, Read Reservation Descriptor

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

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

8.14 PERSISTENT RESERVE OUT (5F)

Table 179 PERSISTENT RESERVE OUT (5F)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|----------------|------|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 5Fh | | | | | | | |
| 1 | Reserved = 0 | | | Service Action | | | | |
| 2 | Scope = 0 | | | | Type | | | |
| 3-6 | Reserved = 0 | | | | | | | |
| 7-8 | Parameter List Length = 18h | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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. Or, 1Ch + Transport ID Param data length (n-27). If not, Check Condition status will be returned, with sense key of Illegal Request and additional sense code of Parameter List Length Error.

8.14.1 Service Action

The following service action codes are supported.

Table 180 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 |

8.14.2 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 181 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 Shared: 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 |

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

8.14.3 Parameter list

The **Parameter List** required to perform the PERSISTENT RESERVE 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 182 Parameter List

| Byte | Bit | | | | | | | | |
|-------|--------------------------------------------|---|---|---|-----------|-----------|----------|-------|--|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0-7 | (MSB) Reservation Key (LSB) | | | | | | | | |
| 8-15 | (MSB) Service Action Reservation Key (LSB) | | | | | | | | |
| 16-19 | (MSB) Reserved = 0 (LSB) | | | | | | | | |
| 20 | Reserved = 0 | | | | SPEC_I_PT | ALL_TG_PT | Reserved | APTPL | |
| 21-23 | Reserved = 0 | | | | | | | | |

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.

If the Specify Initiator Ports (**SPEC_I_PT**) bit is set to zero, the drive 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 183) shall include a list of transport IDs and the drive shall also apply the registration to the I_T nexus for each initiator port specified by a Transport ID. 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.

The All Target Ports (**ALL_TG_PT**) 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. 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, then the device server 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, then the device server shall apply the registration only to the target port through which the PERSISTENT RESERVE OUT command was received. If a device server that does not support an ALL_TG_PT bit set to one receives that value in a REGISTER service action or a REGISTER AND IGNORE EXISTING KEY service action, 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.

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.

APTPL requires the use of persistent flash storage on the device. Excessive-use of this function can result in extensive flash wear, which can lead to product failure. This function should only be used if required and limited to only those situations where it is necessary.

Table 183 PERSISTENT RESERVE OUT specify initiator ports additional parameter data

| Byte | Bit | | | | | | | |
|------|-------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 24 | Transport ID Parameter Data Length = n-27 | | | | | | | |
| ... | | | | | | | | |
| 27 | | | | | | | | |
| | Transport IDs list | | | | | | | |
| 28 | Transport ID [first] | | | | | | | |
| ... | | | | | | | | |
| | ... | | | | | | | |
| | Transport ID [last] | | | | | | | |
| ... | | | | | | | | |
| n | | | | | | | | |

For Transport IDs,

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

8.14.4 Summary

Table 184 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 |

8.14.4.1 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.

8.14.4.2 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.

8.14.4.3 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.

8.14.4.4 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 185 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 |

8.14.4.5 Generation counter

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

8.15 PRE-FETCH (10) - (34)

Table 186 PRE-FETCH (10) - (34)

| Byte | Bit | | | | | | | |
|------|--------------------|-----------------------|--------------|---|---|--------|-----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 34h | | | | | | | |
| 1 | Reserved = 0 | | | | | | Immed = 0 | Obsolete |
| 2-5 | (MSB) | Logical Block Address | | | | | | (LSB) |
| 6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) | Transfer Length | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The PRE-FETCH command requests the drive to transfer data to the cache. No data is transferred to the Initiator.

- **Immed** (Immediate) must be zero. An immediate bit of zero indicates that the status shall not be returned until the operation has completed.

If the Immed bit is set to one, the drive returns a **Check Condition** status. The sense key shall be set to *Illegal Request* and the additional sense code shall be set to *Invalid Field in CDB*.

- The **Logical Block Address** field specifies the LBA of the first logical block accessed by this command.
- The **PREFETCH LENGTH** field specifies the number of contiguous logical blocks that shall be pre-fetched (i.e., transferred to the cache from the medium), starting with the LBA specified by the LOGICAL BLOCK ADDRESS field. A PREFETCH LENGTH field set to zero specifies that all logical blocks starting with the LBA specified in the LOGICAL BLOCK ADDRESS field to the last logical block on the medium shall be pre-fetched. Any other value specifies the number of logical blocks that shall be pre-fetched. If the specified LBA and the specified prefetch length exceed the capacity of the medium, then the device server shall terminate the command with CHECK CONDITION status with the sense key set.
- The **GROUP NUMBER** field specifies the group into which attributes associated with the command should be collected. The GROUP NUMBER field must be set to zero specifying that any attributes associated with the command shall not be collected into any group

8.16 PRE-FETCH (16) - (90)

Table 187 PRE-FETCH (16) - (90)

| Byte | Bit | | | | | | | |
|-------|-----------------------------------|---|------------------|---|---|--------|-----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 90h | | | | | | | |
| 1 | Reserved = 0 | | | | | | Immed = 0 | Reserved |
| 2-9 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 10-13 | (MSB) Pre-Fetch Length (LSB) | | | | | | | |
| 14 | Reserved = 0 | | Group Number = 0 | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The PRE-FETCH command requests the drive to transfer data to the cache. No data is transferred to the Initiator.

- **Immed** (Immediate) must be zero. An immediate bit of zero indicates that the status shall not be returned until the operation has completed.
If the Immed bit is set to one, the drive returns a **Check Condition** status. The sense key shall be set to *Illegal Request* and the additional sense code shall be set to *Invalid Field in CDB*.
- The **Logical Block Address** field specifies the LBA of the first logical block accessed by this command.
- The **PREFETCH LENGTH** field specifies the number of contiguous logical blocks that shall be pre-fetched (i.e., transferred to the cache from the medium), starting with the LBA specified by the LOGICAL BLOCK ADDRESS field. A PREFETCH LENGTH field set to zero specifies that all logical blocks starting with the LBA specified in the LOGICAL BLOCK ADDRESS field to the last logical block on the medium shall be pre-fetched. Any other value specifies the number of logical blocks that shall be pre-fetched. If the specified LBA and the specified prefetch length exceed the capacity of the medium, then the device server shall terminate the command with CHECK CONDITION status with the sense key set.
- The **GROUP NUMBER** field specifies the group into which attributes associated with the command should be collected. The GROUP NUMBER field must be set to zero specifying that any attributes associated with the command shall not be collected into any group.

8.17 READ (6) - (08)

Table 188 READ (6) - (08)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|-------|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 08h | | | | | | | |
| 1 | Reserved = 0 | | | (MSB) | | LBA | | |
| 2-3 | Logical Block Address (LSB) | | | | | | | |
| 4 | Transfer Length | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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** field specifies the logical unit at which the READ operation shall begin.
- **Transfer length** field specifies the number of blocks to be transferred. A value of zero implies 256 blocks are to be transferred.

Note: Error recovery procedure (ERP) handles errors. The error recovery parameters specified by the MODE SELECT command control ERPs. If the drive is formatted with protection information, no protection information will be transmitted or checked.

8.18 READ (10) - (28)

Table 189 READ (10) - (28)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|-----|--------|----------|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 28h | | | | | | | |
| 1 | RDPROTECT | | DPO | FUA | RARC | Obsolete | | |
| 2-5 | (MSB) Logical Block Address | | | | | | | (LSB) |
| 6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Transfer Length | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | NACA=0 | Obsolete | | |

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.

- **RDPROTECT** defines the manner in which protection information read from disk shall be checked during processing of the command. Protection information is stored on disk 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 not transmitted to the initiator and is not checked.

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 READ(32) command only)
- 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 READ(32) command only)
- 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, 110b, 111b, 001b

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.

- **DPO** (Disable Page Out) bit of one indicates that the data accessed by this command is to be assigned the lowest priority for being written into or retained by the cache. A DPO bit of one overrides any retention priority specified in the Mode Select Page 8 Caching Parameters. A DPO bit of zero indicates the priority is determined by the retention priority. The Initiator should set the DPO bit when the blocks read by this command are not likely to be read again in the near future.
- **FUA** (Force Unit Access) bit of one indicates that the data is read from the media and not from the cache. A FUA bit of zero allows the data to be read from either the media or the cache.
- **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** 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.

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.

8.19 READ (12) - (A8)

Table 190 READ (12) - (A8)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|-----|--------|----------|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = A8h | | | | | | | |
| 1 | RDPROTECT | | DPO | FUA | RARC | Obsolete | | |
| 2-5 | (MSB) Logical Block Address | | | | | | | (LSB) |
| 6-9 | (MSB) Transfer Length | | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | NACA=0 | Obsolete | | |

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.

8.20 READ (16) - (88)

Table 191 READ (16) - (88)

| Byte | Bit | | | | | | | | |
|-------|-----------------------------------|------|------------------|-----|-----|--------|----------|------|--|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | Command Code = 88h | | | | | | | | |
| 1 | RDPROTECT | | | DPO | FUA | RARC | Obsolete | DLD2 | |
| 2-9 | (MSB) Logical Block Address (LSB) | | | | | | | | |
| 10-13 | (MSB) Transfer Length (LSB) | | | | | | | | |
| 14 | DLD1 | DLD0 | Group Number = 0 | | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | | |

The READ (16) command causes the drive to transfer data to the initiator. See the READ (10) description for the definitions of RDPROTECT, DPO, FUA, RARC, Logical Block Address, Transfer Length and Group Number.

The duration limit descriptor bits DLD2, DLD1, DLD0 are not defined in table 192.

| Table 192 Duration limit descriptor DLD bits | | | Description |
|----------------------------------------------|------|------|-------------------------------------------------------|
| DLD2 | DLD1 | DLD0 | |
| 0b | 0b | 0b | Command is not a duration limited command (see SAM-6) |
| 0b | 0b | 1b | First command duration limit descriptor |
| 0b | 1b | 0b | Second command duration limit descriptor |
| 0b | 1b | 1b | Third command duration limit descriptor |
| 1b | 0b | 0b | Fourth command duration limit descriptor |
| 1b | 0b | 1b | Fifth command duration limit descriptor |
| 1b | 1b | 0b | Sixth command duration limit descriptor |
| 1b | 1b | 1b | Seventh command duration limit descriptor |

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

Table 193 READ (32) - (7F/09)

| Byte | Bit | | | | | | | |
|-------|-----------------------------|----------------------------------------------|------------------|-----|------|----------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 7Fh | | | | | | | |
| 1 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6 | Reserved = 0 | | Group Number = 0 | | | | | |
| 7 | Additional CDB Length = 18h | | | | | | | |
| 8-9 | Service Action = 0009h | | | | | | | |
| 10 | RDPROTECT | | DPO | FUA | RARC | Obsolete | Reserved | |
| 11 | Reserved = 0 | | | | DLD2 | DLD1 | DLD0 | |
| 12-19 | (MSB) | Logical Block Address | | | | | | (LSB) |
| 20-23 | (MSB) | Expected Initial Logical Block Reference Tag | | | | | | (LSB) |
| 24-25 | (MSB) | Logical Block Application Tag | | | | | | (LSB) |
| 26-27 | (MSB) | Logical Block Application Tag Mask | | | | | | (LSB) |
| 28-31 | (MSB) | Transfer Length | | | | | | (LSB) |

The READ (32) command causes the drive to transfer data to the initiator. See the READ (10) description for the definitions of RDPROTECT, DPO, FUA, RARC, Logical Block Address, Transfer Length and Group Number.

The duration limit descriptor bits DLD2, DLD1, DLD0 are not supported and should be set to 0.

The READ command requests that the drive transfer data from disk 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.

8.22 READ BUFFER (3C)

Table 194 READ BUFFER (3C)

| Byte | Bit | | | | | | | |
|------|-------------------------|---|--------------|------|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 3Ch | | | | | | | |
| 1 | Reserved = 0 | | | Mode | | | | |
| 2 | Buffer ID | | | | | | | |
| 3-5 | (MSB) Buffer Offset | | | | | | | (LSB) |
| 6-8 | (MSB) Allocation Length | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

Table 195 Read Buffer Mode

| 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 |
| 11100 | Error History |
| All others | Not supported |

8.22.1 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 Table 196) is followed by data bytes from the data buffer of the drive.

Table 196 Read Buffer Header

| Byte | Bit | | | | | | | |
|------|-----------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | (MSB) Buffer Capacity (LSB) | | | | | | | |

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.

8.22.2 Get Vendor Unique Log (Mode 00001b)

Table 197 Get Vendor Unique Log Mode Specific field

| Bit | | |
|---------------|-------------|--------------|
| 2 | 1 | 0 |
| BkLenMode = 0 | ReadLog = 1 | Reserved = 0 |

8.22.2.1 WD FACT Log (ID A6h)

Get WDC Field Analytic, Characterization and Telemetry (FACT) Log

- **Mode Specific** field is set to 010b.
- **Buffer ID** field must be set to A6h.
- **Buffer Offset** specifies the log offset and must be in multiple of 512 bytes.
- **Allocation Length** specifies the log offset and must be in multiple of 512 bytes.

Buffer Offset = 0 and Allocation Length = 0x18000 will fetch the entire 96 KB of FACT log data.

Reading beyond the 96KB boundary will result into INVALID field in CDB error.

Table 198 WD FACT Log Structure

| Page | Description |
|------|---------------------------|
| 0 | WDC FACT Log Header – See |
| 1 | General Drive Information |
| 2 | Workload Statistics |
| 3 | Error Statistics |
| 4 | Environmental Statistics |
| 5 | Reliability Statistics |

FACT Log Header Page

The first 16KiB block of the WDC FACT Log contains information about the structure and contents of the following log pages. Additionally, the header contains a unique signature to be used for validity checking. The header structure is defined in.

Table 199 Page 0 : FACT Log Header Structure

| Byte Offset | Data Type | Description |
|-------------|----------------|------------------------------------------|
| 0..7 | Ascii Reversed | Log Signature ("LOGGER" in ASCII) |
| 8..15 | Qword | Log Major Revision = 2 |
| 16..23 | Qword | Log Minor Revision = 4 |
| 24..31 | Qword | Log Sub Revision = 0 |
| 32..39 | Qword | Number of Pages Supported |
| 40..47 | Qword | Log Size in Bytes (Total 96KiB) |
| 48..55 | Qword | Page Size in Bytes (Total 16KiB) |
| 56..63 | Qword | Maximum Drive Heads Supported = 24 heads |
| 64..16383 | Qword | Reserved |

Table 200 FACT Log Page 1-5 Structure

| Byte Offset | Data Type | Description |
|-------------|-----------|-----------------|
| 0..7 | Qword | Log Page Number |
| 8..15 | Qword | Log Copy Number |
| 16..23 | Qword | Field 1 |
| 24..31 | Qword | Field 2 |
| | Qword | |
| N..16383 | Qword | Reserved |

Table 201 FACT Page 1-5 Individual Field Structure

| Byte 7 | Byte 6 | Byte 5 | Byte 4 | Byte 3 | Byte 2 | Byte 1 | Byte 0 |
|-----------------|------------|------------|------------|------------|------------|------------|------------|
| Status Byte See | Field Data | Field Data | Field Data | Field Data | Field Data | Field Data | Field Data |

Table 202 FACT Page 1-5 Status Byte Structure

| Bit | Byte 7 | Byte 6 | Byte 5 | Byte 4 | Byte 3 | Byte 2 | Byte 1 | Byte 0 |
|-------------|-----------------|-------------|------------------------|----------|----------|----------|----------|----------|
| Description | Field Supported | Field Valid | Field Limited lifetime | Reserved | Reserved | Reserved | Reserved | Reserved |

Field Supported : Indicate whether the Field Data is supported in this product.

- 0b : NOT supported.
- 1b : Supported.

Field Valid : Some Field Data needs certain amount of time period to measure. When the amount of time after Power reset does not elapse enough to measure, this field indicates whether it has valid data.

- 0b : It isn't valid at this moment.
- 1b : It is valid.

Field Limited lifetime : Indicate whether the Field Data lifecycle is limited on the since last whole log pull. Means, the counting or measurement will be renewed since last whole log pull.

- 0b : It will NOT be reset at last whole log pull. It would be one of type of fixed value, Life time type data, or valid while power cycle.
- 1b : It will be reset at every last whole log pull. This type of Field Data will NOT be reset at partial log pull. Means that reset will happen only on whole 96KiB log pulled from Log page 0 to 5 with single Host command.

8.22.3 Read Data (Mode 00010b)

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

- **Buffer ID** field must be set to zero, indicating the data transfer buffer. If another value is specified, the results may be unpredictable.
- **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 all available data have been transferred to the Initiator, whichever is less.

8.22.4 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** field should normally be set to zero, indicating the drive data transfer buffer. If any other value is specified, the results may be unpredictable.
- **Buffer Offset** field is reserved.
- **Allocation Length** should be set to four or greater. The drive transfers the allocation length or four bytes of READ BUFFER descriptor, whichever is less. The allocation length of zero indicates no data is transferred. The allocation length of greater than zero and less than four (size of the Descriptor) is an invalid request and 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 described in the table below.

Table 203 Read Buffer Description

| Byte | Bit | | | | | | | |
|------|-----------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Offset Boundary = 0x09 | | | | | | | |
| 1-3 | (MSB) Buffer Capacity (LSB) | | | | | | | |

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.

8.22.5 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.*

8.22.6 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 204 Echo Buffer Descriptor

| Byte | Bit | | | | | | | | |
|------|--------------------------|---|---|-------|---|---|---|-----------------|--|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | Reserved = 0 | | | | | | | EBOS = 0 | |
| 1 | Reserved = 0 | | | | | | | | |
| 2 | Reserved = 0 | | | (MSB) | | | | Buffer Capacity | |
| 3 | Buffer Capacity (LSB) | | | | | | | | |

- **EBOS** (Echo Buffer Overwritten Supported) bit of zero indicates that the echo buffer is shared by all Initiators.
- **Buffer Capacity** field returns the size of the echo buffer in byte aligned to a 4-byte boundary.

8.22.7 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 Section 8.22.5).

8.22.8 Error History (Mode 11100b)

The Buffer ID field specifies the action that the device server shall perform, and the parameter data, if any, that the device server shall return.

Table 205 Error History Buffer ID Field

| Buffer ID Field | Description | Buffer Offset | Error History I_T Nexus Constrained |
|-----------------|--------------------------------------------------------------------------------------------------------------|----------------|-------------------------------------|
| 00h | Return error history directory | 0000h | Yes |
| 01h | Return error history directory and create new error history snapshot | 0000h | Yes |
| 02h | Return error history directory and establish new error history I_T Nexus | 0000h | No |
| 03h | Return error history directory, establish new error history I_T Nexus, and create new error history snapshot | 0000h | No |
| 04h to 0Fh | Reserved | | Yes |
| 10h to EFh | Return error history | 0000h to FFFFh | Yes |
| F0h to FDh | Reserved | | Yes |
| FEh | Clear error history I_T Nexus | Ignored | Yes |
| FFh | Clear error history I_T Nexus and release error history snapshot | Ignored | Yes |

The drive will terminate the Read Buffer command with **Check Condition** status with the sense key set to *Illegal Request* and the additional sense code set to *Operation In Progress* if the drive receives a Read Buffer command:

- with the Mode field set to 1Ch;
- with the Buffer ID field set to a value that is constrained by error history I_T nexus;
- if an error history I_T nexus exists and the command is received from an I_T nexus that is different than that I_T nexus; and
- an error history snapshot exists.

The Buffer Offset field specifies the byte offset from the start of the buffer specified by the Buffer ID field from which the drive will return data. The application client should conform to the offset boundary requirements indicated in the Read Buffer descriptor. If the buffer offset is not one of those shown in the table above or the drive is unable to accept the specified buffer offset, then the drive shall terminate the Read Buffer command with **Check Condition** status, with the sense key set to *Illegal Request*, and the additional sense code set to *Invalid Field In CDB*.

Whenever allowed by established error history I_T nexus constraints, if any, all error history directory device server actions return an error history directory.

Table 206 Error History Directory

| Byte | Bit | | | | | | | |
|-----------|------------------------------------------------------|---|---|---------------|---|------------|---|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-7 | (MSB) T10 Vendor Identification = "WDC"(ASCII) (LSB) | | | | | | | |
| 8 | Version | | | | | | | |
| 9 | Reserved = 0 | | | EHS_Retrieved | | EHS_Source | | CLR_SUP |
| 10-29 | Reserved = 0 | | | | | | | |
| 30-31 | (MSB) Directory Length = n-31 (LSB) | | | | | | | |
| | Error History Directory List | | | | | | | |
| 32-29 | Error History Directory Entry [first] (see) | | | | | | | |
| ... | | | | | | | | |
| (n-7) - n | Error History Directory Entry [last] (see) | | | | | | | |

The error history directory list contains an error history directory entry for each supported buffer ID in the range of 00h to EFh.

8.23 READ CAPACITY (10) - (25)

Table 207 READ CAPACITY (10) - (25)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|---|---|--------|---|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 25h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | Obsolete |
| 2-5 | Obsolete | | | | | | | |
| 6-7 | Reserved = 0 | | | | | | | |
| 8 | Reserved = 0 | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | | Obsolete |

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

8.23.1 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 208 Format of READ CAPACITY command reply

| Byte | Bit | | | | | | | |
|------|-------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | (MSB) Maximum Logical Block Address (LSB) | | | | | | | |
| 4-7 | (MSB) Block Length (LSB) | | | | | | | |

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

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

Table 209 Read Capacity (16) (9E/10)

| Byte | Bit | | | | | | | |
|-------|-------------------------------------|---|--------------|---|----------------------|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 9Eh | | | | | | | |
| 1 | Reserved = 0 | | | | Service Action = 10h | | | |
| 2-9 | Obsolete | | | | | | | |
| 10-13 | (MSB) Allocation Length (LSB) | | | | | | | |
| 14 | Reserved = 0 | | | | | | | Obsolete |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

8.24.1 Returned Data Format

The following data is returned to the initiator in the DATA OUT phase.

Table 210 Returned Data Format

| Byte | Bit | | | | | | | |
|-------|-------------------------------------------|---|---|---|--------------------------------------------|---|---|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-7 | (MSB) Maximum Logical Address (LSB) | | | | | | | |
| 8-11 | (MSB) Block Length (LSB) | | | | | | | |
| 12 | Reserved = 0 | | | | P_Type | | | Prot_EN |
| 13 | P_I_Exponent | | | | Logical Blocks per Physical Block Exponent | | | |
| 14-31 | Reserved = 0 | | | | | | | |

The protection type (P_TYPE) field and the protection enable (PROT_EN) bit indicate the drive's current type of protection.

Table 211 Protection Type (P_TYPE) field

| Prot_EN | P_Type | Description |
|---------|--------|---------------------------------------------|
| 0b | 000b | The drive is formatted to type 0 protection |
| 1b | 000b | The drive is formatted to type 1 protection |
| 1b | 001b | The drive is formatted to type 2 protection |

Table 212 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 |

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

8.25 READ DEFECT DATA (10) - (37)

Table 213 READ DEFECT DATA (10) - (37)

| Byte | Bit | | | | | | | |
|------|-------------------------|---|--------------|-------|--------------------|----------|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 37h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2 | Reserved = 0 | | PList | GList | Defect List Format | | | |
| 3-6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Allocation Length | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | NACA=0 | Obsolete | | |

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 one indicates that the Target returns the PList. A PList bit of zero indicates that the Target shall not return the PList of defects.
- **GList** bit set to one indicates that the Target returns the GList. A GList bit of zero indicates that the Target shall not return the GList.
- **Notes:** When both the PList and GList bits are set to one the Target will return both the primary and grown defect lists. When both bits are set to zero, the Target will return only a 4-byte Defect List Header.
- **Defect List format** field is used by the Initiator to indicate the preferred format for the defect list.
The Defect List Format of '100 (Bytes from Index Format)' and '101 (Physical Sector Format)' are supported. If the requested format is not supported by the drive, it will return the defect list in its default format '101' 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 drive sends defect list (Defect Descriptors) in an 8-byte Absolute Block Address (ABA) format that follows a four-byte Defect List Header.

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

Table 214 Defect List Format

| Preferred Defect List Format | Returned Defect List Format |
|------------------------------|-----------------------------|
| Block (000b) | Physical Sector |
| Bytes from Index (100b) | Bytes from Index |
| Physical Sector (101b) | Physical Sector |
| Vendor Unique (110b) | Physical Sector |
| Reserved (001b) | |
| Reserved (010b) | |
| Reserved (011b) | |
| Reserved (111b) | |

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.

8.25.1 Defect List Header

Table 215 Defect List Header

| Byte | Bit | | | | | | | |
|------|--------------------|--------------------|---|-------|-------|--------------------|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | Defect List Header | | | | | | | |
| 1 | Reserved = 0 | | | PList | GList | Defect List Format | | |
| 2-3 | (MSB) | Defect List Length | | | | | | (LSB) |

The Defect List Format field specifies the format of the defect list data returned by the Target.

The Defect List Length field 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

8.25.2 Defect List Descriptor

Table 216 Defect List Descriptor

| Byte | Bit | | | | | | | |
|-------------|---------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | Defect List Header | | | | | | | |
| 0-7 | Defect Descriptor 0 | | | | | | | |
| 8n - (8n+7) | Defect Descriptor n | | | | | | | |

8.25.3 Bytes from Index Format (100b)

Table 217 Defect Descriptors of Bytes from Index Format

| Byte | Defect Descriptors | |
|------|-----------------------|---------------------------------|
| 0-2 | (MSB) | Cylinder Number of Defect (LSB) |
| 3 | Head Number of Defect | |
| 4-7 | (MSB) | Defect Bytes from Index (LSB) |

Defect Bytes from Index is derived using the following equation:

$$\text{Bytes from Index} = (\text{Physical Sector Number}) * N$$

Where: N = Bytes per sector

8.25.4 Physical Sector Format (101b)

Table 218 Defect Descriptors of Physical Sector Format

| Byte | Defect Descriptors |
|------|---------------------------------------------|
| 0-2 | (MSB) Cylinder Number of Defect (LSB) |
| 3 | Head Number of Defect |
| 4-7 | (MSB) Defective Sector Number (LSB) |

8.26 READ DEFECT DATA (12) - (B7)

Table 219 READ DEFECT DATA (12) - (B7)

| Byte | Bit | | | | | | | |
|------|-------------------------|--------------|---|-------|--------|--------------------|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = B7h | | | | | | | |
| 1 | Reserved = 0 | | | PList | GList | Defect List Format | | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6-9 | (MSB) Allocation Length | | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | Reserved = 0 | | | NACA=0 | Obsolete | | |

See Section 8.25 "READ DEFECT DATA (10) - (37)" for the definitions of fields in this command

8.26.1 Defect List Header

Table 220 Unit Defect List Header

| Byte | Bit | | | | | | | |
|------|--------------------------|---|---|-------|-------|--------------------|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | Defect List Header | | | | | | | |
| 0 | Reserved = 0 | | | | | | | |
| 1 | Reserved = 0 | | | PList | GList | Defect List Format | | |
| 2-3 | Reserved = 0 | | | | | | | |
| 4-7 | (MSB) Defect List length | | | | | | | (LSB) |

See Defect List Header for READ DEFECT DATA (10) - (37) for the definitions of these fields.

8.26.2 Defect List Descriptor

Table 221 Defect List Descriptor

| Byte | Bit | | | | | | | |
|-------------|---------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | Defect List Header | | | | | | | |
| 0-7 | Defect Descriptor 0 | | | | | | | |
| 8n - (8n+7) | Defect Descriptor n | | | | | | | |

See Defect List Descriptor for READ DEFECT DATA (10) - (37) for the definition of these fields.

8.26.3 Bytes from Index Format (100b)

Table 222 Defect Descriptors of Bytes from Index Format

| Byte | Defect Descriptors |
|------|---------------------------------------------|
| 0-2 | (MSB) Cylinder Number of Defect (LSB) |
| 3 | Head Number of Defect |
| 4-7 | (MSB) Defect Bytes from Index (LSB) |

Defect Bytes from Index is derived using the following equation:

$$\text{Bytes from Index} = (\text{Physical Sector Number}) + N$$

where N = Bytes per sector.

8.26.4 Physical Sector Format (101b)

Table 223 Defect Descriptors of Physical Sector Format

| Byte | Defect Descriptors |
|------|---------------------------------------------|
| 0-2 | (MSB) Cylinder Number of Defect (LSB) |
| 3 | Head Number of Defect |
| 4-7 | (MSB) Defective Sector Number (LSB) |

8.27 READ LONG (10) - (3E)

Table 224 READ LONG (10) - (3E)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|---|---|--------|-----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 3Eh | | | | | | | |
| 1 | Reserved = 0 | | | | | PBLOCK | Correct=0 | Obsolete |
| 2-5 | (MSB) Logical Block Address | | | | | | | (LSB) |
| 6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Byte Transfer Length | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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

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 Section 8.24.1) is set to a non-zero value), then:

- a) the device server shall support the physical block (PBLOCK) bit;
- b) a PBLOCK bit set to one specifies that the device server shall return the entire physical block containing the specified logical block; and
- c) a PBLOCK bit set to zero specifies that the device server shall return bytes representing only the specified logical block.

If there are one or more physical blocks per logical block (i.e., the LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field in the READ CAPACITY (16) parameter data (see Section 8.24.1) is set to zero), and the PBLOCK bit is set to one, 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 CDB.

Correct transferred bit of zero causes correction to be attempted, data will be returned without reporting media errors regardless of the drives ability to successfully make corrections. When this bit is set the drive will return media errors if correction is not successful.

- **Logical Block Address** field specifies the logical block at which the read operation shall occur.
- **Byte Transfer Length** field 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.

The transfer length is calculated as follows:

$$\text{transfer length} = \text{logical block size}$$

The data read by this command is neither read from nor retained in the cache. Data returned by this command cannot be corrupted and transferred on a subsequent WRITE LONG command to create recoverable media errors.

8.28 READ LONG (16) - (9E)

Table 225 READ LONG (16) - (9E)

| Byte | Bit | | | | | | | |
|-------|-----------------------------------|---|--------------|---|----------------------|--------|----------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 9Eh | | | | | | | |
| 1 | Reserved = 0 | | | | Service Action = 11h | | | |
| 2-9 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 10-11 | Reserved = 0 | | | | | | | |
| 12-13 | (MSB) Byte Transfer Length (LSB) | | | | | | | |
| 14 | Reserved = 0 | | | | | | PBLOCK | CORRECT |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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

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 Section 8.24.1) is set to a non-zero value), then:

- a) the device server shall support the physical block (PBLOCK) bit;
- b) a PBLOCK bit set to one specifies that the device server shall return the entire physical block containing the specified logical block; and
- c) a PBLOCK bit set to zero specifies that the device server shall return bytes representing only the specified logical block.

If there are one or more physical blocks per logical block (i.e., the LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field in the READ CAPACITY (16) parameter data (see Section 8.24.1) is set to zero), and the PBLOCK bit is set to one, 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 CDB.

- **Correct** transferred bit of zero causes correction to be attempted, data will be returned without reporting media errors regardless of the drives ability to successfully make corrections. When this bit is set the drive will return media errors if correction is not successful.
- **Logical Block Address** field specifies the logical block at which the read operation shall occur.
- **Byte Transfer Length** field 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.

The transfer length is calculated as follows:

$$\text{transfer length} = \text{logical block size}$$

The data read by this command is neither read from nor retained in the cache. Data returned by this command cannot be corrupted and transferred on a subsequent WRITE LONG command to create recoverable media errors.

8.29 REASSIGN BLOCKS (07)

Table 226 REASSIGN BLOCKS (07)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|---|---|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 07h | | | | | | | |
| 1 | Reserved = 0 | | | | | | LONGLBA | Reserved |
| 2-4 | Reserved = 0 | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The REASSIGN BLOCKS command requests the drive to reassign a logical block to an available spare. The REASSIGN BLOCKS command attempts to allocate spare blocks on a spare track. The LBA is transferred to the drive during the DATA OUT phase. One to four blocks may be specified for relocation per REASSIGN BLOCKS command.

Reassignment is complete upon the completion of the REASSIGN BLOCKS command. At this time, the defective logical block address has been added to the GLIST.

All data is preserved during a reassign command except for the target LBA data. The Mode Page 0h DRRT (Disable Restore Reassign Target) bit determines if the reassign blocks command will attempt to recover the Target LBA data. If the Target cannot recover the data at the Target LBA then the Initiator will have to restore the data after the REASSIGN BLOCKS command completes successfully.

If the reassignment begins to move data and is interrupted or fails to complete successfully, the Target enters a degraded mode of operation. In this mode data can be read but writing to the drive is prohibited.

If the REASSIGN BLOCK command is issued to a location that has not yet been written in sequential write required zone ILLEGAL_REQUEST is returned.

Upon successful completion of this command, the location of the physical sectors reassigned during the command are added to the GLIST. The reassigned sectors are marked defective and cannot be accessed again until after a format operation discards the GLIST.

- **LONGLBA** bit of zero indicates that LBAs in the provided defect list are 4-bytes. A LONGLBA bit of one indicates that the LBAs in the provided defect list are 8-bytes

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

Table 227 Format of Reassign Blocks Parameter List data

| Byte | Bit | | | | | | | |
|------|--------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | Reserved = 0 | | | | | | | |
| 2-3 | (MSB) Defect List Length (LSB) | | | | | | | |
| 4-n | Defect LBA List | | | | | | | |

- **Defect List Length** is the total number of bytes in the Defective LBA List (n - 4).
- **Defective LBA List** is a list of Logical Block Addresses to be reassigned. The number of bytes describing each LBA is determined by the LONGLBA field in the command block.

8.30 RECEIVE DIAGNOSTIC RESULTS (1C)

Table 228 RECEIVE DIAGNOSTIC RESULTS (1C)

| Byte | Bit | | | | | | | |
|------|-------------------------|---|--------------|---|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 1Ch | | | | | | | |
| 1 | Reserved = 0 | | | | | | | PCV |
| 2 | Page Code | | | | | | | |
| 3-4 | (MSB) Allocation Length | | | | | | | (LSB) |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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 zero 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.

8.30.1 Receive Diagnostic Results Page 0

This page contains a list of supported pages.

Table 229 Receive Diagnostic Results page 0

| Byte | Bit | | | | | | | |
|------|-----------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Page Code = 00h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2-3 | Page Length = 04h | | | | | | | |
| 4 | (Supported Pages) Page = 0h | | | | | | | |
| 5 | CJTPAT Page = 3Fh | | | | | | | |
| 6 | Translate Address Page = 40h | | | | | | | |
| 7 | Rebuild Assist Support Page = 42h | | | | | | | |

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

8.30.2 Receive Diagnostic Results Page 40

Using the SEND DIAGNOSTIC command, an address in either physical or logical format is supplied to the drive. This page is then used to retrieve the address translated into the other format.

Table 230 Receive Diagnostic Results page 40

| Byte | Bit | | | | | | | |
|------|--------------------------|------|------|--------------|---|------------------|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Page Code = 40h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2-3 | Page Length = 02h or 0Ah | | | | | | | |
| 4 | Reserved = 0 | | | | | Supplier Format | | |
| 5 | RA | ALTS | ALTT | Reserved = 0 | | Translate Format | | |
| 6-13 | Translated Address | | | | | | | |

- **Page Length** is set to 02h if the address is in a Reserved Area (RA =1). Otherwise, Page Length is set to 0Ah.
- **Supplied Format** is the value supplied by the SEND DIAGNOSTIC command; it may be 1of the 3 following values:
 - **000b** Short Block format
 - **011b** Long Block format
 - **100b** Bytes From Index format
 - **101b** Physical Sector format
- **Translate Format** is the value supplied by the SEND DIAGNOSTIC command and specifies the format in which the address has been translated into List. If the Supplied Format is the Short Block or Long Block format, the Translate Format must be either Bytes from Index or Physical Sector format. If the Supplied Format is the Bytes from Index or Physical Sector format, the Translate Format must be Long Block format. Otherwise, the Target will terminate the command with **Check Condition** status.
- **RA (Reserved Area)** is set to one if the translated block is an inaccessible sector, which could reflect a defect, an unused sector on a spare cylinder, or a sector beyond the Maximum Customer LBA.
- **ALTS (Alternate Sector)** is set to one if the translated block is a sector in a spare cylinder that points to a reassigned customer sector.
- **ALTT (Alternate Track)** is not used.
- **Translated Address** contains the address in the Translate Format. For a physical format it is as follows:

Table 231 Translated address

| Byte | Bit | | | | | | | |
|-------|-----------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 6-8 | Cylinder Number | | | | | | | |
| 9 | Head Number | | | | | | | |
| 10-13 | Sector Number of Bytes from Index | | | | | | | |

- The translation for a logical to physical request for an address currently residing in non-volatile cache returns invalid Cylinder, Head and Sector (CHS) information since the address does not currently reside on media.

8.31 RELEASE (6) - (17)

Table 232 RELEASE (6) - (17)

| Byte | Bit | | | | | | | |
|------|----------------------------|---|--------------|----------|--------------------------|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 17h | | | | | | | |
| 1 | Reserved = 0 | | | 3rdPty=0 | 3 rd Party ID | | | EXT=0 |
| 2 | Reservation Identification | | | | | | | |
| 3-4 | Reserved = 0 | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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 currently having reservation active and held by another Initiator. 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.
- **Extents** must be 0. Extension is not supported by the drive.
- **Reservation Identification** field is ignored.

8.32 RELEASE (10) - (57)

Table 233 RELEASE (10) - (57)

| Byte | Bit | | | | | | | |
|------|----------------------------|---|--------------|------------|--------------|--------|----------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 57h | | | | | | | |
| 1 | Reserved = 0 | | | 3rdPty = 0 | Reserved = 0 | | | Ext = 0 |
| 2 | Reservation Identification | | | | | | | |
| 3 | 3rd Party Device ID | | | | | | | |
| 4-8 | Reserved = 0 | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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 currently having reservation active and held by another Initiator. 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.
- **Extent** must be 0. Extension is not supported by the drive.
- **Reservation Identification** field is ignored.

8.33 REMOVE ELEMENT AND TRUNCATE (9E/18)

The REMOVE ELEMENT AND TRUNCATE command requests that the device server depopulate a storage element and truncate the reported capacity of the media.

Table 234 REMOVE ELEMENT AND TRUNCATE (9E/18)

| Byte | Bit | | | | | | | | |
|-------|--------------------------------|---|--------------|---|----------------------|--------|---|----------|--|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | Command Code = 9Eh | | | | | | | | |
| 1 | Reserved | | | | Service Action = 18h | | | | |
| 2-9 | (MSB) Requested Capacity (LSB) | | | | | | | | |
| 10-13 | (MSB) Element Identifier (LSB) | | | | | | | | |
| 14 | Reserved = 0 | | | | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | | Obsolete | |

The REQUESTED CAPACITY field specifies the capacity in logical blocks (i.e., one greater than the number of logical blocks returned by the READ CAPACITY command) of the media upon completion of the command. A value of zero specifies that the device server shall choose the resultant capacity of the media. If the device server is unable to set the capacity of the medium to the specified value, then the device server shall:

- a) not change the capacity of the media; and
- b) 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 CDB.

The ELEMENT IDENTIFIER field specifies the element identifier associated with the storage element to be depopulated. If the ELEMENT IDENTIFIER field specifies a physical element that is not a storage element, (i.e., the PHYSICAL ELEMENT TYPE field is not set to 01h in the corresponding physical element status descriptor) or specifies a physical element not supported by the device, 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 CDB.

If a depopulate operation, a truncate operation, or an initialization initiated by the REMOVE ELEMENT AND TRUNCATE command does not complete successfully, then the logical unit may become format corrupt. Format corrupt shall be cleared by a format operation that completes without error. If the logical unit is format corrupt due to a depopulate operation, a truncate operation, or an initialization initiated by the REMOVE ELEMENT AND TRUNCATE command, then the device server shall terminate any medium access command with CHECK CONDITION status, with the sense key set to MEDIUM ERROR and the additional sense code set to DEPOPULATION FAILED.

If deferred microcode has been saved and not activated, then the device server shall terminate this command with CHECK CONDITION status with the sense key set to NOT READY and the additional sense code set to LOGICAL UNIT NOT READY, MICROCODE ACTIVATION REQUIRED.

If the device server does not support the depopulation of the specified storage element, then the device server shall terminate this command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN CDB.

8.34 REPORT DEVICE IDENTIFIER (A3/05)

Table 235 REPORT DEVICE IDENTIFIER (A3/05)

| Byte | Bit | | | | | | | |
|------|-------------------------|---|--------------|----------------------|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = A3h | | | | | | | |
| 1 | Reserved = 0 | | | Service Action = 05h | | | | |
| 2-3 | Reserved = 0 | | | | | | | |
| 4-5 | (MSB) LUN = 0 | | | | | | | (LSB) |
| 6-9 | (MSB) Allocation Length | | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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

The **LUN** contains the logical unit number parameter. This parameter is expected to be zero. 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.

The **ALLOCATION LENGTH** field 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 236 Report Device Identifier parameter list

| Byte | Bit | | | | | | | |
|------|-------------------------------|---|---|---|---|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | (MSB) Identifier Length = n-3 | | | | | | | (LSB) |
| 4-n | Identifier | | | | | | | |

The IDENTIFIER LENGTH field 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.

The IDENTIFIER field contains a vendor specific value. The value reported is the last value written by a successful SET DEVICE IDENTIFIER command. The value of the identifier is changed only by a SET DEVICE IDENTIFIER command. The identifier value persists through resets, power cycles, 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 drive 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 drive to become ready.

8.35 REPORT LUNS (A0)

Table 237 REPORT LUNS (A0)

| Byte | Bit | | | | | | | | |
|------|-------------------------------|---|--------------|---|---|--------|---|----------|--|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | Command Code = A0h | | | | | | | | |
| 1 | Reserved = 0 | | | | | | | | |
| 2 | Select Report | | | | | | | | |
| 3-5 | Reserved = 0 | | | | | | | | |
| 6-9 | (MSB) Allocation Length (LSB) | | | | | | | | |
| 10 | Reserved = 0 | | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | | 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.

The 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 Request* 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.

Select Report field specifies the types of logical unit addresses that shall be reported.

Table 238 Select Report field

| Code | Description |
|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h | The list shall contain the logical units accessible to the I_T nexus with the following addressing methods (see SAM-6): <ul style="list-style-type: none"> a) simple logical unit addressing method; b) logical unit addressing method; c) peripheral device addressing method; d) flat space addressing method; e) extended flat space addressing method; and f) long extended flat space addressing method. If there are no logical units to report, the LUN LIST LENGTH field shall be set to zero. |
| 01h | The list shall contain only well-known logical units, if any. If there are no well-known logical units, the LUN LIST LENGTH field shall be zero. |
| 02h | The list shall contain all logical units accessible to the I_T nexus. |
| 10h | If the device server processing the command is in LUN 0 or the REPORT LUNS well known logical unit, then the list shall contain only administrative logical units (see SAM-6). The LUN LIST LENGTH field shall be set to zero if the device server processing the command is not in: <ul style="list-style-type: none"> a) LUN 0; or b) the REPORT LUNS well known logical unit. If there are no logical units to report, the LUN LIST LENGTH field shall be set to zero. |
| 11h | If the device server processing the command is in LUN 0 or the REPORT LUNS well known logical unit, then the list shall contain only: <ul style="list-style-type: none"> a) administrative logical units (see SAM-6); b) logical units with the logical unit addressing method at level 1; and c) logical units with single level LUN structure with the following addressing methods (see SAM-6): <ul style="list-style-type: none"> A) peripheral device addressing method; B) flat space addressing method; C) extended flat space addressing method; and D) long extended flat space addressing method. The LUN LIST LENGTH field shall be set to zero if the device server processing the command is not in: <ul style="list-style-type: none"> a) LUN 0; or b) the REPORT LUNS well known logical unit. If there are no logical units to report, the LUN LIST LENGTH field shall be set to zero. |
| 12h | If the device server processing the command is in an administrative logical unit, the list shall contain: <ul style="list-style-type: none"> a) the logical unit processing the command; and b) subsidiary logical units that are contained in the same logical unit conglomerate that contains the logical unit processing the command. The LUN LIST LENGTH field shall be set to zero if the device server processing the command is not in an administrative logical unit. If there are no logical units to report, the LUN LIST LENGTH field shall be set to zero. |

Table 239 LUN Reporting parameter list format

| Byte | Bit | | | | | | | |
|------|-----------------------|---|---|---|---|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | LUN List Length = 08h | | | | | | | (LSB) |
| 4-7 | Reserved = 0 | | | | | | | |
| 8-15 | LUN L = 0 | | | | | | | (LSB) |

The 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.

8.36 REPORT SUPPORTED OPERATION CODES (A3/0C)

Table 240 REPORT SUPPORTED OPERATION CODES (A3/0C)

| Byte | Bit | | | | | | | |
|------|--------------------------|--------------|--------------|---|----------------------|-------------------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = A3h | | | | | | | |
| 1 | Reserved = 0 | | | | Service Action = 0Ch | | | |
| 2 | RCTD | Reserved = 0 | | | | Reporting Options | | |
| 3 | Requested Operation Code | | | | | | | |
| 4-5 | Requested Service Action | | | | | | | |
| 6-9 | Allocation Length | | | | | | | |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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: A return command timeouts descriptor (RCTD) bit set to one specifies that the command timeouts descriptor shall be included in each command descriptor (see Section 8.36.1) that is returned or in the one_command parameter data (see Section 8.36.2) 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 241 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 | 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: a) the operation code specified by the Request Operation Code field specifies an operation code for which the device server does not implement service actions, the Requested Service Action field is set to 00h, and the command is supported; or b) the operation code specified by the Requested Operation Code field specifies an operation code for which the device server implements service actions and the value in the Requested Service Action field is supported, then the command support data shall indicate that the command is supported (i.e., the Support field is set to 011b or 101b). Otherwise, the command support data shall indicate that the command is not supported (i.e., the Support field is set to 001b). |
| 010b-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.

8.36.1 All_command 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-service action operation code).

Table 242 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 243 Command Descriptor format

| Byte | Bit | | | | | | | |
|------|-------------------------------------------------------------|--------|-----|---|------|---|------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Operation Code | | | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2-3 | Service Action | | | | | | | |
| 4 | Reserved = 0 | | | | | | | |
| 5 | Reserved = 0 | RWCDLP | MLU | | CDLP | | CTDP | Servactv |
| 6-7 | CDB Length | | | | | | | |
| 8-19 | Command Timeouts Descriptor, if any (see Section 8.36.3) | | | | | | | |

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.

MLU the multiple logical units supports

Table 244 MLU field description

| Code | Description |
|------|----------------------------------------------------------------------------------------------------|
| 00b | The effect of this command on other logical units is not reported. |
| 01b | This command affects only this logical unit. |
| 10b | This command affects more than one but not all logical units contained in this SCSI target device. |
| 11b | This command affects all of the logical units contained in this SCSI target device. |

RWCDLP the read write command duration limits page bit and

CDLP the command duration limit page fields indicate the mode page, if any that specifies the command duration limited for the command

Table 245 CDLP field

| RWCDL bit | CDLP field | Description |
|-----------------|------------------|-------------------------------------------------------------------|
| 0b | 00b | No command duration limit mode page is indicated for this command |
| 1b | 00b | Reserved |
| 0b ^a | 01b ^a | Command Duration Limit A mode page |
| 0b ^b | 10b ^b | Command Duration Limit B mode page |
| 1b ^c | 01b ^c | Command Duration Limit T2A mode page |
| 1b ^d | 10b ^d | Command Duration Limit T2B mode page |
| 0b or 1b | 11b | Reserved |

^a If this value is returned, the Command Duration Limit A mode page shall be supported.
^b If this value is returned, the Command Duration Limit B mode page shall be supported.
^c If these values are returned, the Command Duration Limit T2A mode page (see 2.11.9.3) shall be supported.
^d If these values are returned, the Command Duration Limit T2A mode page (see 2.11.9.4) shall be supported.

CTDP: A command timeouts descriptor present bit set to one indicates that the command timeouts descriptor (see Section 8.36.3) is included in this command descriptor. A CTDP bit set to zero indicates that the command timeouts descriptor is not included in this command descriptor.

Servactv set to zero indicates the operation code does not have service actions and the Service Action field should be ignored. SERVACTV set to one 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.

8.36.2 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 246 One_command parameter data format

| Byte | Bit | | | | | | | |
|------------|-------------------------------------------------------------|-----|---|------|---|---------|---|--------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved = 0 | | | | | | | RWCDLP |
| 1 | CTDP | MLU | | CDLP | | Support | | |
| 2-3 | CDB Size (n-3) | | | | | | | |
| 4-n | CDB Usage Data | | | | | | | |
| n+1 - n+12 | Command Timeouts Descriptor, if any (see Section 8.36.3) | | | | | | | |

MLU the multiple logical units field is described in [table 244](#)

RWCDLP the read write command duration limits page and

CDLP the command duration limit page fields are described in [table 245](#)

CTDP: A command timeouts descriptor present bit set to one indicates that the command timeouts descriptor is included in this command descriptor (see Section 8.36.3). A CTDP bit set to zero indicates that the command timeouts descriptor is not included in this command descriptor.

The Support field is defined in the table below.

Table 247 One_command parameter support field

| Support | 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. 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.

8.36.3 Command timeouts descriptor format

8.36.3.1 Overview

The command timeouts descriptor (see Table 248) returns time-out 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 drive (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 248 Command timeouts descriptor format

| Byte | Bit | | | | | | | |
|--------|------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 - 1 | Descriptor Length (0Ah) | | | | | | | |
| 2 | Reserved = 0 | | | | | | | |
| 3 | Command Specific | | | | | | | |
| 4- 7 | Nominal Command Processing Timeout | | | | | | | |
| 8 - 11 | Recommended Command Timeout | | | | | | | |

The **DESCRIPTOR LENGTH** field indicates the number of bytes that follow in the command timeouts descriptor.

The **COMMAND SPECIFIC** field contains time-out information (see Table 249) that is specific to one or more commands.

If no command specific time-out information is defined by this or the applicable command standard, the **COMMAND SPECIFIC** field is reserved.

Table 249 Command timeouts descriptor Command Specific Field usage

| Command | Reference |
|--------------|----------------------|
| WRITE BUFFER | See Section 8.36.3.2 |

8.36.3.2 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 mode (06h);
- Download microcode with offsets and save mode (07h);
- Download microcode with offsets and defer activation mode (0Eh) only if the microcode is activated by an event other than an activate deferred microcode mode; and
- Activate deferred microcode mode (0Fh).

If the command timeouts descriptor describes one of the WRITE BUFFER modes listed in this 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.

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

Table 250 Report Supported Task Management Functions (A3/0D)

| Byte | Bit | | | | | | | |
|------|-------------------------|---|--------------|----------------------|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = A3h | | | | | | | |
| 1 | Reserved = 0 | | | Service Action = 0Dh | | | | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6-9 | (MSB) Allocation Length | | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

Table 251 Report Supported Task Management Functions - returned parameter data

| Byte | Bit | | | | | | | |
|------|--------------|------|-------|------|------|------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | ATS | ATSS | CACAS | CTSS | LURS | QTS | Obsolete | |
| 1 | Reserved = 0 | | | | | QAES | QTSS | ITNRS |
| 2-3 | Reserved = 0 | | | | | | | |

ATS (Abort Task) bit set to one indicates that ABORT TASK is supported. An ATS bit of zero indicates that ABORT TASK is not supported.

ATSS (Abort Task Set) bit set to one indicates that ABORT TASK SET is supported. An ATSS bit of zero indicates that ABORT TASK SET is not supported.

CACAS (Clear ACA) bit set to one indicates that CLEAR ACA is supported. A CACAS bit of zero indicates that CLEAR ACA is not supported.

CTSS (Clear Task Set) bit set to one indicates that CLEAR TASK SET is supported. A CTSS bit of zero indicates that CLEAR TASK SET is not supported.

LURS (Logical Unit Reset) bit set to one indicates that LOGICAL UNIT RESET is supported. An LUR bit of zero indicates that LOGICAL UNIT RESET is not supported.

QTS (Query Task) bit set to one indicates that QUERY TASK is supported. A QTS bit of zero indicates that QUERY TASK is not supported.

QAES (Query Asynchronous Event supported) bit set to one indicates the QUERY ASYNCHRONOUS EVENT task management function is supported by the logical unit. A QAES bit set to zero indicates the QUERY ASYNCHRONOUS EVENT task management function is not supported.

QTSS (QUERY TASK SET supported) bit set to one indicates the QUERY TASK SET task management function is supported by the logical unit. A QTSS bit set to zero indicates the QUERY TASK SET task management function is not supported.

ITNRS (I_T NEXUS RESET supported) bit set to one indicates the I_T NEXUS RESET task management function (see SAM-4) is supported by the logical unit. An ITNRS bit set to zero indicates the I_T NEXUS RESET task management function is not supported.

8.38 REPORT TIMESTAMP (A3/0F)

Table 252 REPORT TIMESTAMP (A3/0F)

| Byte | Bit | | | | | | | |
|------|-------------------------|---|--------------|----------------------|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = A3h | | | | | | | |
| 1 | Reserved = 0 | | | Service Action = 0Fh | | | | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6-9 | (MSB) Allocation Length | | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The **REPORT TIMESTAMP** command requests the drive return the current value of a device clock.

Table 253 Report Timestamp parameter list

| Byte | Bit | | | | | | | |
|------|-----------------------------------------------|---|---|---|------------------|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | (MSB) Timestamp Parameter Data Length = 000Ah | | | | | | | (LSB) |
| 2 | Reserved = 0 | | | | Timestamp Origin | | | |
| 3 | Reserved = 0 | | | | | | | |
| 4-9 | (MSB) Timestamp | | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | Reserved = 0 | | | | | | | |

The **TIMESTAMP PARAMETER DATA LENGTH** field indicates the number of bytes of parameter data that follow. The contents of the **TIMESTAMP PARAMETER DATA LENGTH** field are not altered based on the allocation length.

The **TIMESTAMP ORIGIN** field indicates the most recent event that initialized the returned device clock.

The **TIMESTAMP** field contains the current value of a device clock.

8.39 REQUEST SENSE (03)

Table 254 REQUEST SENSE (03)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|---|---|--------|----------|------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 03h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | DESC |
| 2-3 | Reserved = 0 | | | | | | | |
| 4 | Allocation Length | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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

The Descriptor Format (DESC) bit specifies which sense data format the device shall return in the parameter data. The Allocation Length specifies the maximum number of bytes of sense data that the drive should return. Such relationship is shown in the table below. (See Table 248 for more details).

Table 255 Sense Data Format and Length

| DESC Bit | Sense Data Format | Length of Sense Data Returned |
|----------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0b | Fixed Format | The number of bytes in the Allocation Length or 32 bytes, whichever is less |
| 1b | Descriptor Format | The number of bytes in the Allocation Length or a fixed "descriptor sense data size", whichever is less. The "descriptor sense data size" is either 40 or 60 bytes, depending on the drive firmware build. |

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 will 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.

8.40 RESERVE (6) - (16)

Table 256 RESERVE (6) - (16)

| Byte | Bit | | | | | | | |
|------|------------------------------|---|--------------|------------|--------------------------|--------|----------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 16h | | | | | | | |
| 1 | Reserved = 0 | | | 3rdPty = 0 | 3 rd Party ID | | | Ext = 0 |
| 2 | Reservation Identification | | | | | | | |
| 3-4 | (MSB) Extent List Length = 0 | | | | | | | (LSB) |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The RESERVE command is used to reserve a LUN for an Initiator. This reservation is for the Initiator sending the command.

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

- 8.22.2 the reservation is superseded by another valid Reserve command from the Initiator that made the reservation.
- 8.22.2 the reservation is released by a RELEASE command from the same Initiator.
- 8.22.2 a hard Reset condition occurs.
- 8.22.2 a Target Reset message is received from any Initiator.
- 8.22.2 a power off/on cycle occurs.

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.

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.

8.41 RESERVE (10) - (56)

Table 257 RESERVE (10) - (56)

| Byte | Bit | | | | | | | |
|------|------------------------------|---|--------------|------------|--------------|--------|----------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 56h | | | | | | | |
| 1 | Reserved = 0 | | | 3rdPty = 0 | Reserved = 0 | | | Ext = 0 |
| 2 | Reservation Identification | | | | | | | |
| 3 | Third Party Device ID | | | | | | | |
| 4-6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Extent List Length = 0 | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The RESERVE command is used to reserve a LUN for an Initiator. This reservation is for the Initiator sending the command.

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

- 8.22.2 the reservation is superseded by another valid Reserve command from the Initiator that made the reservation.
- 8.22.2 the reservation is released by a RELEASE command from the same Initiator.
- 8.22.2 a hard Reset condition occurs.
- 8.22.2 a Target Reset message is received from any Initiator.
- 8.22.2 a power off/on cycle occurs.

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*.

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.

8.42 RESTORE ELEMENTS AND REBUILD (9E/19)

Table 258 RESTORE ELEMENTS AND REDUILD (9E/19)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|----------------------|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 9Eh | | | | | | | |
| 1 | Reserved = 0 | | | Service Action = 19h | | | | |
| 2-14 | Reserved = 0 | | | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The RESTORE ELEMENTS AND REBUILD command requests that the device server perform a storage element restoration.

If deferred microcode has been saved and not activated (see SPC-6), then the device server shall terminate this command with CHECK CONDITION status with the sense key set to NOT READY and the additional sense code set to LOGICAL UNIT NOT READY, MICROCODE ACTIVATION REQUIRED.

For a RESTORE ELEMENTS AND REBUILD command, 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 COMMAND SEQUENCE ERROR if:

- a) there is at least one depopulated storage element (e.g., the PHYSICAL ELEMENT HEALTH field is set to FFh); and
- b) all depopulated storage elements have the RALWD bit (see Section 8.5.1.1) set to zero.

For a RESTORE ELEMENTS AND REBUILD command, the following shall not be considered an error:

- a) the device has no depopulated storage elements; or
- b) at least one depopulated storage element has the RALWD bit (see Section 8.5.1.1) set to one.

8.43 REZERO UNIT (01)

Table 259 REZERO UNIT (01)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|---|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 01h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2-4 | Reserved = 0 | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The REZERO UNIT command requests that the Target seek to LBA 0.

8.44 SANITIZE (48)

Table 260 SANITIZE (48)

| Byte | Bit | | | | | | | |
|------|---------------------------|----------|--------------|----------------|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 48h | | | | | | | |
| 1 | Immed | Reserved | AUSE | Service Action | | | | |
| 2-6 | Reserved = 0 | | | | | | | |
| 7-8 | Parameter List Length = 0 | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

- **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.

8.44.1 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 261 SANITIZE Service Action Codes

| Code | Name | Descriptions |
|---------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| 00h | Reserved | Returns Check Condition |
| 01h | Overwrite | Causes the drive to alter information by writing a data pattern to the medium one or more times |
| 02h | Reserved | Returns Check Condition |
| 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. |

Table 262 Parameter List Format for Overwrite Service Action

| Byte | Bit | | | | | | | |
|------|-------------------------------------------|------|---|-----------------|---|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Invert | Test | | Overwrite Count | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2-3 | (MSB) Initialization Pattern Length = n-3 | | | | | | | (LSB) |
| 4 | Initialization Pattern | | | | | | | |
| ... | | | | | | | | |
| n | | | | | | | | |

- **Invert** bit set to zero indicates that the initialization pattern and protection information bytes, if any, are written as specified in the Initialization Pattern field on each overwrite pass. If the Invert bit is set to one, then the initialization pattern and protection information bytes, if any, shall be inverted (i.e., each bit XORed with one) between consecutive overwrite passes.
- **Overwrite Count** field specifies the number of overwrite passes to be performed. The value of 00h is reserved.
- **Initialization Pattern Length** field specifies the length in bytes of the Initialization Pattern field. The Initialization Pattern Length field shall be greater than zero and shall not exceed the logical block length. If the Initialization Pattern Length field is set to zero or a value greater than the logical block length, then the drive 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.
- **Initialization Pattern field** specifies the data pattern to be used to write the user data. This data pattern is repeated as necessary to fill each logical block. For each logical block, the first byte of the user data shall begin with the first byte of the initialization pattern. The protection information, if any, shall be set to FFFF_FFFF_FFFF_FFFFh

8.45 SECURITY PROTOCOL IN (A2)

Table 263 SECURITY PROTOCOL IN (A2)

| Byte | Bit | | | | | | | |
|------|----------------------------|-------------------|--------------|---|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = A2h | | | | | | | |
| 1 | Security Protocol | | | | | | | |
| 2-3 | Security Protocol Specific | | | | | | | |
| 4 | INC_512 | Reserved = 0 | | | | | | |
| 5 | Reserved = 0 | | | | | | | |
| 6-9 | (MSB) | Allocation Length | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The SECURITY PROTOCOL IN command requests the device server to return security protocol information or the results of one or more SECURITY PROTOCOL OUT commands.

The SECURITY PROTOCOL field specifies which security protocol is being used.

Table 264 SECURITY PROTOCOL field in SECURITY PROTOCOL IN command

| Code | Description |
|------------|-------------------------------|
| 00h | Security Protocol Information |
| 01h to 06h | Defined by TCG |
| 07h to FFh | Reserved |

The contents of the SECURITY PROTOCOL SPECIFIC field are defined by the protocol specified by the SECURITY PROTOCOL field (see Table 264).

A 512 increment (INC_512) bit set to one specifies that the ALLOCATION LENGTH field expresses the maximum number of bytes available to receive data in increments of 512 bytes (e.g., a value of one means 512 bytes, two means 1024 bytes, etc.). Pad bytes may or may not be appended to meet this length. Pad bytes shall have a value of 00h. An INC_512 bit set to zero specifies that the ALLOCATION LENGTH field expresses the maximum number of bytes available to receive data in increments of one byte.

Indications of data overrun or underrun and the mechanism, if any, for processing retries are defined by the protocol specified by the SECURITY PROTOCOL field (see Table 264).

Any association between a previous SECURITY PROTOCOL OUT command and the data transferred by a SECURITY PROTOCOL IN command depends on the protocol specified by the SECURITY PROTOCOL field (see Table 264). If the device server has no data to transfer (e.g., the results for any previous SECURITY PROTOCOL OUT commands are not yet available), then the device server may transfer data indicating it has no other data to transfer.

The format of the data transferred depends on the protocol specified by the SECURITY PROTOCOL field (see Table 264).

The device server shall retain data resulting from a SECURITY PROTOCOL OUT command, if any, until one of the following events is processed:

- transfer of the data via a SECURITY PROTOCOL IN command from the same I_T_L nexus as defined by the protocol specified by the SECURITY PROTOCOL field (see Table 264);
- Logical unit reset (see SAM-6); or
- I_T nexus loss (see SAM-6) associated with the I_T nexus that sent the SECURITY PROTOCOL OUT command

8.46 SECURITY PROTOCOL OUT (B5)

Table 265 SECURITY PROTOCOL OUT (B5)

| Byte | Bit | | | | | | | |
|------|----------------------------|--------------|--------------|---|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = B5h | | | | | | | |
| 1 | Security Protocol | | | | | | | |
| 2-3 | Security Protocol Specific | | | | | | | |
| 4 | INC_512 | Reserved = 0 | | | | | | |
| 5 | Reserved = 0 | | | | | | | |
| 6-9 | (MSB) Transfer Length | | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The SECURITY PROTOCOL OUT command (see Table 265) requests the device server to process the specified parameter list using the specified security protocol. Depending on the protocol specified by the SECURITY PROTOCOL field, the application client may use the SECURITY PROTOCOL IN command (see 263) to retrieve data that results from the processing of one or more SECURITY PROTOCOL OUT commands.

The SECURITY PROTOCOL field specifies which security protocol is being used.

Table 266 SECURITY PROTOCOL field in SECURITY PROTOCOL OUT command

| Code | Description |
|------------|----------------|
| 00h | Reserved |
| 01h to 06h | Defined by TCG |
| 07h to FFh | Reserved |

The contents of the SECURITY PROTOCOL SPECIFIC field are defined by the protocol specified by the SECURITY PROTOCOL field (see Table 264).

A 512 increment (INC_512) bit set to one specifies that the ALLOCATION LENGTH field expresses the number of bytes to be transferred in increments of 512 bytes (e.g., a value of one means 512 bytes, two means 1024 bytes, etc.). Pad bytes shall be appended as needed to meet this requirement. Pad bytes shall have a value of 00h.

An INC_512 bit set to zero specifies that the TRANSFER LENGTH field indicates the number of bytes to be transferred.

Any association between a SECURITY PROTOCOL OUT command and a subsequent SECURITY PROTOCOL IN command is defined by the protocol specified by the SECURITY PROTOCOL field (see Table 266). Each protocol shall define whether:

- the device server shall complete the command with GOOD status as soon as it determines the data has been correctly received. An indication that the data has been processed is obtained by sending a SECURITY PROTOCOL IN command and receiving the results in the associated data transfer; or
- the device server shall complete the command with GOOD status only after the data has been successfully processed and an associated SECURITY PROTOCOL IN command is not required.

The format of the data transferred depends on the protocol specified by the SECURITY PROTOCOL field (see Table 266).

8.47 SEND DIAGNOSTIC (1D)

Table 267 SEND DIAGNOSTIC (1D)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|----|----------|--------|----------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 1Dh | | | | | | | |
| 1 | Function Code | | | PF | Reserved | Siftst | DevOffl | UntOffl |
| 2 | Reserved = 0 | | | | | | | |
| 3-4 | (MSB) Parameter List Length | | | | | | | (LSB) |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

8.22.2 PF (Page Format) bit set to one 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 Siftst bit is set.

8.22.2 Siftst set to one indicates that the device performs its default self-test. If Siftst is one, the Function code field is ignored. If Siftst is set to zero, the action to perform is specified in Function code field.

8.22.2 DevOffl is ignored by the Target for compatibility.

8.22.2 UntOffl is ignored by the Target for compatibility.

8.22.2 Parameter List Length must be 0 when the Siftst 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 Siftst 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*.

Table 268 SEND DIAGNOSTIC Function Code (1D)

| Value | Function name | Description |
|-------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 000b | NA | Value to be used when the Siftst 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 drive starts its short self-test routine in background mode. |
| 010b | Background extended self-test | The drive 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 drive 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 drive 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 8.11.9 "Mode Page 0A (Control Mode Page Parameters)"). |
| 111b | Reserved. | |

If the motor is not running at the correct speed when the command is received, it is rejected by a **Check Condition** status with a *Not Ready* sense key.

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 10.11 Diagnostics for a detailed listing of operations carried out by the SEND DIAGNOSTIC command and Power on Diagnostics.

8.47.1 Send Diagnostic Page 0

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

Table 269 Diagnostic page 0

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

8.47.2 Send Diagnostic Page 3F

Table 270 Diagnostic page 3F

| Byte | Bit | | | | | | | |
|-------|---------------------------------|------------------------------|----------------------|---|-------------------------------------|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Page Code = 3Fh | | | | | | | |
| 1 | Reserved = 0 | | | | Protocol Identifier = 6h | | | |
| 2-3 | Page Length = 1Ch | | | | | | | |
| 4 | Phy Identifier | | | | | | | |
| 5 | Phy Test Function | | | | | | | |
| 6 | Phy Test Pattern | | | | | | | |
| 7 | Reserved | Phy Test Pattern SATA = 0 | Phy Test Pattern SSC | | Phy Test pattern Physical Link Rate | | | |
| 8-10 | Reserved = 0 | | | | | | | |
| 11 | Phy Test Pattern Dwords Control | | | | | | | |
| 12-19 | Phy Test Pattern Dwords | | | | | | | |
| 20-31 | Reserved = 0 | | | | | | | |

8.22.2 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.

8.22.2 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.

Table 271 Phy Test Function

| Phy Test Function | Description |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h | If the selected phy is performing a phy-test function, then the selected phy stop performing the phy test function and originate a link reset sequence. If the selected phy is not performing a phy test function, then this function as no effect on the selected phy. |
| 01h | If the selected phy is not performing a phy test function, the selected phy will be set to transmit the phy test pattern specified by the Phy Test Pattern field at the physical link rate specified by the Phy Test Pattern Physical |
| 02h - FFh | Not Supported |

8.22.2 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.

Table 272 Phy Test Pattern

| Phy Test Pattern | Description |
|------------------|--------------------------------|
| 00h | Reserved |
| 01h | JTPAT |
| 02h | CJTPAT |
| 03h-0Fh | Reserved |
| 10h | TRAIN |
| 11h | TRAIN_DONE |
| 12h | IDLE |
| 13h | SCRAMBLE_0 |
| 14h - 3Fh | Reserved |
| 40h | TWO_DWORDS |
| 41h – EFh | Reserved |
| F0h | PRBS7 (DC un-balanced version) |
| F1h-FFh | Reserved |

8.22.2 Phy Test Pattern Physical Link Rate specifies the physical link rate at which the phy test pattern shall be transmitted. Supported values are 8h for 1.5 Gbps, 9h for 3.0 Gbps, Ah for 6.0 Gbps and Bh for 12Gbps. 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.

8.22.2 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

8.22.2 Phy Test Pattern SSC field 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.

Table 273 Phy Test Pattern SSC Code

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

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

Table 274 Phy Test Pattern Dwords Control

| Phy Test Pattern Dwords Control | Description |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h | Each byte in the Phy Test Pattern Dwords field shall be sent as a data character (i.e., Dxx.y) without 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 without 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 without 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 without scrambling. |
| All others | Reserved |

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

8.47.3 Send Diagnostic Page 40

This allows the Initiator to translate a LBA or physical sector address to the other format. The address to be translated is passed to the Target with the SEND DIAGNOSTIC command and the results are returned to the Initiator by the RECEIVE DIAGNOSTICS command. The Target will read the parameter list from the Initiator, and, if no errors are detected in the parameter list, **Good** status will be returned. The data translation will be performed upon receipt of the RECEIVE DIAGNOSTICS command.

Table 275 Diagnostic Page 40

| Byte | Bit | | | | | | | |
|-------|----------------------|---|---|---|------------------|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Page Code = 40h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2 - 3 | Page Length = 0Ah | | | | | | | |
| 4 | Reserved = 0 | | | | Supplied Format | | | |
| 5 | Reserved = 0 | | | | Translate Format | | | |
| 6-13 | Address to Translate | | | | | | | |

Supplied Format may take one of the following three values:

Table 276 Supplied Format

| | |
|-------------|-------------------------|
| 000b | Short Block format |
| 011b | Long Block format |
| 100b | Bytes From Index format |
| 101b | Physical Sector format |

It specifies the format in which the address has been supplied.

- **Translate Format** specifies the format that the address should be translated into. If the Supplied Format is the Short Block format or Long Block format, the Translate format must be either Bytes From Index or Physical Sector format. If the Supplied Format is the Bytes From Index or Physical Sector format, the Translate Format must be Long Block format. If either of the format fields is invalid or they specify the same format, the command will terminate with **Check Condition** status with a sense code of *Illegal Request* and *Illegal Field in Parameter List*.
- **Address to Translate** contains the address to translate. If the Short Block format is specified, the first four bytes of the field (bytes 6 to 9) contain the LBA and the remainder must be zero. If the Long Block format is specified, byte 6 to 13 contain the 64-bit LBA. For the physical format the address must be specified as follows.

Table 277 Address to translate

| Byte | Bit | | | | | | | |
|-------|-----------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 6-8 | Cylinder Number | | | | | | | |
| 9 | Head Number | | | | | | | |
| 10-13 | Sector Number or Bytes from Index | | | | | | | |

8.48 SET DEVICE IDENTIFIER (A4/06)

Table 278 SET DEVICE IDENTIFIER (A4/06)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|----------------------|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = A4h | | | | | | | |
| 1 | Reserved = 0 | | | Service Action = 06h | | | | |
| 2 | Reserved = 0 | | | | | | | |
| 3 | Reserved = 0 | | | | | | | |
| 4-5 | Restricted = 0 | | | | | | | |
| 6-9 | (MSB) Parameter List Length | | | | | | | (LSB) |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | 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*.

8.22.2 Parameter List Length field 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 279 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.

8.49 SET TIMESTAMP (A4/0F)

Table 280 SET TIMESTAMP (A4/0F)

| Byte | Bit | | | | | | | |
|------|-----------------------------------|---|--------------|----------------------|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = A4h | | | | | | | |
| 1 | Reserved = 0 | | | Service Action = 0Fh | | | | |
| 2-3 | Reserved = 0 | | | | | | | |
| 4-5 | Restricted = 0 | | | | | | | |
| 6-9 | (MSB) Parameter List Length (LSB) | | | | | | | |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The SET TIMESTAMP command requests the device server to initialize a device clock if the SCSIP bit is set to one in the Control Extension mode page (see Section 8.11.9.1). If the SCSIP bit is set to zero, the device server shall terminate the SET TIMESTAMP command with CHECK CONDITION status, with the sense key set to ILLEGAL REQUEST, and the additional sense code set to INVALID FIELD IN CDB.

The PARAMETER LIST LENGTH field specifies the length in bytes of the SET TIMESTAMP parameters that shall be transferred from the application client to the device server. A parameter list length of zero specifies that no data shall be transferred, and that no change shall be made to a device clock.

8.50 START STOP UNIT (1B)

Table 281 START STOP UNIT (1B)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|---|--------------------------|----------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 1Bh | | | | | | | |
| 1 | Reserved = 0 | | | | | | | Immed |
| 2 | Reserved = 0 | | | | | | | |
| 3 | Reserved = 0 | | | | Power Condition Modifier | | | |
| 4 | Power Condition | | | | Reserved | No_Flush | LoEj = 0 | Start |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The START STOP UNIT command is used to spin up or stop the spindle motor.

8.22.2 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 after a spin-up.

8.22.2 Power Conditions and Power Condition Modifier fields are used to specify that the logical unit be placed into a power condition or to adjust a timer as defined in Table 282, if this field is set to a value other than 0h, then the START bit shall be ignored.

Table 282 Power Conditions

| Power Condition Code | Name | Power Condition Modifier | Description |
|----------------------|-----------------|--------------------------|----------------------------------------------------------|
| 0h | START_VALID | 0h | Process the START bit |
| 1h | ACTIVE | 0h | Place the device into the active power condition |
| 2h | IDLE_A | 0h | Place the device into the idle-a power condition |
| 2h | IDLE_B | 1h | Place the device into the idle-b power condition |
| 2h | IDLE_C | 2h | Place the device into the idle-c power condition |
| 3h | STANDBY_Z | 0h | Place the device into the standby_Z power condition |
| 3h | STANDBY_Y | 1h | Place the device into the standby_Y power condition |
| 4h | Reserved | 0h | Reserved |
| 5h | Obsolete | 0h-Fh | Obsolete |
| 6h | Reserved | 0h | Reserved |
| 7h | LU_CONTROL | 0h | Transfer control of power conditions to the logical unit |
| 8h - 9h | Reserved | 0h | Reserved |
| Ah | FORCE_IDLE_A | 0h | Force the idle_a condition timer to zero. |
| Ah | FORCE_IDLE_B | 1h | Force the idle_b condition timer to zero. |
| Ah | FORCE_IDLE_C | 2h | Force the idle_c condition timer to zero. |
| Bh | FORCE_STANDBY_Z | 0h | Force the standby_z condition timer to zero. |
| Bh | FORCE_STANDBY_Y | 1h | Force the standby_y condition timer to zero. |
| all Others | Reserved | 0h | Reserved |

If the START STOP UNIT command is processed with the POWER CONDITION field set to ACTIVE, IDLE, or STANDBY, then:

- a) the logical unit shall transition to the specified power condition; and
- b) the drive shall disable the idle condition timer if it is active and disable the standby condition timer if it is active until another START STOP UNIT command is processed that returns control of the power condition to the logical unit, or a logical unit reset occurs.
- c) if under initiator control, the two-minute floor and 60 head unloads per 24-hour period limits do not apply as they do when under logical unit/timer control

If the START STOP UNIT command is processed with the POWER CONDITION field set to LU_CONTROL, then the drive shall initialize and start all idle condition timers and standby condition timers that are supported and enabled.

If the START STOP UNIT command is processed with the POWER CONDITION field set to LU_CONTROL, then the drive shall enable the idle condition timer if it is active and disable the standby condition timer if it is active.

If the START STOP UNIT command is processed with the POWER CONDITION field set to FORCE_IDLE_0 or FORCE_STANDBY_0, then the drive shall:

- a) force the specified timer to zero, cause the logical unit to transition to the specified power condition, and return control of the power condition to the drive; or
- b) terminate a START STOP UNIT command that selects a timer that is not supported by the drive or a timer that is not active. The drive 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 CDB.

It is not an error to specify that the logical unit transition to its current power condition. See Section 8.11.13 for more information on idle and standby power conditions.

8.22.2 LoEj is not supported by the drive and must be set to 0.

8.22.2 Start bit set to 0 specifies stop the spindle, set to 1 specifies start the spindle.

Note: *Once the drive has become ready (after a power on), the START STOP UNIT command can be used without any errors regardless of the state of the motor: stopped or spinning.*

8.51 SYNCHRONIZE CACHE (10) - (35)

Table 283 SYNCHRONIZE CACHE (10) - (35)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|---|---|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 35h | | | | | | | |
| 1 | Reserved = 0 | | | | | | Immed | Obsolete |
| 2-5 | (MSB) Logical Block Address | | | | | | | (LSB) |
| 6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Number of Blocks | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The SYNCHRONIZE CACHE command ensures that logical blocks in the cache have their most recent data value recorded on the media.

8.22.2 Logical Block Address is to specify where the operation is to begin.

8.22.2 Immed (immediate) must be zero. An immediate bit of zero indicates that the status shall not be returned until the operation has completed. If the Immed bit is set to one, the drive returns a **Check Condition** status.

The sense key shall be set to *Illegal Request* and the additional sense code shall be set to *Invalid Field in CDB*.

8.22.2 Number of Blocks specifies the total number of contiguous logical blocks within the range. Number of Blocks of zero indicates that all remaining logical blocks on the logical unit shall be within the range.

8.52 SYNCHRONIZE CACHE (16) - (91)

Table 284 SYNCHRONIZE CACHE (16) - (91)

| Byte | Bit | | | | | | | |
|-------|-----------------------------------|---|--------------|---|---|----------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 91h | | | | | | | |
| 1 | Reserved = 0 | | | | | Obsolete | Immed | Reserved |
| 2-9 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 10-13 | (MSB) Number of Blocks (LSB) | | | | | | | |
| 14 | Reserved = 0 | | | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

The SYNCHRONIZE CACHE command ensures that logical blocks in the cache have their most recent data value recorded on the media. See the SYNCHRONIZE CACHE (10) description for definitions of the fields in this command.

8.53 TEST UNIT READY (00)

Table 285 TEST UNIT READY (00)

| Byte | Bit | | | | | | | |
|------|--------------------|---|--------------|---|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 00h | | | | | | | |
| 1-4 | Reserved = 0 | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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 first verify that the motor is spinning at the correct speed. If the spindle motor is not spinning at the correct speed, **Check Condition** status is returned with sense key of *Not Ready*. If the motor is spinning at the correct speed, the drive accepts normal 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 before the completion of motor spin-up and expects the initiator to issue TEST UNIT READY commands to determine when the motor has reached the proper speed.

Note: *The spindle automatically starts in automatic spin-up mode. The drive does not execute any commands other than TEST UNIT READY, 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.*

8.54 VERIFY (10) - (2F)

Table 286 VERIFY (10) - (2F)

| Byte | Bit | | | | | | | |
|------|--------------------------------|---|--------------|-----|----------|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 2Fh | | | | | | | |
| 1 | VRPROTECT | | | DPO | Reserved | BytChk | | Obsolete |
| 2-5 | (MSB) Logical Block Address | | | | | | | (LSB) |
| 6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Verification Length | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

Table 287 BytChk

| BytChk | Function |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00b | Indicates that the data is read from the disk and verified using LDPC. If an LDPC error is detected in the verify process, Check Condition status is returned with sense key set to Medium Error. |
| 01b | Indicates that a byte-by-byte comparison is performed between the data on the disk and data transferred from the initiator during the data-out phase. The number of logical blocks transferred must equal the Verification Length field. If the comparison is unsuccessful, the command is terminated with Check Condition status and the sense key is set to Miscompare. |
| 10b | Not defined |
| 11b | Indicates that a byte-by-byte comparison is performed between the data on the disk and data transferred from the initiator during the data-out phase. The number of logical blocks transferred must equal one. All blocks specified by the Verification Length will be compared against the single block of data transferred by the initiator. If the comparison is unsuccessful, the command is terminated with Check Condition status and the sense key is set to Miscompare. |

8.22.2 DPO (Disable Page Out) bit of one indicates that the data accessed by this command is to be assigned the lowest priority for being written into or retained by the cache. A DPO bit of one overrides any retention priority specified in the Mode Select Page 8 Caching Parameters. A DPO bit of zero indicates the priority is determined by the retention priority. The Initiator should set the DPO bit when the blocks read by this command are not likely to be read again in the near future.

If caching is enabled, the command performs an implied FUA and an implied Synchronize Cache before starting the VERIFY. This ensures that the medium, not the cache, is being verified.

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.

The 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 disk shall be checked during processing of the command. Protection information is stored on disk and may be validated using the drive's internal checking algorithms, and also byte-by-byte compared using data from the initiator when BytChk=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 VERIFY(32) command only)
- Logical Block Reference Tag is checked

VRPROTECT=001b

- Logical Block Guard is checked
- Logical Block Application Tag is checked (applies to VERIFY(32) command only)
- Logical Block Reference Tag is checked

VRPROTECT=010b

- Logical Block Guard is not checked
- Logical Block Application Tag is checked (applies to VERIFY(32) command only)
- 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, 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.

If BytChk=1, the drive's internal checking of protection information is done only when VRPROTECT=000b and the drive is formatted with protection information

If BytChk=1, and VRPROTECT is not set to 000b, checking of protection information is performed on the fields described above as a byte-by-byte comparison against the data transferred to the drive by the initiator during the Data Out phase.

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

8.55 VERIFY (12) - (AF)

Table 288 VERIFY (12) - (AF)

| Byte | Bit | | | | | | | |
|------|-----------------------------------------|---|--------------|-----|----------|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = AFh | | | | | | | |
| 1 | VRPROTECT | | | DPO | Reserved | BytChk | | Obsolete |
| 2-5 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 6-9 | (MSB) Verification Length (LSB) | | | | | | | |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

8.56 VERIFY (16) - (8F)

Table 289 VERIFY (16) - (8F)

| Byte | Bit | | | | | | | |
|-------|-----------------------------------|---|--------------|-----|----------|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 8Fh | | | | | | | |
| 1 | VRPROTECT | | | DPO | Reserved | BytChk | | Reserved |
| 2-9 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 10-13 | (MSB) Verification Length (LSB) | | | | | | | |
| 14 | Reserved = 0 | | | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

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

Table 290 VERIFY (32) - 7F/0A)

| Byte | Bit | | | | | | | |
|-------|-----------------------------|----------------------------------------------|------------------|----------|--------|----------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 7Fh | | | | | | | |
| 1 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6 | Reserved = 0 | | Group Number = 0 | | | | | |
| 7 | Additional CDB Length = 18h | | | | | | | |
| 8-9 | Service Action = 000Ah | | | | | | | |
| 10 | VRPROTECT | | DPO | Reserved | BytChk | | Obsolete | |
| 11 | Reserved = 0 | | | | | | | |
| 12-19 | (MSB) | Logical Block Address | | | | | | (LSB) |
| 20-23 | (MSB) | Expected Initial Logical Block Reference Tag | | | | | | (LSB) |
| 24-25 | (MSB) | Expected Logical Block Application Tag | | | | | | (LSB) |
| 26-27 | (MSB) | Logical Block Application Tag Mask | | | | | | (LSB) |
| 28-31 | (MSB) | Verification Length | | | | | | (LSB) |

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.

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.

8.58 WRITE (6) - (0A)

Table 291 WRITE (6) - (0A)

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|--------------|-----------|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 0Ah | | | | | | | |
| 1 | Reserved = 0 | | | (MSB) LBA | | | | |
| 2-3 | Logical Block Address (LSB) | | | | | | | |
| 4 | Transfer Length | | | | | | | |
| 5 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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). See Section 8.17 "READ (6) - (08)" for the parameters.

8.59 WRITE (10) - (2A)

Table 292 WRITE (10) - (2A)

| Byte | Bit | | | | | | | |
|------|-----------------------------------------|---|--------------|-----|-----|----------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 2Ah | | | | | | | |
| 1 | WRPROTECT | | | DPO | FUA | Reserved | Obsolete | |
| 2-5 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Transfer Length (LSB) | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

8.22.2 DPO (Disable Page Out) bit of one indicates that the data accessed by this command is to be assigned the lowest priority for being written into or retained by the cache. A DPO bit of one overrides any retention priority specified in the Mode Select Page 8 Caching Parameters. A DPO bit of zero indicates that the priority is determined by the retention priority. The Initiator should set the DPO bit when the blocks written by this command are not likely to be read in the near future.

8.22.2 FUA (Force Unit Access) bit of one indicates that the Target must write the data to the media before returning **Good** status. A FUA bit of zero indicates that the Target may return **Good** status prior to writing the data to the media.

8.22.2 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 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 disk:

8.22.2 the Logical Block Guard field is set to a properly generated CRC

8.22.2 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)

8.22.2 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 disk 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 disk 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 WRITE (32) command only)
- 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 WRITE(32) command only)
- 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, 110b, 111b, 001b

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.

8.60 WRITE (12) - (AA)

Table 293 WRITE (12) - (AA)

| Byte | Bit | | | | | | | |
|------|-----------------------------------------|---|--------------|-----|----------|----------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = AAh | | | | | | | |
| 1 | WRPROTECT | | DPO | FUA | Reserved | Obsolete | Reserved | |
| 2-5 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 6-9 | (MSB) Transfer Length (LSB) | | | | | | | |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | NACA=0 | Obsolete | | |

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.

8.61 WRITE (16) - (8A)

Table 294 WRITE (16)-(8A)

| Byte | Bit | | | | | | | |
|-------|-----------------------------------------|------|--------------|-----|----------|----------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 8Ah | | | | | | | |
| 1 | WRPROTECT | | DPO | FUA | Reserved | Obsolete | DLD2 | |
| 2-9 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 10-13 | (MSB) Transfer Length (LSB) | | | | | | | |
| 14 | DLD1 | DLD0 | Reserved = 0 | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

The duration limit descriptor bits DLD2, DLD1, DLD0 are defined in table 192.

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

Table 295 WRITE (32) - (7F/0B)

| Byte | Bit | | | | | | | |
|-------|-----------------------------|----------------------------------------------|--------------|------------------|-----|----------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 7Fh | | | | | | | |
| 1 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6 | Reserved = 0 | | | Group Number = 0 | | | | |
| 7 | Additional CDB Length = 18h | | | | | | | |
| 8-9 | Service Action = 000Bh | | | | | | | |
| 10 | WRPROTECT | | | DPO | FUA | Reserved | Obsolete | Reserved |
| 11 | Reserved = 0 | | | | | DLD2 | DLD1 | DLD0 |
| 12-19 | (MSB) | Logical Block Address | | | | | | (LSB) |
| 20-23 | (MSB) | Expected Initial Logical Block Reference Tag | | | | | | (LSB) |
| 24-25 | (MSB) | Expected Logical Block Application Tag | | | | | | (LSB) |
| 26-27 | (MSB) | Transfer Length | | | | | | (LSB) |

The WRITE command requests that the drive write data transferred from the initiator to disk. 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

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.

The duration limit descriptor bits DLD2, DLD1, DLD0 are defined in table 192.

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

Table 296 WRITE AND VERIFY (10) - (2E)

| Byte | Bit | | | | | | | |
|------|-----------------------------------------|---|--------------|--------------|----------|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 2Eh | | | | | | | |
| 1 | WRPROTECT | | | DPO | Reserved | BytChk | | Reserved |
| 2-5 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 6 | Reserved = 0 | | | Group Number | | | | |
| 7-8 | (MSB) Transfer Length (LSB) | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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. If caching is enabled, an implied FUA (Force Unit Access) and an implied Synchronize Cache are performed before starting the operation. This ensures that data from the disk, not the cache, is verified.

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

8.22.2 Transfer Length is the number of contiguous blocks to transferred. If the transfer length is zero, the seek occurs, but no data is transferred. This condition is not considered an error.

If caching is enabled, the command performs an implied FUA and an implied Synchronize Cache before starting the operation. This ensures that the medium, not the cache, is being verified.

8.22.2 BytChk bit set to zero indicates that the data is read back from the disk and verified using LDPC after the successful write operation. If an LDPC error is detected in the verify process, **Check Condition** status is returned with sense key set to *Medium Error*. BytChk bit set to one indicates that byte-by-byte comparison is performed between data on the disk 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*.

8.22.2 DPO (Disable Page Out) bit of one indicates that the data written by this command is to be assigned the lowest priority for being written into or retained by the cache. A DPO bit of one overrides any retention priority specified in the Mode Select Page 8 Caching parameters. A DPO bit of zero indicates the priority is determined by the retention priority.

The Initiator should set the DPO bit when the blocks written by this command are not likely to be read again in the near future.

8.64 WRITE AND VERIFY (12) - (AE)

Table 297 WRITE AND VERIFY (12) - (AE)

| Byte | Bit | | | | | | | |
|------|-----------------------------------------|---|--------------|----------|--------|----------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = AEh | | | | | | | |
| 1 | WRPROTECT | | DPO | Reserved | BytChk | | Reserved | |
| 2-5 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 6-9 | (MSB) Transfer Length (LSB) | | | | | | | |
| 10 | Reserved = 0 | | | | | | | |
| 11 | VU = 0 | | Reserved = 0 | | NACA=0 | Obsolete | | |

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.

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

Table 298 WRITE and VERIFY (16) - (8E)

| Byte | Bit | | | | | | | |
|-------|-----------------------------------------|---|--------------|------------------|----------|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 8Eh | | | | | | | |
| 1 | WRPROTECT | | | DPO | Reserved | BytChk | | Reserved |
| 2-9 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 10-13 | (MSB) Transfer Length (LSB) | | | | | | | |
| 14 | Reserved = 0 | | | Group Number = 0 | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

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

Table 299 WRITE and VERIFY (32) - (7F/0C)

| Byte | Bit | | | | | | | |
|-------|-----------------------------|----------------------------------------------|------------------|----------|--------|----------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 7Fh | | | | | | | |
| 1 | VU = 0 | | Reserved = 0 | | | NACA = 0 | Obsolete | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6 | Reserved = 0 | | Group Number = 0 | | | | | |
| 7 | Additional CDB Length = 18h | | | | | | | |
| 8-9 | Service Action = 000Ch | | | | | | | |
| 10 | WRPROTECT | | DPO | Reserved | BytChk | | Reserved | |
| 12-19 | (MSB) | Logical Block Address | | | | | | (LSB) |
| 20-23 | (MSB) | Expected Initial Logical Block Reference Tag | | | | | | (LSB) |
| 24-25 | (MSB) | Expected Logical Block Application Tag | | | | | | (LSB) |
| 26-27 | (MSB) | Logical Block Application Tag Mask | | | | | | (LSB) |
| 28-31 | (MSB) | Transfer Length | | | | | | (LSB) |

The WRITE AND VERIFY command requests that the drive write the data transferred from the initiator to disk 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.

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.

8.67 WRITE BUFFER (3B)

Table 300 WRITE BUFFER (3B)

| Byte | Bit | | | | | | | |
|------|----------------------------|---|--------------|------|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 3Bh | | | | | | | |
| 1 | Mode Specific | | | Mode | | | | |
| 2 | Buffer ID | | | | | | | |
| 3-5 | (MSB) Buffer Offset (LSB) | | | | | | | |
| 6-8 | (MSB) Parameter List (LSB) | | | | | | | |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

This command will cause the entire cache to be emptied.

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

Table 301 Mode

| Mode | Description |
|------------|-------------------------------------------------------------------------------------|
| 00000 | Write combined header and data |
| 00010 | Data |
| 00100 | Download Microcode |
| 00101 | Download Microcode and save - single binary file |
| 00111 | Download Microcode with offsets, save, and activate - multiple binary files |
| 01010 | Write Data to Echo Buffer |
| 01101 | Download microcode with offsets, select activation events, save, and defer activate |
| 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*.

8.67.1 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 zero. 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 zero. 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 302 Write Buffer Header

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

8.67.2 Write Data (Mode 00010b)

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

Buffer ID must be zero. 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

8.22.2 less than the capacity of the buffer size after adding the Buffer Offset value and

8.22.2 on a sector boundary

A Parameter List Length of zero 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*.

Mode Specific field is reserved

8.67.3 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 zero. 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.

Mode Specific field is reserved

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.*

8.67.4 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 disk. 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: *It requires up to 30 seconds to update the microcode including the Flash ROM update.*

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 Western Digital development purposes only.

Mode Specific field is reserved

8.67.5 Download Microcode with offsets, save, and activate (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.

The **Buffer Offset** field 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.

8.67.6 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.

Mode Specific field is reserved

8.67.7 Download microcode with offsets, select activation, save, and defer activate mode (Mode 01101b)

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 if a WRITE BUFFER command with the activate deferred microcode mode (0Fh) is processed.

The Mode Specific field specify the specifies additional events that shall be used to activate the deferred microcode

Table 303 Select Report field

| Bit | 7 | 6 | 5 | ... |
|-----|--------|--------|---------|-----|
| | PO_ACT | HR_ACT | VSE_ACT | |

If the power on activate (**PO_ACT**) bit is set to one, then deferred microcode shall be activated and no longer considered deferred if a power on occurs. If the PO_ACT bit is set to zero, then deferred microcode shall not be activated if a power on occurs.

If the hard reset activate (**HR_ACT**) bit is set to one, then deferred microcode shall be activated and no longer considered deferred if a hard reset occurs. If the HR_ACT bit is set to zero, then deferred microcode shall not be activated if a hard reset occurs.

If the vendor specific event activate (**VSE_ACT**) bit is set to one, then deferred microcode shall be activated and no longer considered deferred if a vendor specific event occurs. If the VSE_ACT bit is set to zero, then deferred microcode shall not be activated if a vendor specific event occurs.

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

In this mode, microcode shall be transferred to the drive 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 hard reset;
- c) a START STOP UNIT command is processed;
- d) a FORMAT UNIT command is processed;
- e) a WRITE BUFFER command with the activate deferred microcode mode (0Fh) is processed.

After receiving a FORMAT UNIT command or a START STOP UNIT command, the drive shall, prior to processing the command, activate any deferred microcode that has been downloaded as a result of a WRITE BUFFER command with the MODE field set to 0Eh.

If the current operating state is OM_POWERSAVE (Table 76), the drive shall spin up the drive first to activate the deferred microcode. The drive shall not be placed back into the same OM_POWERSAVE state after the activation via a hard reset or a FORMAT UNIT command is completed. For activation via a START STOP UNIT command, the drive shall be placed into the corresponding power condition specified by **Power Conditions and Power Condition Modifier** fields on the START STOP UNIT command (Table 282). If the START STOP UNIT command does not lead to power condition changes, the drive shall be left in the Active state.

This process generates a unit attention condition for MICROCODE HAS BEEN CHANGED for all Initiators in case of activation via a hard reset, a START STOP UNIT command or FORMAT UNIT command.

8.67.9 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.

8.67.10 Enable Expander Communications Protocol (Mode 11010b)

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

8.68 WRITE LONG (10) - (3F)

Table 304 WRITE LONG (10) - (3F)

| Byte | Bit | | | | | | | |
|------|-----------------------------|----------|--------------|--------------|---|--------|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 3Fh | | | | | | | |
| 1 | Obsolete | WR_UNCOR | Obsolete | Reserved = 0 | | | | Obsolete |
| 2-5 | (MSB) Logical Block Address | | | | | | | (LSB) |
| 6 | Reserved = 0 | | | | | | | |
| 7-8 | (MSB) Byte Transfer Length | | | | | | | (LSB) |
| 9 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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

8.22.2 User Data

8.22.2 18 bytes of MEDC data

All WRITE LONG commands will behave as if the WR_UNCOR bit was set unless the COR_DIS bit is set. The COR_DIS bit behavior will take precedence if both WR_UNCOR and COR_DIS bits are set.

- **WR_UNCOR** - write uncorrectable, bit 6 in byte 1. If the COR_DIS bit is not set, the drive will behave in the following manner regardless of the state of this bit. The drive will create a pseudo unrecovered error with correction enabled. On following read commands to the LBA, the drive will:

Behave like pseudo unrecovered error with correction disabled with the exception that the device waits a predefined period of time before posting uncorrectable error. Time value is equivalent to the amount of time for full step recovery.

8.22.2 Logical Block Address field specifies the logical block at which the write operation shall occur.

8.22.2 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 Section 8.24.1) is set to a non-zero value), then:

- the device server shall support the physical block (PBLOCK) bit;
- a PBLOCK bit set to one specifies that the device shall write the entire physical block containing the specified logical block using the value in the BYTE TRANSFER LENGTH field; and
- a PBLOCK bit set to zero specifies that the device shall Write only the specified logical block using the value in the BYTE TRANSFER LENGTH field.

8.22.2 Logical Block Address field specifies the logical block at which the write operation shall occur.

8.22.2 Byte Transfer Length. This field 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.

Note:

- Pseudo unrecovered error with correction enabled handling (COR_DIS=0, WR_UNCOR=1)
Pseudo unrecovered error with correction enabled is processed like correction is disabled and:
 - performs no error recovery on the affected logical blocks
 - does not log errors on the affected logical blocks in any log page that contain error counters
 Physical sector is not modified but LBA is flagged as an uncorrectable sector.

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

Table 305 WRITE LONG (16) - (9F/11)

| Byte | Bit | | | | | | | |
|-------|-----------------------------|----------|--------------|----------------------|---|--------|----------|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 9Fh | | | | | | | |
| 1 | Obsolete | WR_UNCOR | Obsolete | Service Action = 11h | | | | |
| 2-9 | (MSB) Logical Block Address | | | | | | | (LSB) |
| 10-11 | Reserved = 0 | | | | | | | |
| 12-13 | (MSB) Byte Transfer Length | | | | | | | (LSB) |
| 14 | Reserved = 0 | | | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

Refer to Write Long (10) – (3F) for field definitions.

8.70 WRITE SAME (10) - (41)

Table 306 WRITE SAME (10) - (41)

| Byte | Bit | | | | | | | |
|------|-----------------------------------|---|---|------------------|---|---|----------|----------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 41h | | | | | | | |
| 1 | WRPROTECT | | | Reserved = 0 | | | Obsolete | |
| 2-5 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 6 | Reserved = 0 | | | Group Number = 0 | | | | |
| 7-8 | (MSB) Number of Blocks (LSB) | | | | | | | |
| 9 | VU = 0 | | | Reserved = 0 | | | NACA=0 | Obsolete |

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.

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

8.22.2 Logical Block Address specifies the address at which the write begins. The Number of Blocks specifies the number of contiguous blocks to be written. If the number is zero, all remaining blocks on the specified Logical Unit are written.

8.22.2 Number of Blocks specifies the number of contiguous blocks to be written. If the number is zero, all remaining blocks on the specified logical unit are written.

The data for this command is not retained in the cache.

8.71 WRITE SAME (16) - (93)

Table 307 WRITE SAME (16) - (93)

| Byte | Bit | | | | | | | |
|-------|-----------------------------------|---|--------------|--------------|---|--------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 93h | | | | | | | |
| 1 | WRPROTECT | | | Reserved = 0 | | | Obsolete | |
| 2-9 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 10-13 | (MSB) Byte Transfer Length (LSB) | | | | | | | |
| 14 | Reserved = 0 | | | | | | | |
| 15 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |

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.

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

Table 308 WRITE SAME (32) - (7F/0D)

| Byte | Bit | | | | | | | |
|-------|----------------------------------------------------------|---|--------------|------------------|---|----------|----------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Command Code = 7Fh | | | | | | | |
| 1 | VU = 0 | | Reserved = 0 | | | NACA=0 | Obsolete | |
| 2-5 | Reserved = 0 | | | | | | | |
| 6 | Reserved = 0 | | | Group Number = 0 | | | | |
| 7 | Additional CDB Length = 18h | | | | | | | |
| 8-9 | Service Action = 000Dh | | | | | | | |
| 10 | WRPROTECT | | | Reserved = 0 | | Obsolete | | |
| 11 | Reserved = 0 | | | | | | | |
| 12-19 | (MSB) Logical Block Address (LSB) | | | | | | | |
| 20-23 | (MSB) Expected Initial Logical Block Reference Tag (LSB) | | | | | | | |
| 24-25 | (MSB) Expected Logical Block Application Tag (LSB) | | | | | | | |
| 26-27 | (MSB) Logical Block Application Tag Mask (LSB) | | | | | | | |
| 28-31 | (MSB) Number of Blocks (LSB) | | | | | | | |

The WRITE SAME command requests that the drive write a single block of data transferred from the initiator to disk 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.

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.

9 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 309 Format of the SCSI STATUS byte.

| Bit | | | | | | | |
|--------------|---|-------------|---|---|---|---|----------|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Reserved = 0 | | Status Code | | | | | Reserved |

Table 310 SCSI Status Byte

| 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. |
| 04h | CONDITION MET Not supported. |
| 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. |
| 10h | INTERMEDIATE Not supported (Obsolete). |
| 14h | INTERMEDIATE CONDITION MET Not supported (Obsolete). |
| 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 | TASK SET 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. |
| 30h | ACA ACTIVE Not supported. |
| 40h | TASK ABORTED Not supported. |

10 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.

10.1 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.

10.1.1 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, Task Set 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 10.1.2)
2. Check Condition status for Incorrect Initiator Connection (See Section 10.1.3)
3. Check Condition status for Unit Attention Condition (See Section 10.1.5)
4. Busy Status or Task Set Full Status (See Section 10.1.4)
5. Check Condition status for Deferred Error Condition (See Section 10.1.8)
6. Check Condition status during Startup and Format operations (See Section 10.1.6)
7. Reservation Conflict status (See Section 10.1.10)
8. Check Condition status for invalid command op code
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.

10.1.2 Invalid LUN Processing

Any value other than zero 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 Section 8.6).

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 Section 8.39).

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.

10.1.3 Overlapped Commands

The drive does not perform any overlapped command checking.

10.1.4 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 Section 10.1.1).

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

- 8.22.2 the command is permitted to execute
- 8.22.2 the command is added to the queue
- 8.22.2 Task Set Full status is to be returned
- 8.22.2 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:

- 8.22.2 Check Condition status is returned with sense key set to Logical Unit Not Ready if:
- 8.22.2 the startup operation or a format operation is active. See Command Processing During Execution of Active I/O Process 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 Section 10.1.4)*

The command is permitted to execute if:

- 8.22.2 the command is a priority command (see Section 10.2) and the conditions to execute concurrently are met (see Section 10.5)

The command is added to the queue if:

- 8.22.2 any I/O process already exists at the target, and
- 8.22.2 this is not an incorrect initiator connection.

Task Set Full status is returned if:

- 8.22.2 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 Section 10.1.9) and a Start Unit command was previously queued but has not yet begun execution.

BUSY status is returned if:

- 8.22.2 more than 64 unique Initiators send frames to the drive since the last POR. In that case, BUSY status is only returned for Initiators above and beyond the first 64.

10.1.5 Unit Attention Condition

The target generates a unit attention condition when one of the following occurs:

8.22.2 The target has been reset

This includes a power-on reset or a reset caused by a LUN Reset Task Management function or Hard Reset sequence. In all of these cases, a unit attention condition is generated for each initiator.

8.22.2 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.

8.22.2 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.

8.22.2 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.

8.22.2 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.

8.22.2 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.

8.22.2 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.

8.22.2 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:

Table 311 Command Response Before Reporting a Check Condition for a Pending Unit Attention

| | |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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. |

10.1.6 Command Processing During Startup and Format Operations

If the Target receives a command from an Initiator while the Target is executing a startup or format operation, the response of the Target varies with the command as follows:

Table 312 Command Response While Executing Startup or Format Operation

| | |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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, and 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. |

10.1.7 Internal Error Condition

The Target generates an Internal Error condition for all Initiators when an internally initiated operation ends with an unrecoverable error, that is, the startup sequence for Auto Start enabled terminates after the SCSI bus has been enabled and prior to completion of the bring-up sequence.

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 or 72h) 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:

Table 313 Command Response While an Internal Error Condition Exists

| | |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| INQUIRY | 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. |

10.1.8 Deferred Error Condition

Error code (71h or 73h) 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 a Deferred Error condition when

- 8.22.2 Execution of a Format Unit command, with the immediate bit of one, ends with an error.
- 8.22.2 Execution of a Write command, with WCE (Write Cache Enable) bit of one, ends with an error.

10.1.9 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 3 conditions in the Degraded Mode:

- 8.22.2 Spindle Motor Degrade which is caused by one of the following conditions:
 - Spindle Motor was started (by POR or Unit Start command) and the Target is under Self Configuration.
 - Spindle Motor Failed to start.
 - Spindle Motor was stopped by Unit Stop command after the Target successfully completed the Self Configuration.
- 8.22.2 Self Configuration Failure Degraded which is caused by one of the following conditions:
 - RAM Code, Configuration Sector Read Failure
 - RAM Code, Configuration Sector Revision Mismatch
- 8.22.2 Format Command Failure Degraded. This condition is caused when Format Unit command failed or was interrupted abnormally (Mode Page 0, byte 5, bit 4 FDD controls Format Degraded mode)

10.1.9.1 Response to SCSI Command in Degraded Mode - Disable Auto Start

The tables on the following pages show the degraded mode status with acceptable commands and additional sense codes

Table 314 Spindle Motor Degraded Mode - Disable Auto Start

| Command (w/Option) | Response |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Request Sense | Executed. The Target may return Sense Key 02h (Not Ready) ASC/ASCQ 0402h (Initialize Command Required) |
| Inquiry (EVPD=0) | Executed |
| Inquiry (EVPD=1) | Executed and Check Condition is returned with Sense Key 05h (Illegal Request) ASC/ASCQ 2400h (Invalid Field in CDB) |
| 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 <ul style="list-style-type: none"> - Success: Good Status is returned. Motor Degraded Mode is cleared - Spindle Motor Start Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 0400h (Start Spindle Motor Fail) - Self Configuration Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 4080h (Diag Fail- Bring up Fail) Sense Key 02h (Not Ready) ASC/ASCQ 4085h (Diag Fail-RAM Code NOT load) |
| Start Stop Unit (Stop) | Executed. Good Status is returned. Motor Degraded Mode is NOT cleared |
| Other Commands | Not Executed. Check Condition Status is returned with Sense Key 02h (Not Ready) ASC/ASCQ 0402h (Initialize Command Required) |

10.1.9.2 Response to SCSI Command in Degraded Mode - Auto Start Delay/ Spinning Up

Table 315 Spindle Motor Degraded Mode - Auto Start Delay/Spinning Up

| 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 (EVPD=0) | Executed |
| Inquiry (EVPD=1) | Executed and Check Condition is returned with Sense Key 05h (Illegal Request) ASC/ASCQ 2400h (Invalid Field in CDB) |
| 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 <ul style="list-style-type: none"> - Success: Good Status is returned. Motor Degraded Mode is cleared - Spindle Motor Start Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 0400h (Start Spindle Motor Fail) - Self Configuration Failure: Check Condition with Sense Key 02h (Not Ready) 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 02h (Not Ready) ASC/ASCQ 0401h (In Process of Becoming Ready) |

10.1.9.3 Response to SCSI Command in Degraded Mode - Spindle Start Failure

Table 316 Spindle Motor Degraded Mode - Spindle Start Failure

| Command (w/Option) | Response |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Request Sense | Executed. The Target may return Sense Key 02h (Not Ready) ASC/ASCQ 0400h (Start Spindle Motor Fail) |
| Inquiry (EVPD=0) | Executed |
| Inquiry (EVPD=1) | Executed and Check Condition is returned with Sense Key 05h (Illegal Request) ASC/ASCQ 2400h (Invalid Field in CDB) |
| Test Unit Ready | Executed and Check Condition is returned with Sense Key 02h (Not Ready) ASC/ASCQ 0400h (Start Spindle Motor Fail) |
| Start Stop Unit (Start) | Executed <ul style="list-style-type: none"> - Success: Good Status is returned. Motor Degraded Mode is cleared - Spindle Motor Start Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 0400h (Start Spindle Motor Fail) - Self Configuration Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 4080h (Diag Fail- Bring up Fail) Sense Key 02h (Not Ready) ASC/ASCQ 4085h (Diag Fail-RAM Code NOT load) |
| Start Stop Unit (Stop) | Executed. Good Status is returned. Motor Degraded Mode is NOT cleared |
| Other Commands | Not Executed. Check Condition Status is returned with Sense Key 02h (Not Ready) ASC/ASCQ 0400h (Start Spindle Motor Fail) |

10.1.9.4 Response to SCSI Command in Degraded Mode - Spindle Stopped by Unit Stop Command

Table 317 Spindle Motor Degraded Mode - Spindle Stopped by Command

| Command (w/Option) | Response |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Request Sense | Executed. The Target may return Sense Key 02h (Not Ready) ASC/ASCQ 0402h (Initialize Command Required) |
| Inquiry (EVPD=0) | Executed |
| Inquiry (EVPD=1) | 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) | <p>Executed</p> <ul style="list-style-type: none"> - Success: Good Status is returned. Motor Degraded Mode is cleared - Spindle Motor Start Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 0400h (Start Spindle Motor Fail) - Self Configuration Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 4080h (Diag Fail- Bring up Fail) <p>Sense Key 02h (Not Ready) ASC/ASCQ 4085h (Diag Fail-RAM code NOT load)</p> |
| Start Stop Unit (Stop) | Executed. Good Status is returned. Motor Degraded Mode is NOT cleared |
| Other Commands | Not Executed. Check Condition Status is returned with Sense Key 02h (Not Ready) ASC/ASCQ 0402h (Initialize Command Required) |

10.1.9.5 Self Configuration Failure Degraded Mode

Table 318 Self Configuration Failure Degraded Mode

| Command (w/Option) | Response |
|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Request Sense | Executed. The Target may return Sense Key 02h (Not Ready) ASC/ASCQ 4080h (Diag Fail- Bring up Fail) Sense Key 02h (Not Ready) ASC/ASCQ 4085h (Diag Fail-RAM code NOT load) |
| Inquiry (EVPD=0) | Executed |
| Inquiry (EVPD=1) | Executed and Check Condition is returned with Sense Key 05h (Illegal Request) ASC/ASCQ 2400h (Invalid Field in CDB) |
| Test Unit Ready | Executed and Check Condition is returned with Sense Key 02h (Not Ready) ASC/ASCQ 4080h (Diag Fail- Bring up Fail) Sense Key 02h (Not Ready) ASC/ASCQ 4085h (Diag Fail-RAM code NOT load) |
| Start Stop Unit (Start) | Executed <ul style="list-style-type: none"> - Success: Good Status is returned. Motor Degraded Mode is cleared - Spindle Motor Start Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 0400h (Start Spindle Motor Fail) - Self Configuration Failure: Check Condition with Sense Key 02h (Not Ready) ASC/ASCQ 4080h (Diag Fail- Bring up Fail) Sense Key 02h (Not Ready) ASC/ASCQ 4085h (Diag Fail-RAM code NOT load) |
| Write Buffer (Download and Save) | Executed. <ul style="list-style-type: none"> - Success: Good Status is returned. Motor Degraded Mode is cleared - Self Configuration Failure: Check Condition with Sense Key 02h (Not Ready) 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 02h (Not Ready) ASC/ASCQ 4080h (Diag Fail- Bring up Fail) Sense Key 02h (Not Ready) ASC/ASCQ 4085h (Diag Fail-RAM code NOT load) |

10.1.9.6 Format Command Failure Degraded Mode

Table 319 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 (EVPD=0) | Executed |
| Inquiry (EVPD=1) | Executed |
| Test Unit Ready | Executed and Check Condition is returned with Sense Key 02h (Not Ready) ASC/ASCQ 3100h (Format Corrupted) |
| Format Unit | Executed <ul style="list-style-type: none"> - Success: Good Status is returned. Format Degraded Mode is cleared - Failure: Check Condition Status is returned, and Format Degraded Mode is NOT cleared. |
| Other Commands (read and write) | Not Executed. Check Condition Status is returned with Sense Key 03h (Medium Error) ASC/ASCQ 3100h (Format Corrupted) Non-read/write commands will execute so the drive is as responsive as possible and for restoring normal operation. |

Note: Mode Page 0 byte 5 bit 4 (FDD) = 0

Note: See also Section 10.1.9 "Degraded Mode" and Section 8.4 "FORMAT UNIT (04)".

10.1.10 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 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 10.1.1 "Priority of SCSI Status Byte Reporting".

Command Persistent Reserve Out can perform reservation as well. See Section 8.14 PERSISTENT RESERVE OUT.

10.2 Priority Commands

Certain SCSI commands always execute without returning a Busy Status or Reservation Conflict Status in response to the command. These commands are

- 8.22.2 Inquiry
- 8.22.2 Request Sense
- 8.22.2 Report LUNs

These commands are executed prior to attempting to complete the execution of any other pending command in the queue. These commands are never queued.

10.3 Command Queuing

The following commands are never queued.

- 8.22.2 Priority Commands (i.e.: Request Sense and Inquiry)
- 8.22.2 Commands for an invalid LUN.

10.3.1 Queue Depth

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.

10.3.2 Task Set Full Status

The drive will respond with TASK SET 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.

10.3.3 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:

- 8.22.2 An ABORT TASK terminates the specified I/O process from the issuing initiator
- 8.22.2 An ABORT TASK SET terminates all I/O processes from the issuing initiator
- 8.22.2 A CLEAR TASK SET, TARGET RESET or reset terminates all I/O processes from all initiators

10.4 Command Reordering

Command reordering is supported when enabled by the Queue Algorithm Modifier in Mode Page 0Ah (see Section 8.11.9).

10.5 Concurrent I/O Process

Concurrent commands are always allowed to execute concurrently with non-priority commands. A second priority command received while a priority command is being executed is put at the head of the command queue.

8.22.2 WRITE commands when another WRITE command is an active I/O process

8.22.2 READ commands when another READ command is an active I/O process

When a concurrent command ends in CHECK CONDITION status, the QErr bit on the Mode Page 0Ah will determine how other active I/O processes from the same initiator for that drive will be handled.

10.6 Write Cache

If the WCE (Write cache enable) bit is 1, the drive returns Good Status and closes the connection immediately after receiving the data of the last sector before actually writing the data onto the media.

If the drive detects an error after it returns a Good Status, the drive sets a Deferred Error (Error Code of sense data = 71h) and a following command will be returned with Check Condition and the Contingent allegiance condition is established. Under the Contingent allegiance condition all queued processes including commands from other initiators are suspended.

10.7 Automatic Rewrite/Reallocate

The target supports Auto Reallocate for READ, WRITE, WRITE VERIFY, and VERIFY.

Automatic Reallocate operates from within the read/write command. When an automatic reallocation occurs, the read or write command takes longer to complete.

This operation is sometimes referred to as auto-reassignment due to its similarity to the operation performed by the reassign command.

Following is a description of the target behavior for each setting of ARRE. ARRE setting affects all data errors. (No Sector Found, Data Sync Byte Errors and Data LDPC Errors.)

ARRE=1: An error site determined to need rewriting or reallocation during a read is automatically reallocated as a pending defect prior to the sending of the status. It will not be identified by a read defect data command. It will be rewritten or reallocated on the next write prior to the sending of the status. If it is reallocated it will be identified in a read defect data command.

ARRE=0: Behaves the same as ARRE=1.

The target will automatically rewrite/reallocate for the following commands.

Read

Verify

Verify portion of Write and Verify

For all other commands the ARRE setting is ignored and the target will not automatically rewrite/ reallocate

Following is a description of the target behavior for each setting of AWRE. AWRE setting affects only No Sector Found Errors on writes.

AWRE=1: An error site determined to need reassignment during a write is automatically reallocated at the conclusion of the write and prior to sending the status. The site will be automatically reallocated only if the write recovery succeeded at the conclusion of the write.

AWRE=0: Behaves the same as AWRE=1

The target will automatically reallocate for the following commands.

Write

Write Same

Write portion of Write and Verify

For all other commands the AWRE setting is ignored and the target will not automatically reallocate.

Auto Reallocate information is communicated via the sense data returned following a command during which a site was determined to need rewriting or reassignment. The LBA returned in the sense data is the LBA that was determined to need rewriting or reassignment.

The sense data combinations with auto/recommend rewrite/reallocate are listed below.

Table 320 Sense data combinations with auto/recommend rewrite/reallocate

| Key | Code | Qual | Description |
|-----|------|------|------------------------------------------------|
| 1 | 17 | 01 | Recovered Data with retries |
| 1 | 17 | 06 | Recovered Data without LDPC – Auto Reallocated |
| 1 | 17 | 09 | Recovered Data without LDPC – Data Rewritten |
| 1 | 18 | 00 | Recovered Data with LDPC |
| 1 | 18 | 02 | Recovered Data with LDPC – Auto Reallocated |
| 1 | 18 | 07 | Recovered Data with LDPC – Data Rewritten |

10.8 Segmented Caching

10.8.1 Overview

Segmented Caching divides the data buffer into several smaller buffers. Each buffer is used as Read/ Write/Read-Ahead buffer.

10.8.2 Read Ahead

The Read Ahead function consists of reading data that the Initiator has not yet requested to the drive buffer. This function is intended to improve performance for an initiator that frequently accesses sequential data with successive SCSI read commands. The Read Ahead function works when RCD (the read cache disable) bit of read cache page (page 08h) is set to zero.

The drive initiates the Read ahead function when the following conditions exist:

8.22.2 RCD is 0

8.22.2 Read, Verify and Write and Verify is received.

8.22.2 The consecutive LBA of the requested LBA is not available in the buffer

If SCSI reset or target reset message is received, all contents of segmented buffer is flushed.

Even if an error occurs during the Read ahead, the error will not be reported to the Initiator. The data read before the error occurred will be stored as valid data by the Read Ahead function.

10.9 Multiple Initiator Systems

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

10.9.1 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.

10.9.2 Mode Pages

A single set of Mode pages is maintained, where this is indicated by the Control Mode Page (0xA) TST field = 0. 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 10.1.5 "Unit Attention Condition" for more information.

10.10 Reset

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

This device supports the Hard reset option as defined in the SCSI standards and the reset sources discussed below.

10.10.1 Initiator Sense Data

There are four sources of resets detected by the target:

Table 321 Reset

| 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. |
| Hard Reset | This is the Hard Reset performed during a Link Reset Sequence. |
| LUN Reset | This is a LUN RESET TMF (08h) sent in a TASK IU. |

10.10.2 Reset Actions

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

10.10.2.1 Power-On reset and Self-Initiated reset

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

8.22.2 A power-up sequence

8.22.2 A startup sequence is necessary to put the drive in a ready state

These reset conditions cause the following actions:

8.22.2 If the reset occurs during the power-up sequence, the power-up sequence is re-started.

8.22.2 If the auto-start option is enabled and 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.

8.22.2 If the reset occurs while a physical sector is being written, the WRITE operation is disabled at the end of the current sector. The media is not corrupted if power is maintained to the end of the current sector.

10.11 Diagnostics

The drive will execute Power on Diagnostics at power on time to assure the correct operation of the drive by validating components (ROM, RAM, Sector Buffer, EEPROM, HDC, Spindle Motor, Actuator), checking stored information in the Reserved Area and EEPROM, and verifying fault detects circuits.

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

10.11.1 Power on Diagnostics

At power on time the following tests are executed:

1. Validation of ROM and EEPROM
2. RAM test for internal RAM
3. Test and Initialize HDC registers
4. RAM test for Sector Buffer
5. Start Spindle Motor (if enabled)
6. Calibration of Actuator
7. Read/Write test for all Heads
8. Validation of RAM code and data table (RDM, Log, Mode Page) from the Reserved Area

If Auto spin up is disabled, steps 5 - 8 will be executed by the first START STOP UNIT command which has the Start bit set.

Faults detected before successful completion of the HDC section could prevent the drive from responding to a selection.

Faults detected after the successful completion of the HDC test section 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. Detecting a fault during power on will not terminate execution of the tests nor will it terminate the power on process.

10.11.2 Self-test via SEND DIAGNOSTIC Command

10.11.2.1 Default Self-test

The default self-test is invoked by the SftSt 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. **Spin check** is to check if the spindle motor is running at the correct speed.
2. **Write, Read, and Compare test** is a disk read/write test. It writes data to a predefined location in the reserved area and then reads it back and validates the content. All heads are tested.
3. **Seek test** is a servo test. It validates seeks to 256 random locations out of the full volume.

10.11.2.2 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. A value of FFFFh indicates that the extended self-test takes 65535 seconds or longer. See also the EXTENDED SELF-TEST COMPLETION MINUTES field in Table 81. The results of self-test can be retrieved via the LOG SENSE command for Log Page 10h.

10.11.2.3 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 drive 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 322 Short and Extended Self-Test Description

| Segment Number | Short Self-Test | Extended Self-Test | Test Description |
|----------------|-------------------------------------------------------|------------------------|--------------------------------------------------------------------------------------------------|
| 1h | Drive Ready Test | | Internal check to ensure 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 10.11.2.1 |
| 3h | SMART | | Perform SMART testing and check results to ensure that SMART threshold criteria are not exceeded |
| 4h | Low Level Format Check | | Check to ensure that the media is currently not in the MEDIA FORMAT CORRUPTED state. |
| 5h | Physical Head Check | | Write/Read test on each head in a predefined location in the drive's Reserved Area of the disk. |
| 6h | Random Verify | | Perform 4000 random verify operations and insure no uncorrectable errors. |
| 7h | Verify First 300MB Verify Last 100MB | Verify all LBAs | Sequential verify operation. Ensure that no uncorrectable errors occur within the verify range. |
| 8h | Recheck SMART | | Same as Segment 4h |

10.11.2.4 Background Medium Scan

For a related function, see Mode Page 1C (Informational Exceptions Control).

10.12 Idle Time Function

The drive periodically saves data in logs and S.M.A.R.T. counters in the reserved area of the disks. The information is used by the drive to support various SCSI commands and for the purpose of failure analysis.

10.13 Command Timeout Limits

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

The following times are for environments where Automatic Reallocation is disabled and there are no queued commands.

10.13.1 Reassignment Time

The drive should be allowed a minimum of 5 seconds to complete a "Reassign Blocks" command.

10.13.2 Format Time

Approximately 28 hours should be allowed for completion of a "Format Unit" command when certification is disabled. Allow 56 hours when certification is enabled. If "Fast Format" is enabled via the FFMT bit in mode page 00h, allow 7 minutes for completion.

10.13.3 Start/Stop Unit Time

The drive should be allowed a minimum of 30 seconds to complete a "Start Stop Unit" command (with Immed bit = 0). Initiators should also use this time to allow startup sequences initiated by auto start up and "Start Stop Unit" commands (with Immed bit = 1) to complete and place the drive in a "ready for use" state.

Note: *Extended command execution time of up to 90s can occur after power cycle or F/W download due to additional time required for media cache destaging.*

Note: *A time-out of one minute or more is recommended but NOT required. The larger system time-out limit allows the system to take advantage of the extensive ERP/DRP that the drive may attempt in order to successfully complete the startup sequence.*

Note: *For SAS devices a NOTIFY(Enable Spinup) primitive is required prior to actually starting to spin up the spindle motor (regardless of whether a Start Stop Command with the Start bit set, was received or not).*

10.13.4 Medium Access Command Time

The time-out limit for medium access commands that transfer user data or non-user data or both should be a minimum of 30 seconds. These commands are

- Pre-Fetch
- Read
- Read Defect Data
- Seek
- Send Diagnostic (Function Code = 0)
- Read Long
- Write
- Write and Verify
- Write Buffer
- Write Same
- Verify

Note: *The 30-second limit assumes the absence of bus contention and data transfers of 64 blocks or less. This time should be adjusted for anticipated bus contention and if longer user data transfers are requested.*

10.13.5 Time-out Limits for Other Commands

The drive should be allowed a minimum of 30 seconds to complete these commands:

- Inquiry
- Log Select
- Log Sense
- Mode Select
- Mode Sense
- Persistent Reserve In/Out
- Read Buffer
- Read Capacity
- Read Long
- Reassign Blocks (Note 1)
- Release
- Request Sense
- Reserve
- Security Protocol In/Out (Note 1)
- Set/Report Device Identifier
- Start/Stop Unit (Note 1)
- Synchronize Cache
- Test Unit Ready
- Write Buffer (Note 1)
- Write Long (Note 1)

The command time-out for a command that is not located at the head of the command queue should be increased by the sum of command time-outs for all of the commands that are performed before it is.

Note 1: *Extended command execution time of up to 90s can occur after power cycle or F/W download due to additional time required for media cache destaging.*

10.14 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.
3. System architecture should include all error handling recommendations made in this section. Deviations should have mutual agreement between Drive development and system integration.

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:

8.22.2 OC - Write error

8.22.2 11 - Unrecovered read error

8.22.2 14 - No record found

8.22.2 16 - Data Synchronization mark error

8.22.2 17 - Recovered read error without LDPC correction

8.22.2 18 - Recovered read error with LDPC correction

Typically, data errors do not include positioning of the heads or the data path through the electronics.

Non data errors are those errors that do not have a direct relationship with transferring data to and from the media.

Non data 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.

10.14.1 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

10.14.2 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.

8.22.2 Valid bit and error code (Sense byte 0)

8.22.2 Sense Key (Sense byte 2)

8.22.2 Information bytes (Sense bytes 3 through 6)

8.22.2 Command specific information (Sense bytes 8 through 11)

8.22.2 Additional Sense Code (Sense byte 12)

8.22.2 Additional Sense Code Qualifier (Sense byte 13)

8.22.2 Field Replaceable Unit (Sense byte 14)

8.22.2 Sense Key Specific (Sense bytes 15, 16, and 17)

8.22.2 Vendor Unique error information (Sense bytes 20 through 23)

10.14.3 Data Recovery Procedure

Statistically, most data error activity is noise related and has nothing to do with defects in the media. It is wrong for the system to assume that every data error reported occurred because of a defect in the media. It is also wrong for the system to assume that every data error that occurred because of a media defect rendered the Drive unusable.

Recurring data error activity at the same physical location is an indication of a problem. The problem can be due to a media defect or magnetic damage. A media defect is physical damage to the recording capability of the media while magnetic damage is a defect in the bit pattern written to the media.

In both cases, the error can be corrected without replacing the unit. The physical sector may require relocation. The Drive determines the need to reassign a sector. The Mode Select Page 1 option bit ARRE (See Section 8.11.3) set active allows the Drive to relocate recovered read data errors. Non recovered data errors or the ARRE bit being inactive will have additional sense codes returned to recommend reassignment of sectors.

The need to reassign a sector should be infrequent. Sites not meeting error rate criteria are removed from use during SAT (Surface Analysis Test) in Drive manufacturing. With the exception of some early life SAT escapes (sites that were marginally missed during SAT), reassigning defective sectors should be rare. Frequent sector reassignment may be an (early) indication of another type of failure. Sector reassignments are monitored as part of the predictive failure analysis. When a threshold is exceeded, the Drive will notify the initiator that a scheduled service action is required.

Drive soft error rates are based on extraneous random faults that are not predictable. Media defects discovered after the Drive completes manufacturing final test need to be relocated so that soft error rates are not influenced by predictable known error sites. Failure of the system to properly relocate defective media sites can have a direct influence on system throughput and drive error rates.

10.14.3.1 Reassign a Physical Sector

The Drive determines the need to reassign physical sectors based on error activity. Once a physical sector requires reassignment, the Drive will reassign the physical sector.

10.14.3.2 Data Error Logging

The Drive will report data errors to the initiator that do not require immediate action (successful auto reallocation, successful auto rewrite, or no action needed on this occurrence). The initiator should log these errors in the system error log. No other action is required.

Table 323 Log Only Errors

| Key | Code | Qual | Description |
|-----|------|------|------------------------------------------------|
| 1 | 16 | 00 | Data Synchronization Mark Error |
| 1 | 17 | 01 | Recovered Data with Retries |
| 1 | 17 | 06 | Recovered Data without LDPC - Auto Reallocated |
| 1 | 17 | 09 | Recovered Data without LDPC - Data Rewritten |
| 1 | 18 | 00 | Recovered Data with LDPC |
| 1 | 18 | 02 | Recovered Data with LDPC - Auto Reallocated |
| 1 | 18 | 07 | Recovered Data with LDPC - Data Rewritten |

10.14.3.3 Reassign Blocks Recovery

The Drive provides the capability to remove media defects without reducing capacity.

Recovery from a failed reassignment consists of the following actions:

- Updating the defect descriptor to remove the LBA's that have been successfully reassigned and then retry the Reassign Blocks command. The LBA contained in the Command Specific Information field of the Sense Data is the LBA in the first defect descriptor that was not reassigned because of the failure. If the command failed because of an unrecoverable read error other than those specified in the defect descriptor, add this LBA to the defect descriptor and retry the command. Refer to Section 8.29 for additional information.
- If the retried Reassign Blocks (07) command completes successfully, returning to normal processing.
- If the retried Reassign Blocks (07) command fails, service the drive using the service guidelines recommended in Section 10.14.1.

10.14.4 Non data Error Recovery Procedure

The drive will follow a logical recovery procedure for non data 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.

10.14.4.1 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.

8.22.2 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 Status*.
- If the drive has been busy for longer than the limit specified in Section 10.13, "Command Timeout Limits" then service the drive using the service guidelines recommended in Section 10.14.1 "Drive Service Strategy" Otherwise return to normal processing.

8.22.2 If the *Test Unit Ready (00)* (or media access) command completes with *Good Status*, then return to normal processing.

10.14.4.2 Unrecovered Drive Error

The initiator should retry the failing command.

1. If the retry of the failing command completes with *Good Status* or recovered Sense Key, follow the recovery procedure in Section 10.14.4.3 "Recovered Drive Error".
2. 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.
 - a. If the retry of the failing command completes with *Good Status*, follow the recovery procedure in next Section 10.14.4.3 "Recovered Drive Error".
 - b. 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 10.14.1 "Drive Service Strategy".

10.14.4.3 Recovered Drive Error

The Initiator should log the error as soft with the recovery level.

10.14.4.4 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.
3. If the drive fails to come ready within the specified time, service the drive using the service guidelines specified in Section 10.14.1 "Drive Service Strategy".
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 10.14.1 "Drive Service Strategy".

10.14.4.5 No Defect Spare

Three conditions can cause this error:

1. When the *Reassign Blocks (07)* command is issued and there are no spares available for the Drive to use for the relocation requested.
2. When the GList is full and the sector to be reassigned cannot be added.
3. During a format operation, there was not enough space available to fulfill the spare requirement (DList is too large).

Service the Drive following Section 10.14.1 "Drive Service Strategy".

10.14.4.6 Degraded Mode

Refer to Section 10.1.9 "Degraded Mode", for the definition of this state. There are three causes for entering degraded mode. In all cases the Sense Key is *Not Ready*. The causes are the following:

1. Sense Code/Qualifier of *Logical Unit Not Ready, initializing command required*. The spindle motor not spinning or not at the proper speed. This may not be an error condition. The initiator should issue a *Unit start (1B)* command to start the spindle motor. If the Drive fails to come ready in the time specified in Section 10.13, service the drive using the service guideline recommended in Section 10.14.1.
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 10.14.1

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 10.14.1

Internal target failures

The drive periodically adjusts the track following for each head to compensate for expansion and contraction of the disks due to temperature changes. If one of these adjustments fails, the drive will enter a degraded mode to prevent writing data off track.

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 10.14.1, 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), Sense Code/Qualifier of **Medium Format Corrupted Reassign Failed** Reassign Blocks (07) command, or an automatic reallocation failed or was abnormally terminated.

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 10.14.1.

If the above defined recovery procedures fail to clear the degraded mode condition, the Drive should be replaced. Follow the procedure in Section 10.14.1 when replacing the drive.

10.14.4.7 Reserved Area Hard Error

Sectors found defective in the reserved area of the disk cannot be reassigned after the Drive leaves the factory. The data in the reserved area is not directly accessible by the initiator. For this reason, the reserved area has backup copies of all data. A data error must occur in both copies of the data record before the Drive considers a reserved area read error. When this happens, the integrity of the drive is questionable.

Service the Drive using Section 10.14.1.

10.14.4.8 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 10.14.1.
 - *Other*, follow the recommendations for the error condition reported.

10.14.4.9 Aborted Command

The initiator should determine the cause from the Additional Sense Code (byte 12):

8.22.2 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.

8.22.2 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 Status*, 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 Status*, log the error as recovered.
 - Abort command sense, then service the drive using the service guideline recommended in Section 10.14.1.

8.22.2 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.

10.14.4.10 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, Hard Reset, LUN Reset TMF 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 8.7). 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 Section 8.48). A Unit Attention Condition is reported to all initiators excluding the initiator that issued the Set Device Identifier command.

Persistent Reserve Out 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.

10.14.4.11 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 the microcode version mismatch, the most likely cause is the result of incorrect parts used during a service action.

If the error reported is 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 Status*, 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 10.14.1.

10.14.4.12 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 stop the spindle motor. The initiator can recover by

1. Logging the error
2. Retrying the failing command. If the failing command completes with:
 - *Good Status*, return to normal processing
 - Self-initiated reset sense, service the drive according to the guidelines recommended in Section 10.14.1.
 - Other, follow the recommendations for the error reported.

10.14.4.13 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. The initiator should request one list at a time. If a single list exceeds the maximum returnable length, this may be an indication of a marginally operational drive. Service the drive following the service guidelines in Section 10.14.1.

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 physical (cylinder, sector, head) format. This is the default format. There is no initiator action required for this condition.

10.14.4.14 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 10.14.1.
 - 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 10.14.1.

10.14.4.15 Microcode Error

The microcode from the interface is validated before the device operates using that microcode. When the validation detects incorrect or incomplete data, 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

8.22.2 *Good Status* - return to normal processing

8.22.2 *Check Condition Status* - service the drive using the service guidelines recommended in Section 10.14.1.

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 10.14.1.

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

8.22.2 *Good Status*, return to normal processing. Retry the failing command. If the task completes with

- *Good Status* - Continue normal processing.
- *Check Condition Status* for check sum error - Service the drive using the service guidelines recommended in Section 10.14.1.
- *Check Condition Status* for any other error - follow the recommended recovery procedure for the error reported.

8.22.2 *Check Condition Status* for Check sum error, service the drive using the service guidelines recommended in Section 10.14.1.

8.22.2 *Check Condition Status* for any other error, follow the recommendations for the returned sense data.

10.14.4.16 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 10.14.1.

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.

10.15 RAID Rebuild Assist

A rebuild operation is performed when some or all of the LBAs on a logical unit have become unreadable in a storage array controller and a new logical unit is being initialized to replace the failed logical unit. The data for the new logical unit may be constructed by reading the data from remaining logical units and using that data to reconstruct the data to be written to the replacement logical unit.

The rebuild assist mode allows the storage array controller controlling the rebuild process to determine which logical blocks on the failed logical unit are unreadable without having to read every LBA to determine the unreadable logical blocks (i.e., the read command is terminated with CHECK CONDITION status and the failed LBA is reported in the sense data). The storage array controller then may reconstruct the failed logical blocks. The remaining logical blocks may be copied to the replacement logical unit.

The application client should issue sequential read commands to read the available data from the failed logical unit. If a read command does not encounter an unrecoverable LBA, then the read command should complete without error.

The rebuild assist mode allows reporting of an unrecovered read error or write error that is predicted (i.e., predicted unrecovered error). Predicted unrecovered errors may be determined by the device server when rebuild assist mode is enabled.

The rebuild assist mode also allows reporting of an unrecovered read error or write error that is unpredicted (i.e., unpredicted unrecovered error). Unpredicted unrecovered errors are any unrecovered error that is not predicted when the rebuild assist mode is enabled.

If the device server encounters predicted unrecoverable LBAs on a read command, then:

- A) The sense key is set to ABORTED COMMAND
- B) The additional sense code is set to MULTIPLE READ ERRORS
- C) The INFORMATION field is set to the LBA of the first unrecoverable logical block
- D) The COMMAND-SPECIFIC INFORMATION field is set to the LBA of the last unrecovered logical block in a sequence of contiguous unrecovered logical blocks that started with the LBA specified in the INFORMATION field.

10.15.1 Rebuild Assist diagnostic page

The Rebuild Assist diagnostic page provides:

- A) A method to put the logical unit in the rebuild assist mode.
- B) A method to put the logical unit in a simulated failure mode in conjunction with the rebuild assist mode.

10.15.1.1 Rebuild Assist input diagnostic page

An application client may send a RECEIVE DIAGNOSTIC RESULTS command to retrieve information about a rebuild assist mode that may be enabled.

Table 324 Rebuild Assist input diagnostic page

| Byte | Bit | | | | | | | |
|--------------|-----------------------------|-------------------------------|---|---|---|---|---|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Page Code = 42h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2-3 | (MSB) | Page Length = 4 + 2n | | | | | | (LSB) |
| 4 | Reserved = 0 | | | | | | | ENABLED |
| 5 | Reserved = 0 | | | | | | | |
| 6 | Reserved = 0 | | | | | | | |
| 7 | PHYSICAL ELEMENT LENGTH (n) | | | | | | | |
| 8-(7+n) | (MSB) | DISABLE PHYSICAL ELEMENT MASK | | | | | | (LSB) |
| (8+n)-(7+2n) | (MSB) | DISABLE PHYSICAL ELEMENT | | | | | | (LSB) |

An ENABLED bit set to one indicates that the rebuild assist mode is enabled. An ENABLED bit set to zero indicates that the rebuild assist mode is disabled.

The PHYSICAL ELEMENT LENGTH field indicates the length in bytes of the DISABLED PHYSICAL ELEMENT MASK field and the length in bytes of the DISABLED PHYSICAL ELEMENT field.

The bits in the DISABLED PHYSICAL ELEMENT MASK field indicate the bits in the DISABLED PHYSICAL ELEMENT field that are supported. Each bit set to one in the DISABLED PHYSICAL ELEMENT MASK field indicates that the corresponding bit in the DISABLED PHYSICAL ELEMENT field is supported and may be set to one in a Rebuild Assist Output diagnostic page sent with a SEND DIAGNOSTIC command.

The bits in the DISABLED PHYSICAL ELEMENT field indicate the physical elements that are disabled in this logical unit. Each bit set to one indicates that a physical element is disabled, and the device server shall report predicted read errors and predicted write errors for the associated group of LBAs.

10.15.1.2 Rebuild Assist output diagnostic page

An application client may send a SEND DIAGNOSTIC command to:

- A) Enable rebuild assist mode.
- B) Enable rebuild assist mode with disabling of physical elements (i.e., to simulate predicted failure of physical elements)
- C) Disable rebuild assist mode.

Table 325 Rebuild Assist output diagnostic page

| Byte | Bit | | | | | | | |
|--------------|-----------------------------|-------------------------------|---|---|---|---|---|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Page Code = 42h | | | | | | | |
| 1 | Reserved = 0 | | | | | | | |
| 2-3 | (MSB) | Page Length = 4 + 2n | | | | | | (LSB) |
| 4 | Reserved = 0 | | | | | | | ENABLED |
| 5 | Reserved = 0 | | | | | | | |
| 6 | Reserved = 0 | | | | | | | |
| 7 | PHYSICAL ELEMENT LENGTH (n) | | | | | | | |
| 8-(7+n) | (MSB) | DISABLE PHYSICAL ELEMENT MASK | | | | | | (LSB) |
| (8+n)-(7+2n) | (MSB) | DISABLE PHYSICAL ELEMENT | | | | | | (LSB) |

An ENABLE bit set to one specifies that, after all fields in this diagnostic page have been validated:

- a) a self-test of the physical elements in the logical unit may be performed; and
- b) rebuild assist mode is enabled.

An ENABLE bit set to zero specifies that:

- a) rebuild assist mode shall be disabled;
- b) the other fields in this page shall be ignored; and
- c) all physical elements shall be enabled.

The PHYSICAL ELEMENT LENGTH field shall be set to the same value that is returned from the Rebuilt Assist input diagnostic page.

If the PHYSICAL ELEMENT LENGTH field is not set to the same value, 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.

The device server shall ignore the DISABLED PHYSICAL ELEMENT MASK field.

Each bit in the DISABLE PHYSICAL ELEMENT field specifies a physical element that shall be disabled. A bit set to one in the DISABLE PHYSICAL ELEMENT field specifies that the device server shall respond to read commands and write commands specifying LBAs associated with that physical element as if the associated LBAs have predicted errors. A bit set to zero in the DISABLE PHYSICAL ELEMENT field specifies that the device server shall respond to read commands and write commands specifying LBAs associated with that physical element as if the associated LBAs do not have predicted errors. If the ENABLE bit is set to one, and the DISABLE PHYSICAL ELEMENT field specifies:

- a) any bits set to one that are not supported by the logical unit;
- b) any bits that are supported by the logical unit are set to one; or
- c) setting to zero any bits that are set to one,

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.

11 Firmware Security

This chapter provides information on Western Digital encryption-specific HDD firmware and features. It is assumed that the reader is familiar with the referenced specifications and industry standards.

11.1 Referenced Specifications and Standards

11.1.1 TCG Specifications

This section references 3 separate TCG specifications, which are available on the TCG website: (<http://www.trustedcomputinggroup.org/>):

- TCG Core Specification, Version 2.01, Revision 1.00 (8/15/2015)
 - The TCG Core Specification is the general specification for trusted computing that encompasses all classes of devices, including storage
- TCG Storage Interface Interactions Specification (SIIF), Version 1.07, (1/30/2013)
 - Specifies the interaction between the HDD and the SCSI/ATA protocols
- TCG Storage Security Subsystem Class (SSC): Enterprise, Version 1.01, rev 1.01 (8/5/2015)
 - 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
- TCG Storage Application Note: Encrypting Storage Devices Compliant with SSC: Enterprise, Version 1.00 Revision 1.00 Final
- TCG Storage Security Subsystem Class: Opal Specification, Version 2.01 Final Revision 1.00 (8/5/2015)

11.1.2 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 (<https://csrc.nist.gov/publications/fips/>):

- FIPS 197, Advanced Encryption Standard (AES), 2003 May
- FIPS 180-4, Secure Hash Standard (SHS), 2015 August
- FIPS PUB 186-5, Digital Signature Standard, 2023 February
- FIPS 140-3, Security Requirements for Cryptographic Modules – 2019 March
- FIPS 198-1, The Keyed-Hash Message Authentication Code, 2008 July

This section references the following NIST publications, available on the NIST website (<https://csrc.nist.gov/publications>)

- [SP 800-38A] Recommendation for Block Cipher Modes of Operation: Methods and Techniques, NIST, 2001 December
- [SP800-38E] Recommendation for Block Cipher Modes of Operation: The XTS-AES Mode for Confidentiality on Storage Devices, SP800-38E, NIST, 2010 January
- [SP800-38F] Recommendation for Block Cipher Modes of Operation: Methods for Key Wrapping, NIST, December 2012
- [SP800-57] Recommendation for Key Management – Part I General (Revision 5), NIST, 2020 May
- [SP800-90A] Recommendation for Random Number Generation Using Deterministic Random Bit Generators, NIST, 2015 June
- [SP800-90B] Recommendation for the Entropy Sources Used for Random Bit Generation, NIST, 2018 January
- [SP800-131A] Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, NIST, 2011 January
- [SP800-132] Recommendation for Password-Based Key Derivation, NIST, 2010 December

- [SP800 38A] Recommendation for Block Cipher Modes of Operation: Methods and Techniques, NIST, 2001 December
- [SP800 133] Recommendation for Cryptographic Key Generation (Revision 2), NIST, 2020 June
- [SP800-140C] CMVP Approved Security Functions: CMVP Validation Authority Updates to ISO/IEC 24759 (Revision 1), NIST, 2023 July
- [SP800-140D] CMVP Approved Sensitive Security Parameter Generation and Establishment Methods: CMVP Validation Authority Updates to ISO/IEC 24759 (Revision 2), NIST, 2023 July

11.1.3 RSA Laboratories Standards

RSA PSS per Public-Key Cryptography Standards (PKCS) #1 v2.1, <http://www.rfc-editor.org/info/rfc8017>

11.1.4 Other Standards

- T10 SCSI Standard.(T10 homepage - <http://www.t10.org/index.html>)
- [ISO 19790] ISO/IEC 19790, Information technology - Security techniques - Security requirements for cryptographic modules, International Organization for Standardization (ISO), December 2015, <https://www.iso.org/home.html>

11.2 Implementation Exceptions

The following is a list that describes non-compliance with the TCG Enterprise SSC specification:

- The TCG Enterprise SSC specification allows support for 1024 bands, but the implementation supports up to 16 bands.
- Bands must be 4K aligned. This means Band start (Range start) and Band size (Range size) must be 4K aligned.
- Only one active session is permitted at a time. If a new session is requested when a session is already active, the drive answers the host with SP_BUSY, instead of NO_SESSIONS_AVAILABLE

11.3 Implementation Features and Details Outside of TCG Specifications

The following features are outside of the TCG specifications.

1. Local Ports
2. Firmware signing

The following implementation details are outside of the TCG SSC specification.

- a. The TCG Enterprise SSC Specification states "The TPer SHALL implement the ParamCheck Longitudinal Redundancy Check (LRC) for Get and Set method calls on a PIN value". If the LRC check is erroneously applied to a value other than a PIN it will be ignored, therefore no error is generated.
- b. When handling a "TCG command followed by a Rear/Write 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 Read/Write command ordering and plan accordingly.
- c. The TPer replies with SP_BUSY for requests beyond 1 session.
- d. TCG Life Cycle Model by Activate Method and Revert Method is implemented per Opal SSC specification.

11.4 Encryption Algorithms

11.4.1 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 Western Digital TCG Enterprise SSC implementation in firmware supports AES 256-XTS only.

The AES hardware implementation used for the range encryption has received the FIPS 197 certification by the US National Institute of Standards (NIST), which are available on the NIST website.

11.4.2 ‘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). This Vendor Specific section is documented below.

Table 326 Vendor Specific Data for Level 0 Discovery

| Byte | Bit | | | | | | | |
|-------|-----------------------------------|------|---|---|--------|---------|-----------|---------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 16 | Version (set to 0) | | | | | | | |
| 17 | Vendor Specific State Information | | | | | | | |
| 18 | Reserved = 0 | | | | | | | |
| 19 | Reserved | MB_s | 0 | 0 | Diag_s | Dload_s | Locking_s | FDE_s |
| 20 | Reserved = 0 | | | | | | | |
| 21 | Reserved | MB_e | 0 | 0 | Diag_e | Dload_e | Locking_e | FDE_e |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | In FIPS |
| 23-47 | Reserved = 0 | | | | | | | |

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.

Diag_s/Diag_e - Support for Admin SP vendor specific Diagnostic port / Diagnostics port via Admin SP is locked.

Dload_s/Dload_e - support for Admin SP Firmware download port / Firmware download port via Admin SP is locked.

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).

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.

in FIPS – This bit is set to 1 when the drive operates in FIPS Approved mode.

11.4.2.1 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.

11.4.3 Deterministic Random Bit Generation (DRBG)

Pseudo-random number generation is implemented with a certified NIST SP800-90A DRBG. The DRBG uses AES as a primitive for both entropy mixing and entropy output. DRBG state is kept private to ensure that the keys that are generated by the device are unpredictable. An SP 800-90B validated ring oscillator entropy noise source seeds the DRBG..

11.4.4 Key Wrap

The NIST SP800-38F key wrap algorithm is used to encrypt a key with another key (KEK= Key Encryption Key).

11.4.5 Key Erasure

Cryptographic erase procedure

- Erase and overwrite wrapped key material with 0x00.
- Erase and store the new wrapped key material.

11.5 TCG SSC Tables

Two copies of all TCG SSC 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 SP' C_PIN table
- K_AES_256 table
- 'Locking SP' Locking Access Control table
- 'Locking Info' Table
- 'Locking SP' Locking 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.

11.5.1 'Admin SP' C_PIN and 'Locking SP' C_PIN Tables

Per TCG Enterprise SSC specification, the PIN is set to the MSID at manufacturing time. Try Limit 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 327 Western Digital Default Values for 'Admin SP' C_PIN & 'Locking SP' C_PIN

| PIN | Try Limit | Tries | Persistence |
|------|-----------|-------|-------------|
| SID | 0 | 0 | 0 |
| MSID | 0 | 0 | 0 |

11.5.2 K_AES_256 Table

The K_AES_256 table has as many rows, as number of max Bands supported, 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. Note that Name/Common Name/Key columns are present, but are not accessible to the operator (e.g., via TCG::Get)

Table 328 Western Digital Implementation of K_AES_256 Table

| UID (8 byte hex) | MODE |
|-------------------------|------|
| 00 00 08 06 00 00 00 01 | 7 |
| 00 00 08 06 00 00 00 02 | 7 |
| ... | ... |
| 00 00 08 06 00 00 00 06 | 7 |

The mode is specified in the TCG Enterprise SSC as a "Vendor Unique" (VU) entry. Western Digital initializes it in manufacturing to **mode=7** (media encryption mode, per TCG specification) for all TCG Band entries.

11.5.3 ‘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 **Encryption Support=23** (media encryption mode) in manufacturing.

Table 329 Western Digital Implementation of ‘Locking Info’ Table

| NAME | Version | Encrypt Support | Max Ranges | Max ReEncryptions | Keys Available Cfg |
|---------------|---------|-----------------|------------|-------------------|--------------------|
| ‘LockingInfo’ | 0 | 1 | 16 | 0 | 0 |

11.5.4 ‘Locking SP’ Locking Table

The “Vendor Unique” (VU) values for this table are shown below.

Table 330 Western Digital Implementation of ‘Locking SP’ Locking Table

| Next Key | ReEncrypt State | ReEncrypt Request | Adv Key Mode | Verf Mode | Cont On Reset | Last ReEncrypt LBA | Last Re Enc Stat | 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 0Fh | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In the **ActiveKey** column, the Enterprise SSC allows for byte 3 to be defined as either 05 or 06. The Western Digital implementation uses 06.

11.6 Firmware Download and Signing

The Western Digital 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 HDD.

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 140-3.

All Western Digital firmware packages will be signed. If the signature cannot be successfully verified, the firmware cannot be downloaded onto the Western Digital 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.

11.7 Revert Feature

Western Digital has extended TCG Enterprise to include the TCG Opal Revert method. Revert enables the customer, as needed by organizational policy, to overwrite existing TCG settings to the default values that were written during manufacturing.

Revert introduces a new TCG authority, PSID, to the Admin SP. During manufacturing, the PSID is hashed, and the digest is stored in a reserved area inside the drive. During manufacturing, the PSID is printed, in plaintext, on the drive's physical, external label. The PSID PIN cannot be accessed via the drive's interface, and it cannot be changed.

Below is the procedure to execute Revert:

- Start Session on the Admin SP
- Authenticate to the PSID authority
- Execute the Revert Method
- Successful completion of Revert automatically ends the TCG session

Notes for Revert include:

- Revert execution that encounters an error does not close the TCG session
- Reset of the drive during Revert will cause the subsequent power up sequence to be extended while Revert finishes its work

New ACE table entries related to Revert are illustrated in the following table.

Table 331 PSID Authority Added to 'Admin SP' Authority Table

| UID | Name | Common Name | IsClass | Class | Enabled | Operation | Credential |
|----------------------------------------------|------|--------------------|---------|-------|---------|-----------|------------|
| 00 00 00 09 00 01 FF 01 | PSID | PhysicalDriveOwner | F | Null | T | Password | C_PIN_PSID |

Table 332 PSID Addition to 'Admin SP' C_PIN table

| UID | Name | Common Name | PIN | CharSet | TryLimit | Tries | Persistence |
|----------------------------|------------|--------------------|-----|---------|----------|-------|-------------|
| 00 00 00 09 00 01 FF 01 | C_PIN_PSID | PhysicalDriveOwner | VU | Null | 0 | 0 | FALSE |

Table 333 Additions to 'Admin SP' Access Control Table

| InvokingID | MethodID | ACL | GetACL ACL |
|------------------------------------------|--------------------------------------|------------------------------------------------------------|-------------------------------------------|
| AdminSPObj 00 00 02 05 00 00 00 01 | Revert 00 00 00 06 00 00 02 02 | ACE_SP_SID_ACE_SP_PSID 00 00 00 08 00 01 00 E0 | ACE_Anybody 00 00 00 08 00 00 00 01 |
| PSID 00 00 00 09 00 01 FF 01 | Get 00 00 00 06 00 00 00 06 | Anybody 00 00 00 08 00 00 00 01 | Anybody 00 00 00 08 00 00 00 01 |
| PSID 00 00 00 09 00 01 FF 01 | Set 00 00 00 06 00 00 00 07 | ACE_Makers_Set_Enabled 00 00 00 08 0003 00 01 | Anybody 00 00 00 08 00 00 00 01 |
| C_PIN_PSID 00 00 00 0B 00 01 FF 01 | Get 00 00 00 06 00 00 00 06 | ACE_C_PIN_Get_PSID_NoPIN_UID 00 00 00 80 00 01 00 E1 | Anybody 00 00 00 08 00 00 00 01 |

11.8 Ports

The ports capability is a Western Digital 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 exception of having to authenticate, is anyone can use the Get Firmware Download Port Values command without authenticating. 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 Access Control Table. The ports table and the modified TCG SSC tables are shown below

Table 334 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, Lock On Reset 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 Western Digital 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 Western Digital in debugging |

Table 335 Ports Table

| UID | Name | LockOnReset | PortLocked |
|-------------------------|---------------------|-------------|------------|
| 00 01 00 02 00 01 00 02 | Firmware_Dload_Port | Null | FALSE |
| 00 01 00 02 00 01 00 01 | Diagnostic_Port | PowerCycle | TRUE |

| 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_GetDiag | "" | 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_SetPort ¹ | "" | 00 00 00 09 00 00 00 06 | Null | Null | "PortLocked" | "PortLocked" |
| 00 00 00 08 00 00 8C 09 | SID_GetPort ¹ | "" | 00 00 00 09 00 00 00 06 | Null | Null | "LockOnReset" | "PortLocked" |
| 00 00 00 80 00 01 00 E1 | ACE_C_PIN_Get_PSID_NoPIN | "" | 00 00 00 09 00 00 00 01 | Null | Null | "" | "" |
| 00 00 00 08 00 01 00 E0 | ACE_SP_PSID | "" | 00 00 00 09 00 01 FF 01 | Null | Null | "" | "" |
| 00 00 00 09 00 01 FF 01 | ACE_Makers_Set_Enabled | "" | 00 00 00 09 00 00 00 06 | Null | Null | "" | "" |

¹ These lines are the additional entries required to implement the firmware download port.

| Row Number | UID | Invoking ID | Method ID | Common Name | ACL | Log | Add ACE ACL | Remove ACE ACL | Method ID |
|------------|-----|-------------------------------------------------------------|----------------------------------------------|--------------------------------------------------|-----------------------------------------------|------|-------------|----------------|----------------------------------------------|
| VU | VU | 00 00 00 00 00 00 00 01 (This SP) | 00 00 00 06 00 00 00 0C (Authenticate) | Anybody Authenticate Admin SP | 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 (Anybody Authority object) | 00 00 00 06 00 00 00 06 (Get) | Anybody-Get- Anybody Authority Object | 00 00 00 08 00 00 00 01 (Anybody) | None | Null | Null | 00 00 00 08 00 00 00 01 (Anybody) |
| VU | VU | 00 00 00 09 00 00 00 03 (Makers Authority object) | 00 00 00 06 00 00 00 06 (Get) | Anybody-Get- Anybody 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_Set Self- Set-SID_C_PIN object | 00 00 00 08 00 00 8C 03 (SID_SetSelf) | None | Null | Null | 00 00 00 08 00 00 02 01 (SID) |
| VU | VU | 00 00 00 0B 00 00 84 02 (MSID C_PIN object) | 00 00 00 06 00 00 00 06 (Get) | MSID_Get-Get- MSID C_PIN object | 00 00 00 08 00 00 8C 04 (MSID_Get) | None | Null | Null | 00 00 00 08 00 00 02 01 (SID) |
| VU | VU | 00 00 00 09 00 00 00 03 (Makers Authority object) | 00 00 00 06 00 00 00 07 (Set) | SID_SetMakers- Set-Makers Authority Object | 00 00 00 08 00 00 8C 05 (SID_SetMakers) | None | Null | Null | 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 | Null | Null | 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 | Null | Null | 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 | Null | Null | 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_SetD iag | None | Null | Null | 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_SetD iag | None | Null | Null | 00 00 00 08 00 00 02 01 (SID) |

11.9 MSID

The MSID is set for each drive at the time of manufacturing to a random 32-byte value, based on TCG rules. The MSID is accessible two ways:

- On the device label
- Electronically accessible via TCG tables. The MSID value is stored in the PIN column of the MSID C_PIN object.

11.10 Logging

Western Digital logging functions will not record any sensitive data such as customer plain text data, passwords, encryption keys or wrapping keys.

11.11 Number of Sessions

The Western Digital 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.

11.12 Number of Bands

The Enterprise SSC specification calls for support of up to 1024 bands. The Western Digital implementation supports a maximum of 16 bands.

Bands must be 4K aligned. This means Band start (Range start) and Band size (Range size) must be 4K aligned.

11.13 Number of COMIDs

The Western Digital Enterprise SSC implementation supports 2 COMIDs, the minimum requirement in the Enterprise SSC specification. Only 1 COMID can be in use at any time.

11.14 Locked and Unlocked Behavior

11.14.1 T10 SCSI Commands

The table below describes how basic T10 SCSI commands behave on encryption drives in the locked and unlocked states.

Table 337 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. |
| GET PHYSICAL ELEMENT STATUS (9E/17) | OEM | OEM |
| 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 snap shorted 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 (3E) | OEM | Ent_A authorized only |
| REASSIGN BLOCKS (07) | OEM | Command access denied if the effective range is locked. |
| RECEIVE DIAGNOSTICS RESULTS (1C) | OEM | OEM |
| RELEASE (17) | OEM | OEM |
| RELEASE (57) | OEM | OEM |
| REMOVE ELEMENT AND TRUNCATE (9E/18) | OEM | Command can't be executed when locked. Must unlock with MSID or password, due to formatting. |
| 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 |
| RESTORE ELEMENTS AND REBUILD (9E/19) | OEM | Command can't be executed when locked. Must unlock with MSID or password, due to formatting. |

| | | |
|----------------------------------------|------------------------------------|----------------------------------------------------------------------|
| REZERO UNIT (01) | OEM | OEM |
| SECURITY_IN | OEM | Per TCG spec. Contains TCG payload. |
| SECURITY_OUT | OEM | Per TCG spec. Contains TCG payload. |
| 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 |
| VERIFY (2F) | OEM | Command access denied if the effective range is locked. |
| VERIFY (12) - (AF) | OEM | Command access denied if the effective range is locked. |
| VERIFY (16) - (8F) | OEM | Command access denied if the effective range is locked. |
| VERIFY (32) - (7F/0A) | OEM | Command access denied if the effective range is locked. |
| WRITE (6) - (0A) | OEM | Command access denied if the effective range is locked. |
| WRITE (10) - (2A) | OEM | Command access denied if the effective range is locked. |
| WRITE (12) - (AA) | OEM | Command access denied if the effective range is locked. |
| WRITE (16) - (8A) | OEM | Command access denied if the effective range is locked. |
| WRITE (32) - (7F/0B) | OEM | Command access denied if the effective range is locked. |
| WRITE AND VERIFY (10) - (2E) | OEM | Command access denied if the effective range is locked. |
| WRITE AND VERIFY (12) - (AE) | OEM | Command access denied if the effective range is locked. |
| WRITE AND VERIFY (16) - (8E) | OEM | Command access denied if the effective range is locked. |
| WRITE AND VERIFY (32) - (7F/0C) | OEM | Command access denied if the effective range is locked. |
| WRITE BUFFER (3B) (T10) | OEM (write DRAM on to 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 (3F) | 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 |

11.14.2 TCG Enterprise 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 Enterprise requires the implementation of the Base, Admin, Locking, and Crypto Templates.

Table 338 TCG Enterprise SSC Commands Behavior -1

| 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 Start Session 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 |
| Start Session | Start a session | N/A | N/A |
| Sync Session | Response to say session successfully started. | N/A | N/A |
| Close Session | End (Close) a session | N/A | N/A |

Table 339 TCG Enterprise SSC Commands Behavior -2

| 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. |

Table 340 TCG Enterprise SSC Commands Behavior -3

| Command | Description | unlocked | Locked |
|-------------------------------|---------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|--------------------------------------------------------------------|
| Cryptographic Template | | | |
| Random | This is the only required method in the crypto template for SSC. It is a random number generator in software. | N/A - Not related to bands/data on drive. Authentication required. | N/A - Not related to bands/data on drive. Authentication required. |

Table 341 TCG Enterprise SSC Commands Behavior -4

| 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. |
| GetACL | 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. |

Table 342 TCG Enterprise SSC Commands Behavior -5

| 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 range | Can erase if authorized. | Generates error. |

11.15 Error Codes

All error codes are compliant with the TCG Core specification and SIF, 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.

11.16 Customer Specific Requirements

This specification does not cover customer-specific requirements. Customer-specific requirements are submitted by the customer to Western Digital in the form of a customer-specification document.

11.17 FIPS 140 Cryptographic Officer Instructions

Within FIPS 140-3 the Crypto Officer takes on the role of an individual or a process acting on behalf of an individual that accesses a cryptographic module to perform cryptographic initialization or management functions of a cryptographic module. A cryptographic module's Security Policy defines the required actions necessary to assume the Crypto Officer role and perform all required cryptographic initialization or management functions, and general security services, such as module initialization, management of Critical Security Parameters (CSP), Public Security Parameters (PSP), inspection for tamper evidence, etc.

The Crypto Officer shall faithfully review and execute the instructions within the Security Policy.

Information on FIPS 140 validated modules is posted on a public NIST website at <https://csrc.nist.gov/projects/cryptographic-module-validation-program/module-validation-lists>

Each posting includes a downloadable copy of the Security Policy as well as the applicable FIPS 140 certification number, model names, cryptographic algorithm certificates, validated firmware versions, validated hardware version, the overall security level.

11.17.1 Physical Security

Verify that the drive has not been tampered with by inspecting the tamper evidence labels as described in the Security Policy.

11.17.2 Security Protocol Parameters

11.17.2.1 Security Protocol Information Description Overview

The security protocol information security protocol (i.e., the SECURITY PROTOCOL field set to 00h in a SECURITY PROTOCOL IN command) returns security protocol related information. A SECURITY PROTOCOL IN command in which the SECURITY PROTOCOL field is set to 00h is not associated with a previous SECURITY PROTOCOL OUT command and shall be processed without regard for whether a SECURITY PROTOCOL OUT command has been processed.

If the SECURITY PROTOCOL IN command is supported, the SECURITY PROTOCOL field set to 00h shall be supported as defined in this standard.

11.17.2.2 CDB Description

If the SECURITY PROTOCOL field is set to 00h in a SECURITY PROTOCOL IN command, the contents of the SECURITY PROTOCOL SPECIFIC field are defined as in the table.

Table 343 SECURITY PROTOCOL SPECIFIC Field for SECURITY PROTOCOL IN Protocol 00h

| Type | Code | Description |
|------|------------|----------------------------------|
| M | 0000h | Supported security protocol list |
| M | 0001h | Certificate data |
| O | 0002h | Security compliance information |
| | all others | Reserved |

All other CDB fields for SECURITY PROTOCOL IN command shall meet the requirements stated in Each time a SECURITY PROTOCOL IN command with the SECURITY PROTOCOL field set to 00h is received, the device server shall transfer the data defined in 11.17.2.1 starting with byte 0.

11.17.2.2.1 Supported Security Protocols List Description

If the SECURITY PROTOCOL field is set to 00h and the SECURITY PROTOCOL SPECIFIC field is set to 0000h in a SECURITY PROTOCOL IN command, then the parameter data shall have the format shown in the table.

Table 344 Supported Security Protocols SECURITY PROTOCOL IN Parameter Data

| Byte | Bit | | | | | | | |
|------|-----------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-5 | Reserved = 0 | | | | | | | |
| 6-7 | Supported Security Protocol List Length = m-7 | | | | | | | |
| | Supported Security Protocol List | | | | | | | |
| 8 | Supported Security Protocol (00h) [first] | | | | | | | |
| ... | ... | | | | | | | |
| m | Supported Security Protocol [last] | | | | | | | |
| m+1 | Pad Bytes (if any) | | | | | | | |
| ... | | | | | | | | |
| n | | | | | | | | |
| | | | | | | | | |

- The **SUPPORTED SECURITY PROTOCOL LIST LENGTH** field indicates the total length, in bytes, of the supported security protocol list that follows.
- Each **SUPPORTED SECURITY PROTOCOL** field in the supported security protocols list shall contain one of the security protocol values supported by the logical unit. The values shall be listed in ascending order starting with 00h.
- **Pad bytes** may be appended so the total data length conforms to the ALLOCATION LENGTH field requirements. Pad bytes shall have a value of 00h.

11.17.2.2.2 Certificate Data Description

11.17.2.2.2.1 Certificate Overview

A certificate is either an X.509 Public Key Certificate (see Section 11.17.2.2.2.2) or an X.509 Attribute Certificate (see Section 11.17.2.2.2.3) depending on the capabilities of the logical unit.

If the SECURITY PROTOCOL field is set to 00h and the SECURITY PROTOCOL SPECIFIC field is set to 0001h in a SECURITY PROTOCOL IN command, then the parameter data shall have the format shown:

Table 345 Certificate Data SECURITY PROTOCOL IN Parameter Data

| Byte | Bit | | | | | | | |
|---------|--------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | Reserved = 0 | | | | | | | |
| 2-3 | Certificate Length = m-3 | | | | | | | |
| 4-m | Certificate | | | | | | | |
| (m+1)-n | Pad Bytes (if any) | | | | | | | |

- **CERTIFICATE LENGTH** field indicates the total length, in bytes, of the certificate or certificates that follow. The length may include more than one certificate. If the device server doesn't have a certificate to transfer, the CERTIFICATE LENGTH field shall be set to 0000h.
- **CERTIFICATE** is either an X.509 Public Key Certificate or an X.509 Attribute Certificate depending on the capabilities of the logical unit.
- **Pad bytes** may be appended so the total data length conforms to the ALLOCATION LENGTH field requirements. Pad bytes shall have a value of 00h.

11.17.2.2.2 Public Key Certificate Description

RFC 5280 defines the certificate syntax for certificates consistent with X.509v3 Public Key Certificate Specification.

11.17.2.2.3 Attribute Certificate Description

RFC 3281 defines the certificate syntax for certificates consistent with X.509v2 Attribute Certificate Specification.

11.17.2.3 Security Compliance Information Description

11.17.2.3.1 Security Compliance Information Overview

The security compliance information parameter data contains information about security standards that apply to this SCSI target device.

If the SECURITY PROTOCOL field is set to 00h and the SECURITY PROTOCOL SPECIFIC field is set to 0002h in a SECURITY PROTOCOL IN command, then the parameter data shall have the format shown:

Table 346 Security Compliance Information SECURITY PROTOCOL IN Parameter Data

| Byte | Bit | | | | | | | |
|------------------------|----------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-3 | Security Compliance Information Length = m-3 | | | | | | | |
| Compliance Descriptors | | | | | | | | |
| 4 | Compliance Descriptor [first] | | | | | | | |
| ... | ... | | | | | | | |
| m | Compliance Descriptor [last] | | | | | | | |
| m+1 | Pad Bytes (if any) | | | | | | | |
| ... | | | | | | | | |
| n | | | | | | | | |

- The **SECURITY COMPLIANCE INFORMATION LENGTH** field indicates the total length, in bytes, of the compliance descriptors that follows.
- Each **Compliance descriptor** field in the supported security protocols list shall contain one of the security protocol values supported by the logical unit. The values shall be listed in ascending order starting with 00h.
- **Pad bytes** may be appended so the total data length conforms to the ALLOCATION LENGTH field requirements. Pad bytes shall have a value of 00h.

11.17.2.3.2 Compliance Descriptor Overview

The format of a compliance descriptor in the security compliance information SECURITY PROTOCOL IN parameter data is shown in table.

Table 347 Compliance Descriptor Format

| Byte | Bit | | | | | | | |
|------|------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | Compliance Descriptor Type | | | | | | | |
| 2-3 | Reserved = 0 | | | | | | | |
| 4-7 | Compliance Descriptor Length = n-3 | | | | | | | |
| 8-n | Descriptor Specific Information | | | | | | | |

- The **COMPLIANCE DESCRIPTOR TYPE** field indicates the format of the descriptor specific information. The security compliance information SECURITY PROTOCOL IN parameter data may contain more than one compliance descriptor with the same value in the COMPLIANCE DESCRIPTOR TYPE field.

Table 348 COMPLIANCE DESCRIPTOR TYPE Field

| Code | Description | Related Standards | Reference |
|------------|-------------------------------------------------|--------------------------|---------------|
| 0001h | Security requirements for cryptographic modules | FIPS 140-2 FIPS 140-3 | 11.17.2.2.3.3 |
| All others | Reserved | | |

- The **COMPLIANCE DESCRIPTOR LENGTH** field indicates the number of bytes that follow in the compliance descriptor.
- The contents of the **Descriptor specific information** depend on the value in the COMPLIANCE DESCRIPTOR TYPE field.

11.17.2.2.3.3 FIPS 140 Compliance Descriptor

The FIPS 140 compliance descriptor contains information that may be used to locate information about a FIPS 140 certificate associated with the SCSI target device. The SCSI target device may or may not be operating in the mode specified by that certificate.

Table 349 FIPS 140 Compliance Descriptor

| Byte | Bit | | | | | | | |
|---------|-------------------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0-1 | Compliance Descriptor Type (0001h) | | | | | | | |
| 2-3 | Reserved = 0 | | | | | | | |
| 4-7 | Compliance Descriptor Length (0000 0208h) | | | | | | | |
| 8 | Related Standard | | | | | | | |
| 9 | Overall Security Level | | | | | | | |
| 10-15 | Reserved = 0 | | | | | | | |
| 16-143 | Compliance Descriptor Hardware Version | | | | | | | |
| 144-271 | Compliance Descriptor Version | | | | | | | |
| 272-527 | Compliance Descriptor Module Name | | | | | | | |

- The **COMPLIANCE DESCRIPTOR TYPE** field and **COMPLIANCE DESCRIPTOR LENGTH** field are defined in 11.17.2.2.3.1
- Compliance Descriptor Overview and shall be set as shown in Table 349 for the FIPS 140 compliance descriptor.
- The **RELATED STANDARD** field (see Table 350) is an ASCII data field that indicates the related standard described by this compliance descriptor.

Table 350 RELATED STANDARD Field

| Code | Related Standards |
|------------|-------------------|
| 32h | FIPS 140-2 |
| 33h | FIPS 140-3 |
| All others | Reserved |

- The **OVERALL SECURITY LEVEL** field is an ASCII data field that indicates the FIPS 140 overall security level that is reported by NIST or CSEC.
- The **COMPLIANCE DESCRIPTOR HARDWARE VERSION** field is null terminated, null padded data that indicates the version number of the firmware or software in the module, as reported by NIST or CSEC. The value in the **COMPLIANCE DESCRIPTOR VERSION** field is not related to the PRODUCT REVISION LEVEL field of standard INQUIRY data.
- The **COMPLIANCE DESCRIPTOR MODULE NAME** field is null terminated, null padded data that indicates the name or identifier of the cryptographic module, as reported by NIST or CSEC.

11.17.3 Certified Models, Hardware Versions and Firmware Versions

Use the INQUIRY command to read the model number and the firmware version from the device. Verify that these have been certified by comparing against the values published in the Security Policy or on the CMVP website Module Validation Lists:

11.17.4 Zeroization of the Cryptographic Module

The TCG Revert method overwrites all security parameters to factory defaults,

1. StartSession and SyncSession on 'AdminSP'.
2. Authenticate 'PSID'.
3. Execute the TCG Revert method.
4. EndSession.

Reset the drive and clear the authentication values established during zeroization.

11.18 Switching between TCG Enterprise and ISE model

Note: This section covers certain capabilities of the new generation of Western Digital products that is not commonly needed in typical use-cases.

The new generation of Western Digital products can function as a simple SED with Instant Secure Erase feature support and also support TCG Enterprise SSC at the same time, right out of the box. The drives support the SANITIZE command with CRYPTO ERASE option (for Instant Secure Erase) or the non-instant way of OVERWRITE option to scrub/erase the drive. The drives also support TCG command interactions in accordance with the SII specification.

In the factory default state, the drive can be used out of the box as a plain SED drive with Instant Secure Erase (ISE) capability, while the drive also reports as TCG enabled/ready drive (thus allowing it to be recognized/detected as a TCG capable device by any standards based RAID controllers for example).

The drive is said to be in ISE-mode of operation, until such time any of the TCG Settings/configurations are accessed (on the LOCKING SP). Upon TCG LOCKING SP access (e.g.: Authenticating to BANDMASTER or ERASEMASTER or a TCG-Activate command is issued (though TCG-Activate is not necessary)), the drive is said to be in TCG-mode of operation.

The drive, though reports as TCG enabled/ready drive, will not enforce certain SII spec compliance unless the drive is (implicitly) used as a TCG drive or put in TCG-mode.

11.18.1 ISE-mode and TCG-mode

As stated above, the factory default state of the drive is ISE-mode (which the drive also reports as TCG enabled/read and responds to TCG commands and operations). If and when the drive is access as a TCG drive (by access LOCKING SP), the drive automatically goes into TCG-mode and fully support SII specification (including ReadLong/WriteLong behavior restrictions, and Western Digital unique Logical-Ports (e.g.: FW-Download port-locking etc.)).

While there are ways to put the drive in its factory default state, the below list mechanism could be used to quickly put the drive in factory default state.

To revert the drive back to factory default state from TCG-mode, perform a TCG Revert operation (see TCG commands section for details.) **IMPORTANT NOTE:** All data on the drive will be lost when performing the Revert operation.

11.19 Block SID Authentication

If a Block SID Authentication command has been successfully executed, SID Authentication will be blocked. This feature based on TCG Storage Feature Set: Block SID Authentication Specification Version 1.00 Published Revision 1.00.

If Block SID Authentication is supported, Level 0 Discovery returns feature descriptor as Feature Code = 0402.

The Block SID Authentication command is delivered by the transport IF-SEND command. There is no IF-RECV response to the Block SID Authentication command.

The Block SID Authentication command is defined as follows:

Command: IF_SENF
Protocol ID: 0x02
Transfer Length: Non-zero
ComID: 0x0005
Byte 0: Clear Events (0 or 1)
Bytes 1 to Transfer Length -1: Reserved (00)

Block SID Authentication state will be cleared by Power Cycle or Revert Method. If a Block SID Authentication command issued with Clear Events = 1, Block SID Authentication state is also cleared by Hardware Reset.

12 SCSI Sense Data

12.1 SCSI Sense Data Format Introduction

Sense data is returned as CHECK CONDITION status and as parameter data in response to the REQUEST SENSE command. The sense data returned by the drive can be in either fixed or descriptor format

12.1.1 Sense Data Format

Format of sense data returned as a CHECK CONDITION status is based on the value of the D_SENSE bit in the Control mode page (See Section 8.11.9). The REQUEST SENSE command may be used to request either the fixed format sense data or the descriptor format sense data (See Section 8.39).

12.1.2 Sense Data Length

Length of the sense data returned as part of CHECK CONDITION status is determined by the sense data format:

- a) Length of fixed format sense data is always 32 bytes.
- b) Length of descriptor format sense data is variable, based on the error and the number of descriptors included.

For REQUEST SENSE command, length of the sense data is the number of bytes in the command's Allocation Length or the sense data length described above, whichever is less.

12.1.3 Sense Data Response Code

The first byte of all sense data contains the RESPONSE CODE field that indicates the error type and format of the sense data. Table 351 shows the RESPONSE CODE values which may be returned by the drive

Table 351 Sense data response codes

| Response Code | Error Type | Sense Data Format |
|---------------|------------|-------------------|
| 70h | Current | Fixed |
| 71h | Deferred | Fixed |
| 72h | Current | Descriptor |
| 73h | Deferred | Descriptor |

Current Error: This indicates an error for the current command.

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 or write caching. Format unit (04h) command is an example of a command that may return a deferred error.

12.2 Fixed Format Sense Data

Table 352 Fixed Format Sense Data

| Byte | Bit | | | | | | | |
|-------|------------------------------------|-------------------------|---|-----------|----------------------------|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Valid | | | | Response Code (70h or 71h) | | | |
| 1 | Rsvd=0 | | | | | | | |
| 2 | 0 | ILI | 0 | Sense Key | | | | |
| 3-6 | (MSB) Information Bytes | | | | | | | (LSB) |
| 7 | Additional Sense Length | | | | | | | |
| 8-11 | (MSB) Command Specific Information | | | | | | | (LSB) |
| 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 = 0 | | | | | | | |
| 20-23 | Vendor unique Error information | | | | | | | |
| 24-29 | Command Specific Information | | | | | | | |
| 30-31 | Reserved = 0 | | | | | | | |

12.2.1 Valid (Bit 7 of byte 0)

Table 353 Fixed Format Sense Data Valid Bit

| | |
|---|---------------------------------------------------------------------------------|
| 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. |

12.2.2 Response Code (Bit 6 - 0 of byte 0)

Table 354 Fixed Format Sense Data Response Code

| | |
|-----|---------------------------------------------------------------------------------|
| 70h | Current Error. See section 12.1.3 "Sense Data Response Code" for more details. |
| 71h | Deferred Error. See section 12.1.3 "Sense Data Response Code" for more details. |

12.2.3 ILI: Incorrect Length Indicator (Bit 5 of byte 2)

The ILI bit is valid for the READ LONG (10) - (3E) command and WRITE LONG (10) - (3F) 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.

| 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 disk |

12.2.4 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 an 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 10.1.5)
- 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 Completed**

12.2.5 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.

Note: An LBA other than the command LBA may be reported on the Reassign Block (07h) command.

Note: When the value that needs to be stored in the Information field is greater than 0xFFFFFFFF (e.g., an LBA greater than 2TiB) the VALID bit will always be set to 0. To retrieve such information in such cases, the drive must be configured to return sense data in descriptor format. See section 8.11.9 for details

- ILI = 1: This field contains the difference (residue) of the requested length in bytes. Negative values are indicated by two's complement notation.

Table 355 Information Bytes (Byte 3 through 6)

| Valid | ILI | Description |
|-------|-----|------------------------------------------|
| 0 | x | 0x00000000 - (not used/invalid) |
| 1 | 0 | LBA |
| 1 | 1 | Residue of the requested length in bytes |

12.2.6 Additional Sense Length (Byte 7)

Indicates the remaining number of bytes in the sense data. (It is always set to 18h.)

12.2.7 Command Specific Information (Byte 8 through 11)

This field is unused and will be set to zero.

12.2.8 Additional Sense Code/Qualifier (Byte 12 and 13)

The following table shows the description of the combination of Sense Key / Sense Code / Qualifier.

Table 356 Sense Code/Qualifier

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|--------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | Sense Key = No Sense |
| 00 | 00 | 00 | No Additional Sense Information |
| | | | 0000 No Error |
| | | | Sense Key = No Sense |
| 0 | 0B | 01 | SMART Temperature Warning |
| | | | 1A02 SMART: Temperature Warning (No Sense) |
| | | | 2A02 SMART: Temperature Warning (Recovered Sense) |
| | | | 3A02 SMART: Temperature Warning (Unit Attention) |
| 0 | 0B | 03 | SMART Background Self-Test Failure |
| | | | 1A03 SMART: Background Self-Test Failure (No Sense) |
| | | | 2A03 SMART: Background Self-Test Failure (Recovered Sense) |
| | | | 3A03 SMART: Background Self-Test Failure (Unit Attention) |
| 0 | 0B | 04 | SMART Background Pre-Scan Failure |
| | | | 1A04 SMART: Background Pre-Scan Failure (No Sense) |
| | | | 2A04 SMART: Background Pre-Scan Failure (Recovered Sense) |
| | | | 3A04 SMART: Background Pre-Scan Failure (Unit Attention) |
| 0 | 0B | 05 | Background Media Scan Failure Warning |
| | | | 1A05 SMART: Background Media Scan Failure (No Sense) |
| | | | 2A05 SMART: Background Media Scan Failure (Recovered Sense) |
| | | | 3A05 SMART: Background Media Scan Failure (Unit Attention) |
| 0 | 5D | 20 | Extreme Over-Temperature Warning |
| | | | 1A22 SMART: Extreme Over-Temperature Warning (No Sense) |
| | | | 2A22 SMART: Extreme Over-Temperature Warning (Recovered Sense) |
| | | | 3A22 SMART: Extreme Over-Temperature Warning (Unit Attention) |
| 0 | 5D | 21 | Milli-Actuator Error |
| | | | 1A21 SMART: Milli-Actuator Error (No Sense) |
| | | | 2A21 SMART: Milli-Actuator Error (Recovered Sense) |
| | | | 3A21 SMART: Milli-Actuator Error (Unit Attention) |
| 0 | 5D | 50 | Load/Unload cycle Count Warning |
| | | | 1A50 SMART: Start/Stop Load/Unload Cycle Count Warning (No Sense) |
| | | | 2A50 SMART: Start/Stop Load/Unload Cycle Count Warning (Recovered Sense) |
| | | | 3A50 SMART: Start/Stop Load/Unload Cycle Count Warning (Unit Attention) |
| 0 | 5D | 5B | Spinup Retry Count Warning |
| | | | 1A5B SMART: Spinup Retry Count Warning (No Sense) |
| | | | 2A5B SMART: Spinup Retry Count Warning (Recovered Sense) |
| | | | 3A5B SMART: Spinup Retry Count Warning (Unit Attention) |
| 0 | 5D | 61 | FW Security At Risk |
| | | | 1A12 SMART: FW Security At Risk (No Sense) |
| | | | 2A12 SMART: FW Security At Risk (Recovered Sense) |
| | | | 3A12 SMART: FW Security At Risk (Unit Attention) |
| 0 | 5D | 62 | Read/Write Error Rate Warning |
| | | | 1A32 SMART: Read Error Rate Warning (No Sense) |
| | | | 2A32 SMART: Read Error Rate Warning (Recovered Sense) |
| | | | 3A32 SMART: Read Error Rate Warning (Unit Attention) |
| | | | 1A4A SMART: Write Error Rate Warning (No Sense) |
| | | | 2A4A SMART: Write Error Rate Warning (Recovered Sense) |
| | | | 3A4A SMART: Write Error Rate Warning (Unit Attention) |
| 0 | 5D | 63 | Seek Error Rate Warning |
| | | | 1A43 SMART: Seek Error Rate Warning (No Sense) |
| | | | 2A43 SMART: Seek Error Rate Warning (Recovered Sense) |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|-----------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 3A43 SMART: Seek Error Rate Warning (Unit Attention) |
| 0 | 5D | 64 | Spare Sector Availability Warning |
| | | | 1A14 SMART: Spare Sector Availability Warning (No Sense) |
| | | | 2A14 SMART: Spare Sector Availability Warning (Recovered Sense) |
| | | | 3A14 SMART: Spare Sector Availability Warning (Unit Attention) |
| 0 | 5D | 66 | Spinup Time Warning |
| | | | 1A56 SMART: Spinup Time Warning (No Sense) |
| | | | 2A56 SMART: Spinup Time Warning (Recovered Sense) |
| | | | 3A56 SMART: Spinup Time Warning (Unit Attention) |
| 0 | 5D | FD | Internal Environment Status Error |
| | | | 1AFD SMART: Internal Environment Status Error (No Sense) |
| | | | 2AFD SMART: Internal Environment Status Error (Recovered Sense) |
| | | | 3AFD SMART: Internal Environment Status Error (Unit Attention) |
| 0 | 5D | FF | Test Warning Threshold Reached |
| | | | 1AFF SMART: Test Warning Threshold Reached (No Sense) |
| | | | 2AFF SMART: Test Warning Threshold Reached (Recovered Sense) |
| | | | 3AFF SMART: Test Warning Threshold Reached (Unit Attention) |
| 0 | 5E | 01 | Idle_A Condition activated by timer |
| | | | 1831 CMD: Power Mode Idle_A By Timer |
| 0 | 5E | 02 | Standby_Z Condition activated by timer |
| | | | 1834 CMD: Power Mode Standby_Z By Timer |
| 0 | 5E | 03 | Idle_A Condition activated by Command |
| | | | 1835 CMD: Power Mode Idle_A By Command |
| 0 | 5E | 04 | Standby_Z Condition activated by Command |
| | | | 1838 CMD: Power Mode Standby_Z By Command |
| 0 | 5E | 05 | Idle_B Condition activated by timer |
| | | | 1832 CMD: Power Mode Idle_B By Timer |
| 0 | 5E | 06 | Idle_B Condition activated by Command |
| | | | 1836 CMD: Power Mode Idle_B By Command |
| 0 | 5E | 07 | Idle_C Condition activated by timer |
| | | | 1833 CMD: Power Mode Idle_C By Timer |
| 0 | 5E | 08 | Idle_C Condition activated by Command |
| | | | 1837 CMD: Power Mode Idle_C By Command |
| 0 | 5E | 09 | Standby_Y Condition activated by timer |
| | | | 1839 CMD: Power Mode Standby_Y By Timer |
| 0 | 5E | 0A | Standby_Y Condition activated by Command |
| | | | 183A CMD: Power Mode Standby_Y by Command |
| | | | Sense Key = Recovered Error |
| 1 | 02 | 00 | No Seek Complete |
| | | | 141B Servo: Recovered Current error |
| | | | 141D Servo: Recovered Seek timeout |
| | | | 141F Servo: Recovered Seek error |
| | | | 142B Servo: Recovered RRO Calibration timeout |
| | | | 14A0 Servo: Recovered IDLEA Grab Error |
| | | | 14A2 Servo: Recovered IDLEA Seek Error |
| | | | 14A4 Servo: Recovered AVEDAC Error |
| | | | 14A6 Servo: Recovered IDLEA Exit Timeout Error |
| | | | 14A8 Servo: Recovered IDLEA Long Seek Error |
| | | | 14AA Servo: Recovered IDLEA SID ACQ Error |
| | | | 14CB Servo: Recovered IDLEA Check CMPLT Error |
| 1 | 03 | 00 | Peripheral Device Write Fault |
| | | | 1733 Media: Recovered Read Write Abort Error |
| | | | 1737 Media: Recovered Post Write Abort Error |
| | | | 1739 Media: Recovered Post PES Check Write Abort Error |
| | | | 17E0 Media: Recovered Write Splice Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 1EC0 Media: Recovered R/W Abort Due to SSW Calibration Track |
| | | | 1EC2 Media: Recovered R/W Abort Due to RAW TID |
| | | | 1EC4 Media: Recovered R/W Abort Due to Burst In Progress |
| | | | 1EC6 Media: Recovered R/W Abort Due to DSW Not Settled |
| | | | 1EC8 Media: Recovered R/W Abort Due to Preheat |
| | | | 1ECA Media: Recovered R/W Abort Due to HMA R/W Offset |
| | | | 1ECC Media: Recovered R/W Abort Due to WCSBUSY Pro Check |
| | | | 1ECE Media: Recovered R/W Abort Due to Vibration Condition (Other) |
| | | | 1ED0 Media: Recovered R/W Abort Due to Vibration Condition (Estimator) |
| | | | 1ED2 Media: Recovered R/W Abort Due to Vibration Condition (Predictor) |
| | | | 1ED4 Media: Recovered R/W Abort Due to Vibration Condition (PES Error) |
| | | | 1ED6 Media: Recovered R/W Abort Off Track Write Error |
| | | | 1ED8 Media: Recovered R/W Abort RRO Field Misread Error |
| | | | 1EDA Media: Recovered R/W Abort RRO Field Missing Error |
| | | | 1EDC Media: Recovered R/W Abort Idle Seek Error |
| | | | 1EDE Media: Recovered R/W Abort Seek Timeout Error |
| | | | 1EE0 Media: Recovered R/W Abort Estimator Error |
| | | | 1EE2 Media: Recovered R/W Abort Predictor Error |
| | | | 1EE4 Media: Recovered R/W Abort PES Error |
| | | | 1EE6 Media: Recovered R/W Abort RPC Resync Error |
| | | | 1EE8 Media: Recovered R/W Abort PES Reset Error |
| | | | 1EEA Media: Recovered R/W Abort SID Unlock Error |
| | | | 1EEC Media: Recovered R/W Abort WCS Error |
| | | | 1EEE Media: Recovered R/W Abort Hard Reset Error |
| | | | 1EF0 Media: Recovered R/W Abort Shock Error |
| | | | 1EF2 Media: Recovered R/W Abort Unlock Macro Error |
| | | | 1EF4 Media: Recovered R/W Abort Sharp Error |
| | | | 1EF6 Media: Recovered R/W Abort Aggressive Error |
| | | | 1EF8 Media: Recovered R/W Abort VWI Limit Error |
| | | | 1EFA Media: Recovered R/W Abort Gray Code Error |
| | | | 1EFC Media: Recovered R/W Abort Linger Error |
| | | | 1EFE Media: Recovered R/W Abort No STM Error |
| 1 | 09 | 00 | Track Following Error |
| | | | 1421 Servo: Recovered Track following error |
| | | | 1423 Servo: Recovered Track follow timeout |
| 1 | 0C | 01 | Recovered Write Error with Auto Reallocation - Auto Reallocated |
| | | | D703 Media: Auto Reallocated Write Error |
| 1 | 0C | 03 | Recovered Write Error - Recommend Reassignment |
| | | | 1704 Media: Recovered Write Error - Recommend reassign |
| 1 | 10 | 02 | Recovered Application Tag Error |
| | | | 17BA Media: Recovered Application Tag Error |
| 1 | 10 | 03 | Recovered Reference Tag Error |
| | | | 17B8 Media: Recovered Reference Tag Error |
| 1 | 11 | 14 | Recovered LBA Write Correctable Error |
| | | | 17CB Media: Recovered LBA Write Correctable Error |
| 1 | 15 | 00 | Random Positioning Error |
| | | | 1712 Media: Recovered LBA MEDC Error |
| | | | 1714 Media: Recovered Sector Overflow Error |
| | | | 171A Media: Recovered Sector miss cause watchdog expire |
| | | | 173D Media: Recovered Sector Miss Error |
| | | | 176E Media: Correctable Channel Ready Error |
| | | | 1770 Media: Recovered SID Timeout Error |
| | | | 177C Media: Recovered Servo Area Timeout |
| | | | 1780 Media: Recovered DLC SID Delay Timeout |
| | | | 17B2 Media: Recovered Abort Window Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|--------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 17EE Media: Recovered Sector Number Cylinder Error |
| 1 | 16 | 00 | Data Synchronization Mark Error |
| | | | 1652 Channel: Recovered Read Gate Fault Error |
| | | | 165C Channel: Recovered Mode Overlap Read Fault Error |
| | | | 1724 Media: Recovered READ Overrun Servo Gate Active |
| | | | 1735 Channel: Recovered No Sync Detected Error |
| | | | 173B Media: Recovered Data Address Mark Error |
| | | | 17AA Media: Recovered Read Overrun Error |
| 1 | 16 | 01 | Data Sync Error - Data Rewritten |
| | | | E70E Media: Recovered Data Address Mark Error - Rewritten |
| 1 | 16 | 02 | Data Sync Error - Recommend Rewrite |
| | | | E70F Media: Recovered Data Address Mark Error - Recommend Rewrite |
| 1 | 16 | 03 | Data Sync Error - Auto Reallocated |
| | | | D710 Media: Recovered Data Address Mark Error - Reassigned |
| 1 | 16 | 04 | Data Sync Error - Recommend Reassignment |
| | | | E711 Media: Recovered Data Address Mark Error - Recommend Reassign |
| 1 | 17 | 00 | Recovered ATA Stream Error |
| | | | 17C4 Media: Recovered DRAM ECC Error |
| 1 | 17 | 01 | Recovered Data with Retries |
| | | | 1718 Media: Recovered Sync Mark Retry Timeout |
| | | | 171E Media: Recovered Read Latency Error |
| | | | 1726 Media: Recovered Internal Write Catch Error |
| | | | 172C Media: Recovered Data |
| | | | 172E Media: Recovered Error on Last Data Read |
| | | | 176C Media: Recovered MEDC Correctable Error |
| | | | 1782 Media: Recovered Force Soft Error |
| | | | 1784 Media: Recovered Channel Sector Marginal Error |
| | | | 17B1 Media: Recovered track ECC recovery |
| | | | 17E6 Media: Recovered NRZ Sector Marginal Error |
| 1 | 17 | 06 | Recovered Data Without LDPC - Data Auto-Reallocated |
| | | | D705 Media: Error With OTF Correction - Reassigned |
| 1 | 17 | 07 | Recovered Data Without LDPC - Recommend Reassignment |
| | | | E706 Media: Error With OTF Correction - Recommend Reassign |
| 1 | 17 | 08 | Recovered Data Without LDPC - Recommend Rewrite |
| | | | E707 Media: Error With OTF Correction - Recommend Rewrite |
| 1 | 17 | 09 | Recovered Data Without LDPC - Data Rewritten |
| | | | E708 Media: Error With OTF Correction - Rewritten |
| 1 | 18 | 00 | Recovered Data With LDPC |
| | | | 1709 Media: Recovered Error With Offline Correction |
| | | | 17AE Media: Recovered ECC Correctable Error |
| 1 | 18 | 01 | Recovered Data - Forced Channel Fault |
| | | | 167E Channel: Recovered Forced Channel Fault Error |
| 1 | 18 | 02 | Recovered Data - Data Auto-Reallocated |
| | | | D70A Media: Error With Offline Correction - Reassigned |
| | | | D71C Media: Internal rewrite skipped |
| 1 | 18 | 05 | Recovered Data - Recommend Reassignment |
| | | | E70B Media: Error With Offline Correction - Recommend Reassign |
| 1 | 18 | 06 | Recovered Data With LDPC - Recommend Rewrite |
| | | | E70C Media: Error With Offline Correction - Recommend Rewrite |
| 1 | 18 | 07 | Recovered Data With LDPC - Data Rewritten |
| | | | 170D Media: IWV Verify Soft error |
| | | | E70D Media: Error With Offline Correction - Rewritten |
| 1 | 1C | 00 | Defect List Format Not Supported |
| | | | 1746 Media: Recovered Defect List Format Not Supported Error |
| 1 | 1C | 01 | Primary Defect List Not Found. Requested Format Not Supported |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 1747 Media: Recovered Primary Defect List Not Found Error |
| 1 | 1C | 02 | Grown Defect List Not Found. Requested Format Not Supported |
| | | | 1748 Media: Recovered Grown Defect List Not Found Error |
| 1 | 1F | 00 | Partial Defect List Transfer |
| | | | 1749 Media: Recovered Partial Defect List Transferred Error |
| 1 | 40 | 80 | Primary Flash Not ready |
| | | | 1138 BATS error: Primary Flash Not Ready |
| 1 | 44 | 00 | Internal Target Failure |
| | | | F132 GEM FH track read error |
| | | | 1201 Sanity: Error In UEC Class |
| | | | 1202 Sanity: Error In UEC Cause |
| | | | 1301 Motor: Recovered internal error |
| | | | 1303 Motor: Recovered Open Loop Commutation failure |
| | | | 1305 Motor: Recovered No feedback detected error |
| | | | 1307 Motor: Recovered Settle timeout |
| | | | 1309 Motor: Recovered Gross speed error |
| | | | 130B Motor: Recovered 12V OK error |
| | | | 130D Motor: Recovered Speed error |
| | | | 1311 Motor: Recovered Internal 12V not OK timeout |
| | | | 1313 Motor: Recovered Inductive Sense measurement timeout |
| | | | 1315 Motor: Recovered Spin Sense speed error |
| | | | 1319 Motor: Recovered Target speed error |
| | | | 131D Motor: Recovered Over current error |
| | | | 1321 Motor: Recovered Negative regulator fault |
| | | | 1323 Motor: Recovered Module overtemp error |
| | | | 1325 Motor: Recovered 12V or 5V OK error |
| | | | 1327 Motor: Recovered unknown error |
| | | | 1365 Motor: Recovered Predriver Voltage Offset Calibration Error |
| | | | 1367 Motor: Recovered Predriver BEMF Gain Calibration Error |
| | | | 1369 Motor: Recovered Predriver BEMF Unload Calibration Error |
| | | | 136F Motor: Recovered IDCS Calibration Measurement 1 Error |
| | | | 1371 Motor: Recovered IDCS Calibration Measurement 2 Error |
| | | | 1373 Motor: Recovered IDCS Calibration Saturation Error |
| | | | 1375 Motor: Recovered IDCS Calibration Adjustment Error |
| | | | 1377 Motor: Recovered Predriver VDUAL over current |
| | | | 1379 Motor: Recovered Predriver NEG Chargepump Fault |
| | | | 137B Motor: Recovered Predriver VGH Fault |
| | | | 137D Motor: Recovered Predriver Ext Interrupt |
| | | | 137F Motor: Recovered Predriver Ext Fault |
| | | | 1381 Motor: Recovered PMIC Not Detected |
| | | | 1383 Motor: Recovered Get MA Error |
| | | | 1385 Motor: Recovered Unexpected HD on Ramp |
| | | | 1387 Motor: Recovered VCPDSA Driver Failure |
| | | | 1389 Motor: Recovered Motor Start Timeout |
| | | | 138B Motor: Recovered Motor PMIC UV12 |
| | | | 138D Motor: Recovered Motor PMIC UV5 |
| | | | 138F Motor: Recovered Motor PMIC UV09 |
| | | | 1391 Motor: Recovered Motor PMIC OT12 |
| | | | 1393 Motor: Recovered Motor PMIC OT5 |
| | | | 1395 Motor: Recovered Motor PMIC EOTW12 |
| | | | 1397 Motor: Recovered Motor PMIC EOTW5 |
| | | | 1399 Motor: Recovered Motor PMIC OC12 |
| | | | 139B Motor: Recovered Motor PMIC OC5 |
| | | | 139D Motor: Recovered Motor PMIC OC09 |
| | | | 139F Motor: Recovered Motor PMIC OV12 |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 13A1 Motor: Recovered Motor PMIC OV5 |
| | | | 13A3 Motor: Recovered I2C READ Error |
| | | | 13A5 Motor: Recovered I2C WRITE Error |
| | | | 13A7 Motor: Recovered PMIC not supported |
| | | | 1401 Servo: Recovered Requested rezero head does not exist |
| | | | 1403 Servo: Recovered Back EMF movement in progress |
| | | | 1405 Servo: Recovered Back EMF timeout error |
| | | | 1407 Servo: Recovered ADC conversion timeout |
| | | | 1409 Servo: Recovered Load/unload calibration error |
| | | | 140B Servo: Recovered Invalid 5 volts |
| | | | 140D Servo: Recovered Invalid 12 volts |
| | | | 140F Servo: Recovered Invalid harmonic requested |
| | | | 1415 Servo: Recovered Invalid temperature |
| | | | 1417 Servo: Recovered Truncated rezero |
| | | | 1419 Servo: Recovered Heads not loaded |
| | | | 1425 Servo: Recovered KT Seek out of range |
| | | | 1427 Servo: Recovered DAC Offset calibration error |
| | | | 1429 Servo: Recovered Load speed error |
| | | | 142D Servo: Recovered ADC Calibration error |
| | | | 142F Servo: Recovered ADC Offset error |
| | | | 1431 Servo: Recovered ADC Limit error |
| | | | 1433 Servo: Recovered Balancer Resistance error |
| | | | 1435 Servo: Recovered Balancer Resistance Limit error |
| | | | 1437 Servo: Recovered First Cylinder error |
| | | | 1439 Servo: Recovered Valid Cylinder error |
| | | | 143B Servo: Recovered ADC Saturation error |
| | | | 143D Servo: Recovered Latch Break timeout |
| | | | 143F Servo: Recovered MR Resistance out of range error |
| | | | 1441 Servo: Recovered VCM Retract error |
| | | | 1443 Servo: Recovered Load Retry error |
| | | | 1445 Servo: Recovered DFT Sharp error |
| | | | 1447 Servo: Recovered Load/Unload state error |
| | | | 1449 Servo: Recovered TFCR out-of-range error |
| | | | 144B Servo: Recovered Measure GMR Timeout |
| | | | 144D Servo: Recovered Coil Resistance Measurement Failure |
| | | | 145F Servo: Recovered WCS Hang Error |
| | | | 1461 Servo: Recovered DFT Timeout Error |
| | | | 1463 Servo: Recovered SDM Timeout Error |
| | | | 1465 Servo: Recovered RRO Write Error |
| | | | 1467 Servo: Recovered Velocity Error |
| | | | 1469 Servo: Recovered Start SID Incorrect Error |
| | | | 146B Servo: Recovered End Sid Incorrect Error |
| | | | 146D Servo: Recovered Measure GMR SDM Failure |
| | | | 146F Servo: Recovered VCM Free Speed Error |
| | | | 1471 Servo: Recovered Emergency Brake Timeout Error |
| | | | 1473 Servo: Recovered Excessive Current Error |
| | | | 1475 Servo: Recovered Excessive Velocity Error |
| | | | 147D Servo: Recovered RROF SDM Timeout Error |
| | | | 147F Servo: Recovered RROF Over Limit Error |
| | | | 1482 Servo: Recovered Measure Asymmetry SDM Failure |
| | | | 1486 Servo: Recovered Milli-Calibration Error |
| | | | 148C Servo: Recovered Measure Qsamp SDM Failure |
| | | | 148E Servo: Recovered Tilt Calibration Error |
| | | | 1490 Servo: Recovered Tilt Numerical Error |
| | | | 1496 Servo: Recovered DTID Inhibit Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|--------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 1498 Servo: Recovered Waketime Error |
| | | | 149A Servo: Recovered SHARP Pulse TFC Entry Error |
| | | | 149C Servo: Recovered Heads Not Loaded FFSULI |
| | | | 149E Servo: Recovered Load Abort FFSULI |
| | | | 14AC Servo: Recovered ODCS Detect Error |
| | | | 14AE Servo: Recovered Unexpected Motion Error |
| | | | 14B0 Servo: Recovered BEMF Loop Error |
| | | | 14B2 Servo: Recovered BEMF DTID Error |
| | | | 14B4 Servo: Recovered BEMF Lock Error |
| | | | 14B6 Servo: Recovered BEMF Fail Error |
| | | | 14B8 Servo: Recovered BEMF Speed Error |
| | | | 14BA Servo: Recovered Measure GTM SDM Failure |
| | | | 14BC Servo: Recovered SAM2SG SDM Failure |
| | | | 14BE Servo: Recovered Invalid MULTRG Descriptor Error |
| | | | 14C0 Servo: Recovered Filter COEF Overflow |
| | | | 14C2 Servo: Recovered WCS Watchdog Expire |
| | | | 14C7 Servo: Recovered HD on RAMP SWCAL Unload |
| | | | 14C9 Servo: Recovered HD on RAMP SWCAL IDsearch |
| | | | 14CD Servo: Recovered IDLEA Time Base Duration |
| | | | 14CF Servo: Recovered Emergency Brake Duration |
| | | | 14D1 Servo: Recovered VCM Free Duration |
| | | | 14D5 Servo: Recovered Search Mode Duration |
| | | | 14D7 Servo: Recovered Invalid Seek Target |
| | | | 14D9 Servo: Recovered safe zone seek error |
| | | | 14DB Servo: Recovered head switch at safe zone fail |
| | | | 1601 Channel/AE: Recovered Internal Logic Error |
| | | | 1602 AE: Recovered IVC fault error |
| | | | 1606 AE: Recovered AE Last Data Read Error |
| | | | 1609 AE: Recovered TFC Short Error |
| | | | 160B AE: Recovered Shorted MR Element Error |
| | | | 1610 AE: Recovered ECS Shorted Fault |
| | | | 1612 AE: Recovered ECS Open Fault |
| | | | 1614 AE: Recovered ECS Fault |
| | | | 1616 Channel: Recovered Channel Error |
| | | | 1618 AE: Recovered STO current fault error |
| | | | 161AAE: Recovered Open MR Element Error |
| | | | 161C AE: Recovered IC Over Temperature Error |
| | | | 161E AE: Recovered IP Clock Count Error |
| | | | 1620 AE: Recovered DLC SVCLK Error |
| | | | 1622 AE: Recovered Write Data BLS Error |
| | | | 1624 AE: Recovered STO short fault error |
| | | | 1626 AE: Recovered Power Supply Error |
| | | | 1628 AE: Recovered Open Write Head Error |
| | | | 162AAE: Recovered Write Transition Error |
| | | | 162E Channel: Recovered Channel NRZ Clear Timeout Error |
| | | | 1630 AE: Recovered SPE Low In Write Fault |
| | | | 1632 AE: Recovered STO Open fault error |
| | | | 1636 AE: Recovered Short Write Head Error |
| | | | 163C AE: Recovered TFC Open Error |
| | | | 163E AE: Recovered SoC DIE Temperature Dropped Below Warning |
| | | | 163F AE: Recovered SoC DIE Temperature Above Fatal |
| | | | 1646 AE: Recovered CHN Power Sequence Error |
| | | | 1648 Channel: Recovered Reset Flag Error |
| | | | 164A Channel: Recovered Gate Command Queue Underflow Error |
| | | | 164C Channel: Recovered Sector Size Fault Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|---------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 164E Channel: Recovered Last Split Fault Error |
| | | | 1650 Channel: Recovered Servo-Servo Overlap Error |
| | | | 1654 Channel: Recovered RWBI Out Fault Error |
| | | | 1656 Channel: Recovered No Write Clock Error |
| | | | 1658 Channel: Recovered No NRZ Clock Error |
| | | | 165A Channel: Recovered Calibration Block Fault Error |
| | | | 165E Channel: Recovered Gate Command Queue Overflow Error |
| | | | 1660 Channel: Recovered Ending Write Splice Fault Error |
| | | | 1662 Channel: Recovered Write Gate Overlap Fault Error |
| | | | 1664 Channel: Recovered Write Gate Fault Error |
| | | | 1666 Channel: Recovered Buffer Overflow Write Error |
| | | | 1668 Channel: Recovered Buffer Underflow Write Error |
| | | | 166A Channel: Recovered Write Parity Error |
| | | | 166C Channel: Recovered Buffer Overflow Read Error |
| | | | 166E Channel: Recovered CTG Wedge Slip Fault Error |
| | | | 1670 Channel: Recovered CTG Packet Late Fault Error |
| | | | 1672 Channel: Recovered Baseline Instability Count Late Error |
| | | | 1674 Channel: Recovered Preamp Count Fault Error |
| | | | 1676 Channel: Recovered Pfault Read Error |
| | | | 1678 Channel: Recovered Pfault Write Error |
| | | | 167A Channel: Recovered Last Data Fault Error |
| | | | 167C Channel: Recovered WRPO Fault Error |
| | | | 1680 Channel: Recovered PLLFloor Error |
| | | | 1682 Channel: Recovered Loss lock Error |
| | | | 1684 Channel: Recovered VGA Floor Error |
| | | | 1686 Channel: Recovered Buffer EVGA Floor Error |
| | | | 1688 Channel: Recovered TA Detector Error |
| | | | 168A Channel: Recovered NPLD Error |
| | | | 168C Channel: Recovered ZGR Flag Error |
| | | | 168E Channel: Recovered DPLL Freq Flag Error |
| | | | 1690 Channel: Recovered Massive Drop Out Detection Error |
| | | | 1692 Channel: Recovered CTG Parameter Out of Bounds Error |
| | | | 1694 Channel: Recovered Flaw Signal Sync Error |
| | | | 1696 Channel: Recovered ACQ Flag Error |
| | | | 1698 Channel: Recovered No Clock Error |
| | | | 169A Channel: Recovered PLL Loss lock Error |
| | | | 169E Channel: Recovered ADC Sample Not Ready Error |
| | | | 16A2 Channel: Recovered Auto RST NRZ-Clock Error |
| | | | 16A4 Channel: Recovered Write CRC Fault Error |
| | | | 16A6 Channel: Recovered Read Synthesizer Loss of Lock Error |
| | | | 16A8 Channel: Recovered RLL Parameter Error |
| | | | 16AA Channel: Recovered FIFO Underflow Error |
| | | | 16AC Channel: Recovered FIFO Overflow Error |
| | | | 16AE Channel: Recovered Iterative Decoder Error |
| | | | 16B0 Channel: Recovered Iterative Read Error |
| | | | 16B2 Channel: Recovered Encoder Overflow Error |
| | | | 16B4 Channel: Recovered Encoder Underflow Error |
| | | | 16B6 Channel: Recovered Encoder RAM CRC Error |
| | | | 16B8 Channel: Recovered Interface Fault |
| | | | 16BC Channel: Recovered DiBit Timeout Error |
| | | | 16BE Channel: Recovered MXP Write Fault |
| | | | 16C0 Channel: Recovered Data Jam Error |
| | | | 16C2 Channel: Recovered Code-Word Out Of Order Error |
| | | | 16C4 Channel: Recovered Read RLL Buffer CRC Flag Error |
| | | | 16C6 Channel: Recovered Write RLL Buffer CRC Flag Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|----------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 16C8 Channel: Recovered CTG No SAM Detected Fault Error |
| | | | 16CA Channel: Recovered ITI Adjust Preload Fault Track Error |
| | | | 16CC Channel: Recovered WTG SRV Fault Error |
| | | | 16CE Channel: Recovered CTG Engine Not Ready Fault Error |
| | | | 16D0 Channel: Recovered LLI Abort Fault Error |
| | | | 16D2 Channel: Recovered Retry Fault Error |
| | | | 16D4 Channel: Recovered WTG Timeout Fault Error |
| | | | 16D6 Channel: Recovered ITI Fault TS Transfer All Error |
| | | | 16D8 Channel: Recovered ITI Data Fault Error |
| | | | 16DC Channel: Recovered Data Jam Fault Error |
| | | | 16DE Channel: Recovered Code-Word Out of Order Error |
| | | | 16E0 Channel: Recovered RLL Initialization Timeout Error |
| | | | 16E4 Channel: Recovered DLC out of criteria |
| | | | 16E7 Channel: Recovered Mode Overlap Write Error |
| | | | 16E9 Channel: Recovered Ready Fault Error |
| | | | 16EB Channel: Recovered Synchronous Abort Done Error |
| | | | 16ED Channel: Recovered NRZ Clear Fault Error |
| | | | 16EF Channel: Recovered Collision Fault Error |
| | | | 16F1 Channel: Recovered Read Synthesizer Precharge Fail Fault Error |
| | | | 16F3 Channel: Recovered Servo Synthesizer Precharge Fail Fault Error |
| | | | 16F5 Channel: Recovered Read Synthesizer Loss of Lock Error |
| | | | 16F7 Channel: Recovered Fragment Number Fault Error |
| | | | 16F9 Channel: Recovered Preamble Quality Monitor Fault Error |
| | | | 1716 Media: Recovered Write Overrun Error |
| | | | 1722 Media: Recovered WRITE Overrun Servo Gate Active |
| | | | 1728 Media: Recovered S2S MAX Flag Fault |
| | | | 172A Media: Recovered track ECC unrecoverable error |
| | | | 1731 Media: Recovered Write Fault |
| | | | 1744 Media: Recovered Sudden Stop Error |
| | | | 1759 Media: Recovered Unknown Error |
| | | | 1786 Media: Recovered LLI Underrun Error |
| | | | 178C Media: Recovered FFSULI Timeout |
| | | | 1792 Media: Recovered MEDC Write Data Not Ready Error |
| | | | 1794 Media: Recovered DMA Timeout Error |
| | | | 1798 Media: Recovered ID Not Found Error |
| | | | 179C Media: Recovered Channel Read Timeout Error |
| | | | 179E Media: Recovered End Sector PHSN Error on READ |
| | | | 17B4 Media: Recovered Shock Sensor Error |
| | | | 17C6 Media: Recovered DRAM ECC LBA Error |
| | | | 17C8 Media: Recovered End Sector PHSN Error on WRITE |
| | | | 17D1 Media: Recovered DCHW Hang |
| | | | 17D4 Media: Recovered Parity PTR FIFO Error |
| | | | 17D6 Media: Recovered Parity LBA FIFO Error |
| | | | 17D8 Media: Recovered Parity Uncorrectable FIFO Error |
| | | | 17DA Media: Recovered Status Uncorrectable FIFO Error |
| | | | 17DC Media: Recovered Parity EDC SRAM Error |
| | | | 17DE Media: Recovered REQ/ACK Handshake Error |
| | | | 17E2 Media: Recovered Read Parity Error |
| | | | 17E4 Media: Recovered EPO Error |
| | | | 17E8 Media: Recovered AE Access Inhibit Error |
| | | | 17EA Media: Recovered PTR FIFO Error |
| | | | 17EC Media: Recovered LBA FIFO Error |
| | | | 17F0 Media: Recovered Read Transfer Length Error |
| | | | 17F2 Media: Recovered DS RDC Burst Error |
| | | | 17F4 Media: Recovered SV RDC Burst Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|--------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | 17F6 Media: Recovered Channel AE WG Error |
| | | | 17F8 Media: Recovered Dummy Error ERP MEAS |
| 1 | 44 | 0B | Vendor Unique - Internal Target Failure |
| | | | 130F Motor: Recovered Spindle Current error |
| | | | 1317 Motor: Recovered Spin Sense timeout |
| | | | 131F Motor: Recovered System clock watchdog error |
| | | | 1329 Motor: Recovered VCM DAC watchdog error |
| | | | 132B Motor: Recovered Module mid-die overtemp fault |
| | | | 132D Motor: Recovered Module Vcmp hi-side overtemp fault |
| | | | 132F Motor: Recovered Module Vcmn hi-side overtemp fault |
| | | | 1331 Motor: Recovered Invalid standby RPM request |
| | | | 1333 Motor: Recovered Invalid spin state request |
| | | | 1335 Motor: Recovered Hardware retract timeout |
| | | | 1337 Motor: Recovered thermal limit exceeded |
| | | | 1339 Motor: Recovered Predriver fault |
| | | | 133B Motor: Recovered Predriver Watchdog Fsys error |
| | | | 133D Motor: Recovered Predriver Watchdog DAC error |
| | | | 133F Motor: Recovered Predriver Speed Low error |
| | | | 1341 Motor: Recovered Predriver UV Vboost error |
| | | | 1343 Motor: Recovered Predriver NREG UV error |
| | | | 1345 Motor: Recovered Predriver Ext NPOR error |
| | | | 1347 Motor: Recovered Predriver Reg UV error |
| | | | 1349 Motor: Recovered Predriver Under Voltage 12 Volt Supply error |
| | | | 134B Motor: Recovered Predriver Under Voltage 5 Volt Supply error |
| | | | 134D Motor: Recovered Predriver Over Voltage 12 Volt Supply error |
| | | | 134F Motor: Recovered Predriver Under Voltage 1.8 Volt Supply error |
| | | | 1351 Motor: Recovered Predriver Under Voltage 0.9 Volt Supply error |
| | | | 1353 Motor: Recovered Predriver Under Voltage 1.5 Volt Supply error |
| | | | 1355 Motor: Recovered Predriver Shock Detected error |
| | | | 1357 Motor: Recovered Predriver Over Temperature error |
| | | | 1359 Motor: Recovered Predriver Under Voltage 3.3 Volt Supply error |
| | | | 135B Motor: Recovered Predriver Under Voltage 5 and 12 Volt Supply error |
| | | | 135D Motor: Recovered Predriver Error in Enabling Power Saving Mode |
| | | | 135F Motor: Recovered Predriver Fault in Auto Retract |
| | | | 1361 Motor: Recovered Predriver Error in Utilizing External Power Supply |
| | | | 1363 Motor: Recovered Predriver Regulator Supply Fault |
| | | | 136B Motor: Recovered Predriver VCM Short Error |
| | | | 136D Motor: Recovered Predriver NREG disable error |
| 1 | 44 | F9 | Vendor Unique - Internal Target Failure |
| | | | 1411 Servo: Recovered Sharp DRAM Parity error |
| | | | 1413 Servo: Recovered Sharp DRAM Parity Rate error |
| | | | 144F Servo: Recovered SHARP Parity Error |
| | | | 1451 Servo: Recovered SHARP Parity Rate Error |
| | | | 1453 Servo: Recovered SHARP Decode Error |
| | | | 1455 Servo: Recovered SHARP Decode Rate Error |
| | | | 1457 Servo: Recovered SHARP Timeout Error |
| | | | 1459 Servo: Recovered SHARP Timeout Rate Error |
| | | | 145B Servo: Recovered SHARP Other Error |
| | | | 145D Servo: Recovered SHARP Other Rate Error |
| 1 | 5D | 00 | NVC Non Meta Data Error |
| | | | FF73 NVC Non Meta Data Error |
| 1 | 5D | 01 | Self-Test Error |
| | | | 1A85 Self-Test: Recovery Error |
| | | | 2A85 Self-Test: Servo Error |
| | | | 4A85 Self-Test: Command Timeout Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|-----------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | FA85 Self-Test: Unrecoverable Error |
| 1 | 5D | 14 | Self-Test GLIST Error Threshold Reached |
| | | | 2A83 Self-Test: GLIST Error Count Threshold Reached |
| | | | Sense Key = Not Ready |
| 2 | 04 | 00 | Logical Unit Not Ready - Start Spindle Motor Fail |
| | | | F501 Host Interface: Logical unit not ready |
| 2 | 04 | 01 | Logical Unit Is In The Process of Becoming Ready |
| | | | F502 Host Interface: Logical unit becoming ready |
| 2 | 04 | 02 | Logical Unit Not Ready, initializing command required |
| | | | F124 Bring-up error |
| | | | F503 Host Interface: Logical unit not ready - initializing command required |
| 2 | 04 | 03 | Logical Unit Not Ready, Manual Intervention Required |
| | | | F572 Host Interface: LUN not ready; manual intervention required |
| 2 | 04 | 04 | Logical Unit Not Ready, Format In Progress |
| | | | F504 Host Interface: Not ready - format in progress |
| 2 | 04 | 09 | Not Ready - Self-test In Progress |
| | | | F505 Host Interface: Not ready - self-test in progress |
| 2 | 04 | 0E | Not Ready - Session opened |
| | | | F508 Host Interface: Not Ready - Session opened |
| 2 | 04 | 11 | Not Ready - Notify (Enable Spin-up) Required |
| | | | F553 Host Interface: LUN Not ready, Notify (Enable Spinup) required (SAS) |
| 2 | 04 | 1B | Host Interface Not Ready - Sanitize In Progress |
| | | | F50B Host Interface: Not Ready - Sanitize in progress |
| 2 | 04 | 1C | Not Ready - Power Grant Required |
| | | | F556 LUN Not ready, Power Grant required (SAS) |
| 2 | 04 | 1E | Not Ready - Microcode activation required |
| | | | F513 Host Interface: Not Ready - Microcode activation required |
| 2 | 04 | F0 | Vendor Unique - Logical Unit Not Ready |
| | | | F133 BATS error: Vendor ID mismatch |
| 2 | 31 | 00 | Medium Format Corrupted - Reassign Failed |
| | | | F506 Host Interface: Reassign failed |
| 2 | 31 | 01 | Format Command Failed |
| | | | F507 Host Interface: Format failed |
| | | | Sense Key = Medium Error |
| 3 | 03 | 00 | Medium Error - Write Fault |
| | | | F734 Media: Unrecovered Read Write Abort Error |
| | | | F738 Media: Unrecovered Post Write Abort |
| | | | F73A Media: Unrecovered Post PES Check Write Abort Error |
| | | | F797 Media: SAT Write Abort |
| | | | F7E1 Media: Unrecovered Write Splice Error |
| | | | FEC1 Media: Unrecovered R/W Abort Due to SSW Calibration Track |
| | | | FEC3 Media: Unrecovered R/W Abort Due to RAW TID |
| | | | FEC5 Media: Unrecovered R/W Abort Due to Burst In Progress |
| | | | FEC7 Media: Unrecovered R/W Abort Due to DSW Not Settled |
| | | | FEC9 Media: Unrecovered R/W Abort Due to Preheat |
| | | | FECB Media: Unrecovered R/W Abort Due to HMA R/W Offset |
| | | | FECD Media: Unrecovered R/W Abort Due to WCSBUSY Pro Check |
| | | | FECF Media: Unrecovered R/W Abort Due to Vibration Condition (Other) |
| | | | FED1 Media: Unrecovered R/W Abort Due to Vibration Condition (Estimator) |
| | | | FED3 Media: Unrecovered R/W Abort Due to Vibration Condition (Predictor) |
| | | | FED5 Media: Unrecovered R/W Abort Due to Vibration Condition (PES Error) |
| | | | FED7 Media: Unrecovered R/W Abort Off Track Write Error |
| | | | FED9 Media: Unrecovered R/W Abort RRO Field Misread Error |
| | | | FEDB Media: Unrecovered R/W Abort RRO Field Missing Error |
| | | | FEDD Media: Unrecovered R/W Abort Idle Seek Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|-----------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | FEDF Media: Unrecovered R/W Abort Seek Timeout Error |
| | | | FEE1 Media: Unrecovered R/W Abort Estimator Error |
| | | | FEE3 Media: Unrecovered R/W Abort Predictor Error |
| | | | FEE5 Media: Unrecovered R/W Abort PES Error |
| | | | FEE7 Media: Unrecovered R/W Abort RPC Resync Error |
| | | | FEE9 Media: Unrecovered R/W Abort PES Reset Error |
| | | | FEEB Media: Unrecovered R/W Abort SID Unlock Error |
| | | | FEED Media: Unrecovered R/W Abort WCS Error |
| | | | FEEF Media: Unrecovered R/W Abort Hard Reset Error |
| | | | FEF1 Media: Unrecovered R/W Abort Shock Error |
| | | | FEF3 Media: Unrecovered R/W Abort Unlock Macro Error |
| | | | FEF5 Media: Unrecovered R/W Abort Sharp Error |
| | | | FEF7 Media: Unrecovered R/W Abort Aggressive Error |
| | | | FEF9 Media: Unrecovered R/W Abort VWI Limit Error |
| | | | FEFB Media: Unrecovered R/W Abort Gray Code Error |
| | | | FEFD Media: Unrecovered R/W Abort Linger Error |
| | | | FEFF Media: Unrecovered R/W Abort No STM Error |
| 3 | 0C | FF | Unrecovered Write OCT Error |
| | | | F7A2 Media: Unrecovered Write Dcatch OCT Error |
| 3 | 11 | 00 | Unrecovered Read Error |
| | | | F67F Channel: Unrecovered Forced Channel Fault Error |
| | | | F702 Too many notches |
| | | | F719 Media: Unrecovered Sync Mark Retry Timeout |
| | | | F71F Media: Unrecovered Read Latency Error |
| | | | F727 Media: Unrecovered Internal Write Catch Error |
| | | | F72D Media: Unrecovered Uncorrectable Read Data error |
| | | | F72F Media: Unrecovered Error on Last Data Read |
| | | | F730 Media: Recommend targeted scan |
| | | | F73F Media: NFZ Table Full |
| | | | F740 Media: Defect SID Table Full Error |
| | | | F74A Media: Unrecovered Alternate Track Table Full Error |
| | | | F74D Media: Unrecovered Too Many Heads Error |
| | | | F74E Media: Unrecovered Skew Table Size Error |
| | | | F74F Media: Unrecovered Too Many Zones Error |
| | | | F750 Media: Unrecovered Too Many SIDs Error |
| | | | F751 Media: Unrecovered Alternate Track Table Full Error |
| | | | F752 Media: Unrecovered Drive Capacity Too Small |
| | | | F753 Media: Unrecovered G-list Full (Format command) |
| | | | F754 Media: Unrecovered G-list Full (2) (Format command) |
| | | | F755 Media: Unrecovered Pointer Repeat Size Error |
| | | | F756 Media: Unrecovered DST Slot Size Error |
| | | | F757 Media: Unrecovered P-list Full Error |
| | | | F758 Media: Unrecovered Invalid NFZ Table Error |
| | | | F75E Media: Unrecovered Maximum Servo Cylinder Number Too Small Error |
| | | | F76D Media: Unrecovered MEDC Uncorrectable Error |
| | | | F783 Media: Unrecovered Force Soft Error |
| | | | F785 Media: Unrecovered Channel Sector Marginal Error |
| | | | F79A Media: Unrecovered HS Measure Target Mismatch |
| | | | F7A6 Media: Unrecovered LBA ECC Last Data Read Error |
| | | | F7A7 Media: Unrecovered Committed Write Hard Error |
| | | | F7CE Media: Unrecovered Offline Already TAR Error |
| | | | F7E7 Media: Unrecovered NRZ Sector Marginal Error |
| 3 | 11 | 14 | Unrecovered LBA Error |
| | | | F7A8 Media: Unrecovered Committed Write Correction Disabled Error |
| | | | F7A9 Media: Unrecovered Committed Write Uncorrectable Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F7CA Media: Unrecovered LBA Correction Disabled Error |
| | | | F7CC Media: Unrecovered LBA Write Uncorrectable Error |
| 3 | 15 | 00 | Random Positioning Error |
| | | | F713 Media: Unrecovered LBA MEDC Error |
| | | | F715 Media: Unrecovered Sector Overflow Error |
| | | | F71B Media: Unrecovered Sector miss cause watchdog expire |
| | | | F73E Media: Unrecovered Sector Miss Error |
| | | | F76F Media: Uncorrectable Channel Ready Error |
| | | | F771 Media: Unrecovered SID Timeout Error |
| | | | F77A Media: BUFCNT Timeout Error |
| | | | F77D Media: Unrecovered Servo Area Timeout |
| | | | F781 Media: Unrecovered DLC SID Delay Timeout |
| | | | F7B3 Media: Unrecovered Abort Window Error |
| | | | F7EF Media: Unrecovered Sector Number Cylinder Error |
| 3 | 15 | 03 | Unrecovered Sector Error |
| | | | F7AF Media: Unrecovered Sector Missing Error |
| | | | F7B0 Media: Unrecovered Sector Overflow |
| 3 | 16 | 00 | Data Synchronization Mark Error |
| | | | F653 Channel: Unrecovered Read Gate Fault Error |
| | | | F65D Channel: Unrecovered Mode Overlap Read Fault Error |
| | | | F725 Media: Unrecovered READ Overrun Servo Gate Active |
| | | | F736 Channel: Unrecovered No Sync Detected Error |
| | | | F73C Media: Unrecovered Data Address Mark Error |
| | | | F7AB Media: Unrecovered Read Overrun Error |
| 3 | 19 | 02 | Defect List Error in Primary List |
| | | | F74B Media: Unrecovered Primary Defect List Error |
| 3 | 19 | 03 | Defect List Error in Grown List |
| | | | F74C Media: Unrecovered Grown Defect List Error |
| 3 | 31 | 00 | Medium Format Corrupted Reassign Failed |
| | | | F701 Format corrupted |
| | | | FF01 IndSys: Drive Not Loaded |
| | | | FF02 IndSys: Drive Not Loaded - Format Invalid |
| | | | FF03 IndSys: Indirection System Not Online |
| | | | FF04 IndSys: Drive Not Loaded - Old Version Mismatch |
| | | | FF05 IndSys: Drive Not Loaded - Heap Pointer Mismatch |
| | | | FF06 IndSys: Drive Not Loaded - Heap size Mismatch |
| | | | FF07 IndSys: Drive Not Loaded - Rid Heap Size Mismatch |
| | | | FF08 IndSys: Drive Not Loaded - Heap Version Mismatch |
| | | | FF09 IndSys: Drive Not Loaded - Incompatible Rid |
| | | | FF0A IndSys: Drive Not Loaded - Corrupt Rid |
| | | | FF0B IndSys: Drive Not Loaded - Rid Num Objects Mismatch |
| | | | FF0C IndSys: Drive Not Loaded - Rid Version Mismatch |
| | | | FF0D IndMgr: Drive Not Loaded - Rid Version Mismatch |
| | | | FF0E IndSys: Drive Not Loaded - Layout Rid Version Mismatch |
| | | | FF0F IndSys: Drive Not Loaded - W2C Rid Version Mismatch |
| | | | FF10 IndSys: Drive Not Loaded - Layout Manager Restore Failed |
| | | | FF11 IndSys: Drive Not Loaded - W2C Manager Restore Failed |
| | | | FF13 IndSys: Drive Not Loaded - DMM Format Failed |
| | | | FF14 IndSys: Drive Not Loaded - IM Format Failed |
| | | | FF1A IndSys: Drive Not Loaded - Metadata First Primary |
| | | | FF1B IndSys: Drive Loaded - Metadata First Primary and Secondary |
| | | | FF1C IndSys: Drive Loaded - IBA Out of Range |
| | | | FF1E IndSys: Drive Loaded - Context Sequence ID Mismatch |
| | | | FF70 NVC Not Loaded |
| | | | FF71 NVC Command Spec Too Large |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|-------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | FF72 ESL Command Spec Mismatch |
| 3 | 31 | 01 | Indirection System Failure |
| | | | F761 Media: Unrecovered Wrong TDC MIN Number Sector Per Track EST |
| | | | F765 Media: Unrecovered Wrong TDC MAX Number Sector Per SID |
| | | | FF12 IndSys: Drive Not Loaded - Layout Failed |
| | | | FF15 IndSys: Drive Not Loaded - Pseudo Write Failed |
| | | | FF16 IndSys: Drive Not Loaded - Full drop Failed |
| | | | FF17 IndSys: Drive Not Loaded - EPO Format Failed |
| | | | FF18 IndSys: Drive Not Loaded - Set IM Valid Failed |
| | | | FF19 IndSys: Drive Not Loaded - Bring Online failed |
| | | | FF20 IndSys: Drive Not Loaded - EPD Flash Entry Invalid |
| | | | FF21 LayoutMgr: All Flash Entries Erased |
| | | | FF22 IndSys: Drive Loaded - Replay Failed |
| | | | FF23 Out of Order EPO SRAM Copy Object |
| | | | FF24 ShowStop During EPO |
| | | | FF25 Error While Loading Object |
| | | | FF26 Missing NVC SPEC |
| | | | FF27 Showstop during EPO replay |
| | | | FF28 IndSys: Full context drop write overflow |
| | | | FF29 IndSys: Interruptible full context drop not started |
| | | | FF2A EPD num EPO pages exceeded |
| | | | FF2B IndSys: IFCD repopulate invalid spec |
| | | | FF41 LayoutMgr: Format Capacity Not Met |
| | | | FF43 IndSys: Drive Not Loaded - Metadata ATI |
| | | | FF44 IndSys: Drive Loaded - Replay Fail |
| | | | FF45 Format Too Many Regions |
| | | | FF46 Format No Tracks in Region |
| | | | FF47 Format Not Enough Tracks For Spares |
| | | | FF48 Format Too Many Data Tracks |
| | | | FF50 IndMgr: IM Demand Split Too Deep Failure |
| | | | FF51 IndMgr: Allocate Failed Delta Group |
| | | | FF52 IndMgr: Allocate Failed Split Spec |
| | | | FF53 IndMgr: Allocate Failed Split Delta |
| | | | FF54 IndMgr: Allocate Failed Unsplit Delta Group |
| | | | FF55 IndMgr: Generic Insert Exception Failed |
| | | | FF56 IndMgr: Commit write LBA out of range |
| | | | FF57 IndMgr: Format insufficient heap size |
| | | | FF60 EpoMgr: Flash Read RS Syndrome Gen Timeout |
| | | | FF61 EpoMgr: Uncorrectable Flash RS ECC Error |
| | | | FF62 EpoMgr: Correctable EPO Timeout |
| | | | FF63 EpoMgr: ARM FPS Engine and Not Spinning |
| | | | FF66 EpoMgr: Flash Header Not Pre Erased |
| | | | FF67 EpoMgr: Flash Data Not Pre Erased |
| | | | FF68 EpoMgr: Flash Header Not Written |
| 3 | 31 | 03 | Sanitize Command failed |
| | | | F50C Host Interface: Sanitize Command failed |
| 3 | 40 | 00 | Unrecovered SAT No Buffer Overflow Error |
| | | | F720 Media: RC Dump Overflow Error |
| | | | F721 Media: Format Configuration Invalid |
| | | | F75F Media: Unrecovered SAT No Buffer Overflow Error |
| 3 | 40 | 01 | Unrecovered SAT Buffer Overflow Error |
| | | | F760 Media: Unrecovered SAT Buffer Overflow Error |
| 3 | 40 | 02 | Unrecovered SAT No Buffer Overflow With ECS Fault |
| | | | F78E Media: Unrecovered SAT No Buffer Overflow With ECS Fault |
| 3 | 40 | 03 | Unrecovered SAT Buffer Overflow With ECS Fault |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|---------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F78F Media: Unrecovered SAT Buffer Overflow With ECS Fault |
| 3 | 40 | FF | No Buffer Overflow Reset Error |
| | | | F790 Media: Unrecovered SAT No Buffer Overflow Reset Media |
| | | | F791 Media: Unrecovered SAT No Buffer Overflow Reset with ECS Fault |
| 3 | 5D | 01 | Self-Test Unrecoverable Error Threshold Exceeded |
| | | | FA81 Self-Test: Unrecoverable Error Count Threshold Exceeded |
| 3 | 81 | 00 | Vendor Unique - Internal Logic Error |
| | | | F75B Media: Unrecovered Too Many Sectors Error |
| | | | Sense Key = Hardware Error |
| 4 | 02 | 00 | No Seek Complete |
| | | | F41C Servo: Unrecovered Current error |
| | | | F41E Servo: Unrecovered Seek timeout |
| | | | F420 Servo: Unrecovered Seek error |
| | | | F42C Servo: Unrecovered RRO Calibration timeout |
| | | | F4A1 Servo: Unrecovered IDLEA Grab Error |
| | | | F4A3 Servo: Unrecovered IDLEA Seek Error |
| | | | F4A5 Servo: Unrecovered AVEDAC Error |
| | | | F4A7 Servo: Unrecovered IDLEA Exit Timeout Error |
| | | | F4A9 Servo: Unrecovered IDLEA Long Seek Error |
| | | | F4AB Servo: Unrecovered IDLEA SID ACQ Error |
| | | | F4CC Servo: Unrecovered IDLEA Check CMPLT Error |
| 4 | 09 | 00 | Track Following Error |
| | | | F422 Servo: Unrecovered Track following error |
| | | | F424 Servo: Unrecovered Track follow timeout |
| 4 | 31 | 00 | Medium Format Corrupted - Reassign Failed |
| | | | F204 Reassign reserved area media error |
| 4 | 32 | 00 | No Defect Spare Location Available |
| | | | F205 G-list full - can't reassign any more sectors |
| | | | F206 No spares available |
| 4 | 3E | 03 | Self-test Failed |
| | | | F481 Servo: Unrecovered Self-Test Failed |
| | | | F75D Media: Unrecovered Self-Test Failed Error |
| | | | FA8D SMART: Disk shift exceeded threshold |
| 4 | 3E | 04 | Unrecovered Self-Test Hard-Cache Test Fail |
| | | | F762 Media: Unrecovered Self-Test Hard-Cache Test Fail |
| 4 | 3E | 05 | Unrecovered Self-Test OTF-Cache Fail |
| | | | F763 Media: Unrecovered Self-Test OTF-Cache Fail |
| 4 | 40 | 80 | Diagnostic Failure |
| | | | F101 BATS error: Reserved Area - Invalid request |
| | | | F102 BATS error: Reserved Area - Broken |
| | | | F103 BATS error: Reserved Area - Invalid version |
| | | | F104 BATS error: Reserved Area - Invalid checksum |
| | | | F105 BATS error: Reserved Area - Invalid eyecatcher |
| | | | F106 BATS error: Reserved Area - Invalid main header checksum |
| | | | F107 BATS error: Reserved Area - Invalid read length |
| | | | F108 BATS error: Reserved Area - Address boundary error |
| | | | 1109 BATS error: Reserved Area - Error reading first copy |
| | | | F10D BATS error: Reserved Area - Write fix hard error |
| | | | F10E BATS error: Reserved Area - EPO Flash Log |
| | | | F111 BATS error: RAM code load error |
| | | | F112 BATS error: RAM code check |
| | | | F113 BATS error: Exception in primary FW image |
| | | | F114 BATS error: Reserved Area - Invalid request |
| | | | F11D BATS error: Incorrect Disk Code |
| | | | F123 BATS error: Reserved map index too large |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|-----------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F125 BATS error: Invalid RID/FID |
| | | | F12B BATS error: Reserved area - invalid model |
| | | | F12D Format Reserved: FAT Size Exceeded Error |
| | | | F12E Format Reserved: Insufficient DIRS Good Error |
| | | | F12F Format Reserved: Insufficient FATS Good Error |
| | | | F131 Flash timeout |
| | | | F137 Flash ECC error |
| | | | F139 Format Reserved: Resize RID/FID Error |
| | | | F13A Format Reserved: Too many RDEF entries |
| | | | F13C BATS error: NCDE DRAM failure |
| | | | F140 Format Reserved: Too many Defects Error |
| | | | F142 ATA Diagnostic Code: No Error |
| | | | F143 ATA Diagnostic Code: Formatter Error |
| | | | F144 ATA Diagnostic Code: Sector Buffer Error |
| | | | F147 ATA Diagnostic Code: Read/Write Test Error |
| | | | F148 BATS error: Still broken after clear |
| | | | F149 BATS#2 error: Security: AES Error |
| | | | F14A BATS#2 error: Security: RSA Error |
| | | | F14B BATS#2 error: Security: DRGB Error |
| | | | F14C BATS#2 error: Security: SHA256 Error |
| | | | F14D BATS#2 error: Security: HMAC Error |
| | | | F14E BATS#2 error: Security: Hardware AES Error |
| | | | F14F BATS#2 error: Security: Hardware SHA256 Error |
| 4 | 40 | 81 | DRAM Failure |
| | | | F12A DRAM test error |
| 4 | 40 | 90 | Diagnostic Failure |
| | | | F118 BATS#2 error: Seek test error |
| 4 | 40 | 91 | Diagnostic Failure |
| | | | F13E BATS#2 error: TCG Test Failed |
| | | | F146 BATS#2 error: EDC Encryption Test error |
| 4 | 40 | A0 | Diagnostic Failure |
| | | | F119 BATS#2 error: Read/write test error |
| | | | F11B BATS#2 error: CRC test error |
| | | | F11C BATS#2 error: XOR test error |
| | | | F136 BATS#2 error: End-To-End Data Protection error |
| | | | F13F BATS#2 error: Read/Write Test Compare Failed |
| | | | F145 BATS#2 error: EDC Compare Test error |
| 4 | 44 | 00 | Internal Target Failure |
| | | | F11E SoC compatibility failure |
| | | | F11F HI test: No command slot available |
| | | | F121 HI test: Loopback sector compare failure |
| | | | F122 HI test: Failed to gain word sync |
| | | | F12C Host Interface Test: Port active error |
| | | | F203 Sanity: Sanity Check Failure |
| | | | F208 Mode Page Structure Mismatch |
| | | | F209 Miscompare of SBA in the P-List |
| | | | F20B DSLT: Invalid number of splits |
| | | | F20C DSLT: Invalid relaxed format |
| | | | F20D DSLT: First Fragment too large |
| | | | F20E DSLT: Invalid end offset |
| | | | F20F DSLT: Cycle not complete |
| | | | F220 MFG: Consistency Check failed |
| | | | F221 MFG: General Align Tables Missing |
| | | | F230 SEC_MGR: AES Hardware Error |
| | | | F231 SEC_MGR: BDE Unwrap Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|--------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F240 SEC_MGR: PRNG Seed Error |
| | | | F241 SEC_MGR: PRNG General Error |
| | | | F302 Motor: Unrecovered internal error |
| | | | F304 Motor: Unrecovered Open Loop Commutation failure |
| | | | F306 Motor: Unrecovered No feedback detected error |
| | | | F308 Motor: Unrecovered Settle timeout |
| | | | F30A Motor: Unrecovered Gross speed error |
| | | | F30C Motor: Unrecovered 12V OK error |
| | | | F30E Motor: Unrecovered Speed error |
| | | | F312 Motor: Unrecovered Internal 12V not OK timeout |
| | | | F314 Motor: Unrecovered Inductive Sense speed error |
| | | | F316 Motor: Unrecovered Spin Sense speed error |
| | | | F31A Motor: Unrecovered Target speed error |
| | | | F31C Motor: Unrecovered Power driver version error |
| | | | F31E Motor: Unrecovered Over current error |
| | | | F322 Motor: Unrecovered Negative regulator fault |
| | | | F324 Motor: Unrecovered Module overtemp error |
| | | | F326 Motor: Unrecovered 12V or 5V OK error |
| | | | F328 Motor: Unrecovered unknown error |
| | | | F366 Motor: Unrecovered Predriver Voltage Offset Calibration Error |
| | | | F368 Motor: Unrecovered Predriver BEMF Gain Calibration Error |
| | | | F36A Motor: Unrecovered Predriver BEMF Unload Calibration Error |
| | | | F370 Motor: Unrecovered IDCS Calibration Measurement 1 Error |
| | | | F372 Motor: Unrecovered IDCS Calibration Measurement 2 Error |
| | | | F374 Motor: Unrecovered IDCS Calibration Saturation Error |
| | | | F376 Motor: Unrecovered IDCS Calibration Adjustment Error |
| | | | F378 Motor: Unrecovered Predriver VDUAL over current |
| | | | F37A Motor: Unrecovered Predriver NEG Chargepump Fault |
| | | | F37C Motor: Unrecovered Predriver VGH Fault |
| | | | F37E Motor: Unrecovered Predriver Ext Interrupt |
| | | | F380 Motor: Unrecovered Predriver Ext Fault |
| | | | F382 Motor: Unrecovered PMIC Not Detected |
| | | | F384 Motor: Unrecovered Get MA Error |
| | | | F386 Motor: Unrecovered Unexpected HD on Ramp |
| | | | F388 Motor: Unrecovered VCPDSA Driver Failure |
| | | | F38A Motor: Unrecovered Motor Start Timeout |
| | | | F38C Motor: Unrecovered Motor PMIC UV12 |
| | | | F38E Motor: Unrecovered Motor PMIC UV5 |
| | | | F390 Motor: Unrecovered Motor PMIC UV09 |
| | | | F392 Motor: Unrecovered Motor PMIC OT12 |
| | | | F394 Motor: Unrecovered Motor PMIC OT5 |
| | | | F396 Motor: Unrecovered Motor PMIC EOTW12 |
| | | | F398 Motor: Unrecovered Motor PMIC EOTW5 |
| | | | F39A Motor: Unrecovered Motor PMIC OC12 |
| | | | F39C Motor: Unrecovered Motor PMIC OC5 |
| | | | F39E Motor: Unrecovered Motor PMIC OC09 |
| | | | F3A0 Motor: Unrecovered Motor PMIC OV12 |
| | | | F3A2 Motor: Unrecovered Motor PMIC OV5 |
| | | | F3A4 Motor: Unrecovered I2C READ Error |
| | | | F3A6 Motor: Unrecovered I2C WRITE Error |
| | | | F3A8 Motor: Unrecovered PMIC not supported |
| | | | F402 Servo: Unrecovered Requested rezero head does not exist |
| | | | F404 Servo: Unrecovered Back EMF movement in progress |
| | | | F406 Servo: Unrecovered Back EMF timeout error |
| | | | F408 Servo: Unrecovered ADC conversion timeout |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|-------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F40A Servo: Unrecovered Load/unload calibration error |
| | | | F40C Servo: Unrecovered Invalid 5 volts |
| | | | F40E Servo: Unrecovered Invalid 12 volts |
| | | | F410 Servo: Unrecovered Invalid harmonic requested |
| | | | F416 Servo: Unrecovered Invalid temperature |
| | | | F418 Servo: Unrecovered Truncated rezero |
| | | | F41A Servo: Unrecovered Heads not loaded |
| | | | F426 Servo: Unrecovered KT Seek out of range |
| | | | F428 Servo: Unrecovered DAC Offset calibration error |
| | | | F42A Servo: Unrecovered Load speed error |
| | | | F42E Servo: Unrecovered ADC Calibration error |
| | | | F430 Servo: Unrecovered ADC Offset error |
| | | | F432 Servo: Unrecovered ADC Limit error |
| | | | F434 Servo: Unrecovered Balancer Resistance error |
| | | | F436 Servo: Unrecovered Balancer Resistance Limit error |
| | | | F438 Servo: Unrecovered First Cylinder error |
| | | | F43A Servo: Unrecovered Valid Cylinder error |
| | | | F43C Servo: Unrecovered ADC Saturation error |
| | | | F43E Servo: Unrecovered Latch Break timeout |
| | | | F440 Servo: Unrecovered MR Resistance out of range error |
| | | | F442 Servo: Unrecovered VCM Retract error |
| | | | F444 Servo: Unrecovered Load Retry error |
| | | | F446 Servo: Unrecovered DFT Sharp error |
| | | | F448 Servo: Unrecovered Load/Unload state error |
| | | | F44A Servo: Unrecovered TFCR out-of-range error |
| | | | F44C Servo: Unrecovered Measure GMR Timeout |
| | | | F44E Servo: Unrecovered Coil Resistance Measurement Failure |
| | | | F460 Servo: Unrecovered WCS Hang Error |
| | | | F462 Servo: Unrecovered DFT Timeout Error |
| | | | F464 Servo: Unrecovered SDM Timeout Error |
| | | | F466 Servo: Unrecovered RRO Write Error |
| | | | F468 Servo: Unrecovered Velocity Error |
| | | | F46A Servo: Unrecovered Start SID Incorrect Error |
| | | | F46C Servo: Unrecovered End Sid Incorrect Error |
| | | | F46E Servo: Unrecovered Measure GMR SDM Failure |
| | | | F470 Servo: Unrecovered VCM Free Speed Error |
| | | | F472 Servo: Unrecovered Emergency Brake Timeout Error |
| | | | F474 Servo: Unrecovered Excessive Current Error |
| | | | F476 Servo: Unrecovered Excessive Velocity Error |
| | | | F477 Servo: Unrecovered Invalid SDM CDB Error |
| | | | F478 Servo: Unrecovered Invalid SDM Descriptor Error |
| | | | F479 Servo: Unrecovered Invalid DFT Descriptor Error |
| | | | F47A Servo: Unrecovered SDM or DFT Allocation Error |
| | | | F47B Servo: Unrecovered SDM OR DFT Transfer Error |
| | | | F47C Servo: Unrecovered SDM Physical Parameter Error |
| | | | F47E Servo: Unrecovered RROF SDM Timeout Error |
| | | | F480 Servo: Unrecovered RROF Over Limit Error |
| | | | F483 Servo: Unrecovered Measure Asymmetry SDM Failure |
| | | | F484 Servo: Unrecovered Measure Overwrite SDM Failure |
| | | | F485 Servo: Unrecovered TFC Utility SDM Failure |
| | | | F487 Servo: Unrecovered Milli-Calibration Error |
| | | | F488 Servo: Unrecovered SIDSAT Timeout Error |
| | | | F489 Servo: Unrecovered SDM Load-And-Drop-Anchor Error |
| | | | F48A Servo: Unrecovered Filter Table Full Error |
| | | | F48B Servo: Unrecovered Filter Table Invalid Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F48D Servo: Unrecovered Measure Qsamp SDM Failure |
| | | | F48F Servo: Unrecovered Tilt Calibration Error |
| | | | F491 Servo: Unrecovered Tilt Numerical Error |
| | | | F492 Servo: Unrecovered Milli Table Load Error |
| | | | F493 Servo: Unrecovered TFCR DAC Out of Range |
| | | | F494 Servo: Unrecovered MRR DAC Out of Range |
| | | | F495 Servo: Unrecovered TFCR Open/Short |
| | | | F497 Servo: Unrecovered DTID Inhibit Error |
| | | | F499 Servo: Unrecovered Waketime Error |
| | | | F49B Servo: Unrecovered SHARP Pulse TFC Entry Error |
| | | | F49D Servo: Unrecovered Heads Not Loaded FFSULI |
| | | | F49F Servo: Unrecovered Load Abort FFSULI |
| | | | F4AD Servo: Unrecovered ODCS Detect Error |
| | | | F4AF Servo: Unrecovered Unexpected Motion Error |
| | | | F4B1 Servo: Unrecovered BEMF Loop error |
| | | | F4B3 Servo: Unrecovered BEMF DTID Error |
| | | | F4B5 Servo: Unrecovered BEMF Lock Error |
| | | | F4B7 Servo: Unrecovered BEMF Fail Error |
| | | | F4B9 Servo: Unrecovered BEMF Speed Error |
| | | | F4BB Servo: Unrecovered Measure GTM SDM Failure |
| | | | F4BD Servo: Unrecovered SAM2SG SDM Failure |
| | | | F4BF Servo: Unrecovered Invalid MULTRG Descriptor Error |
| | | | F4C1 Servo: Unrecovered Filter COEF Overflow |
| | | | F4C3 Servo: Unrecovered WCS Watchdog Expire |
| | | | F4C4 Servo: Unrecovered DFTSQZ Timeout Error |
| | | | F4C6 Servo: Unrecovered Measure HS SDM Failure |
| | | | F4C8 Servo: Unrecovered HD on RAMP SWCAL Unload |
| | | | F4CA Servo: Unrecovered HD on RAMP SWCAL IDsearch |
| | | | F4CE Servo: Unrecovered IDLEA Time Base Duration |
| | | | F4D0 Servo: Unrecovered Emergency Brake Duration |
| | | | F4D2 Servo: Unrecovered VCM Free Duration |
| | | | F4D6 Servo: Unrecovered Search Mode Duration |
| | | | F4D8 Servo: Unrecovered Invalid Seek Target |
| | | | F4DA Servo: Unrecovered safe zone seek error |
| | | | F4DC Servo: Unrecovered head switch at safe zone fail |
| | | | F4DE Servo: Seek Length histogram bin order error |
| | | | F603 AE: Unrecovered IVC fault error |
| | | | F604 Channel/AE: Unrecovered Internal Calibration Error |
| | | | F605 Channel/AE: Unrecovered Internal MR Calibration Error |
| | | | F607 Channel/AE: Unrecovered data with PPM or precomp load |
| | | | F60AAE: TFC Short Error |
| | | | F60C AE: Unrecovered Shorted MR Element Error |
| | | | F60D Unsupported Read Channel Command Error |
| | | | F60E Init: RRCIk Dead Error |
| | | | F60F Init: RRCIk Unlock Error |
| | | | F611 AE: Unrecovered ECS Shorted Fault |
| | | | F613 AE: Unrecovered ECS Open Fault |
| | | | F615 AE: Unrecovered ECS Fault |
| | | | F617 Channel: Unrecovered Channel Error |
| | | | F619 Init: SVCLK Unlock Error |
| | | | F61B AE: Unrecovered Open MR Element Error |
| | | | F61D AE: Unrecovered IC Over Temperature Error |
| | | | F61F AE: Unrecovered IP Clock Count Error |
| | | | F621 AE: Unrecovered DLC SVCLK Error |
| | | | F623 AE: Unrecovered Write Data BLS Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F625 AE: Unrecovered ECSR Dac Out of Range |
| | | | F627 AE: Unrecovered Power Supply Error |
| | | | F629 AE: Unrecovered Open Write Head Error |
| | | | F62B AE: Unrecovered Write Transition Error |
| | | | F62C AE: Unrecovered I2C Command Error |
| | | | F62D AE: Unrecovered I2C Memory Read Error |
| | | | F631 AE: Unrecovered SPE Low In Write Fault |
| | | | F633 Channel: Unrecovered Write Synth Unlock error |
| | | | F635 Unrecovered CH WPTP Timeout |
| | | | F637 AE: Unrecovered Short Write Head Error |
| | | | F638 AE: Unrecovered I2C 5V Register Data Error |
| | | | F639 AE: Unrecovered I2C 12V Register Data Error |
| | | | F63AAE: Unrecovered I2C Memory Checksum Error |
| | | | F63D AE: Unrecovered TFC Open Error |
| | | | F640 AE: Unrecovered DCR Location Error |
| | | | F641 AE: Unrecovered AE Burst overlapped Error |
| | | | F642 AE: Unrecovered Software Readback Error |
| | | | F643 AE: Unrecovered Readback Error |
| | | | F645 AE: Unrecovered Latch Fault Error |
| | | | F647 AE: Unrecovered CHN Power Sequence Error |
| | | | F649 Channel: Unrecovered Reset Flag Error |
| | | | F64B Channel: Unrecovered Gate Command Queue Underflow Error |
| | | | F64D Channel: Unrecovered Sector Size Fault Error |
| | | | F64F Channel: Unrecovered Last Split Fault Error |
| | | | F651 Channel: Unrecovered Servo-Servo Overlap Error |
| | | | F655 Channel: Unrecovered RWBI Out Fault Error |
| | | | F657 Channel: Unrecovered No Write Clock Error |
| | | | F659 Channel: Unrecovered No NRZ Clock Error |
| | | | F65B Channel: Unrecovered Calibration Block Fault Error |
| | | | F65F Channel: Unrecovered Gate Command Queue OverflowError |
| | | | F661 Channel: Unrecovered Ending Write Splice Fault Error |
| | | | F663 Channel: Unrecovered Write Gate Overlap Fault Error |
| | | | F665 Channel: Unrecovered Write Gate Fault Error |
| | | | F667 Channel: Unrecovered Buffer Overflow Write Error |
| | | | F669 Channel: Unrecovered Buffer Underflow Write Error |
| | | | F66B Channel: Unrecovered Write Parity Error |
| | | | F66D Channel: Unrecovered Buffer Overflow Read Error |
| | | | F66F Channel: Unrecovered CTG Wedge Slip Fault Read Error |
| | | | F671 Channel: Unrecovered CTG Packet Late Fault Error |
| | | | F673 Channel: Unrecovered Baseline Instability Count Late Error |
| | | | F675 Channel: Unrecovered Preamp Count Fault Error |
| | | | F677 Channel: Unrecovered Pfault Read Error |
| | | | F679 Channel: Unrecovered Pfault Write Error |
| | | | F67B Channel: Unrecovered Last Data Fault Error |
| | | | F67D Channel: Unrecovered WRPO Fault Error |
| | | | F681 Channel: Unrecovered PLLFloor Error |
| | | | F683 Channel: Unrecovered Loss lock Error |
| | | | F685 Channel: Unrecovered VGA Floor Error |
| | | | F687 Channel: Unrecovered Buffer EVGA Floor Error |
| | | | F689 Channel: Unrecovered TA Detector Error |
| | | | F68B Channel: Unrecovered NPLD Error |
| | | | F68D Channel: Unrecovered ZGR Flag Error |
| | | | F68F Channel: Recovered DPLL Freq Flag Error |
| | | | F691 Channel: Unrecovered Massive Drop Out Detection Error |
| | | | F693 Channel: Unrecovered CTG Parameter Out of Bounds Flag Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F695 Channel: Unrecovered Flaw Signal Sync Error |
| | | | F697 Channel: Unrecovered ACQ Flag Error |
| | | | F699 Channel: Unrecovered No Clock Error |
| | | | F69B Channel: Unrecovered PLL Loss lock Error |
| | | | F69D Channel: Unrecovered ESNR Timeout Error |
| | | | F69F Channel: Unrecovered ADC Sample Not Ready Error |
| | | | F6A0 AE: Unrecovered Fuse Load Fail Error |
| | | | F6A1 AE: Unrecovered Configuration Error |
| | | | F6A3 Channel: Unrecovered Auto RST NRZ-Clock Error |
| | | | F6A5 Channel: Unrecovered Write CRC Fault Error |
| | | | F6A7 Channel: Unrecovered Read Synthesizer Loss of Lock Error |
| | | | F6A9 Channel: Unrecovered RLL Parameter Error |
| | | | F6AB Channel: Unrecovered FIFO Underflow Error |
| | | | F6AD Channel: Unrecovered FIFO Overflow Error |
| | | | F6AF Channel: Unrecovered Iterative Decoder Error |
| | | | F6B1 Channel: Unrecovered Iterative Read Error |
| | | | F6B3 Channel: Unrecovered Encoder Overflow Error |
| | | | F6B5 Channel: Unrecovered Encoder Underflow Error |
| | | | F6B7 Channel: Unrecovered Encoder RAM CRC Error |
| | | | F6B9 Channel: Unrecovered Interface Fault |
| | | | F6BB Channel: Unrecovered QMM EVDump Parse Error |
| | | | F6BD Channel: Unrecovered DiBit Timeout Error |
| | | | F6BF Channel: Unrecovered MXP Write Fault |
| | | | F6C1 Channel: Unrecovered Data Jam Error |
| | | | F6C3 Channel: Unrecovered Code-Word Out Of Order Error |
| | | | F6C5 Channel: Unrecovered Read RLL Buffer CRC Flag Error |
| | | | F6C7 Channel: Unrecovered Write RLL Buffer CRC Flag Error |
| | | | F6C9 Channel: Unrecovered CTG No SAM Detected Fault Error |
| | | | F6CB Channel: Unrecovered ITI Adjust Preload Fault Track Error |
| | | | F6CD Channel: Unrecovered WTG SRV Fault Error |
| | | | F6CF Channel: Unrecovered CTG Engine Not Ready Fault Error |
| | | | F6D1 Channel: Unrecovered LLI Abort Fault Error |
| | | | F6D3 Channel: Unrecovered Retry Fault Error |
| | | | F6D5 Channel: Unrecovered WTG Timeout Fault Error |
| | | | F6D7 Channel: Unrecovered ITI Fault TS Transfer All Error |
| | | | F6D9 Channel: Unrecovered ITI Data Fault Error |
| | | | F6DA Channel: Unrecovered Insufficient TFC Preheat Error |
| | | | F6DB Channel: Unrecovered AE And FAEP Do Not Match |
| | | | F6DD Channel: Unrecovered Data Jam Fault Error |
| | | | F6DF Channel: Unrecovered Code-Word Out of Order Error |
| | | | F6E1 Channel: Unrecovered RLL Initialization Timeout Error |
| | | | F6E2 Channel: Unrecovered AEQ Timeout Error |
| | | | F6E3 Channel: Unrecovered AEQ NLD Initialization Error |
| | | | F6E5 Channel: Unrecovered DLC out of criteria |
| | | | F6E8 Channel: Unrecovered Mode Overlap Write Error |
| | | | F6EA Channel: Unrecovered Ready Fault Error |
| | | | F6EC Channel: Unrecovered Synchronous Abort Done Error |
| | | | F6EE Channel: Unrecovered NRZ Clear Fault Error |
| | | | F6F0 Channel: Unrecovered Collision Fault Error |
| | | | F6F2 Channel: Unrecovered Read Synthesizer Precharge Fail Fault Error |
| | | | F6F4 Channel: Unrecovered Servo Synthesizer Precharge Fail Fault Error |
| | | | F6F6 Channel: Unrecovered Read Synthesizer Loss of Lock Error |
| | | | F6F8 Channel: Unrecovered Fragment Number Fault Error |
| | | | F6FA Channel: Unrecovered Preamble Quality Monitor Fault Error |
| | | | F6FC Channel: Unrecovered RTM Configuration Error |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|----------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F6FD Channel: Unrecovered RTM Failure Error |
| | | | F6FE Channel: Unrecovered RTM Timeout Error |
| | | | F717 Media: Unrecovered Write Overrun Error |
| | | | F71D Media: Unrecovered DRAM CRC Error |
| | | | F723 Media: Unrecovered WRITE Overrun Servo Gate Active |
| | | | F729 Media: Unrecovered S2S MAX Flag Fault |
| | | | F732 Media: Unrecovered Write Fault |
| | | | F745 Media: Unrecovered Sudden Stop Error |
| | | | F75A Media: Unrecovered Unknown Error |
| | | | F764 Media: Unrecovered Merge G-List Failed - No P-List Exists |
| | | | F76B Media: Unrecovered No NRZ Clock Error |
| | | | F787 Media: Unrecovered LLI Underrun Error |
| | | | F78D Media: Unrecovered FFSULI Timeout |
| | | | F793 Media: Unrecovered MEDC Write Data Not Ready error |
| | | | F795 Media: Unrecovered DMA Timeout Error |
| | | | F799 Media: Unrecovered ID Not Found Error |
| | | | F79B Media: Unrecovered Hard Clock Stop until the RDWTCLK is running again |
| | | | F79D Media: Unrecovered Channel Read Timeout Error |
| | | | F79F Media: Unrecovered End Sector PHSN Error on READ |
| | | | F7B5 Media: Unrecovered Shock Sensor Error |
| | | | F7C1 Media: Unrecovered End Sector Check Error |
| | | | F7C3 Media: Unrecovered Read CRC Error |
| | | | F7C5 Media: Unrecovered DRAM ECC Error |
| | | | F7C7 Media: Unrecovered DRAM ECC LBA Error |
| | | | F7C9 Media: Unrecovered End Sector PHSN Error on WRITE |
| | | | F7CD Media: Unrecovered LBA Encryption Error |
| | | | F7D2 Media: Unrecovered DCHW Hang |
| | | | F7D3 Media: Unrecovered SG Drive Error |
| | | | F7D5 Media: Unrecovered Parity PTR FIFO Error |
| | | | F7D7 Media: Unrecovered Parity LBA FIFO Error |
| | | | F7D9 Media: Unrecovered Parity Uncorrectable FIFO Error |
| | | | F7DB Media: Unrecovered Status Uncorrectable FIFO Error |
| | | | F7DD Media: Unrecovered Parity EDC SRAM Error |
| | | | F7DF Media: Unrecovered REQ/ACK Handshake Error |
| | | | F7E3 Media: Unrecovered Read Parity Error |
| | | | F7E5 Media: Unrecovered EPO Error |
| | | | F7E9 Media: Unrecovered AE Access Inhibit Error |
| | | | F7EB Media: Unrecovered PTR FIFO Error |
| | | | F7ED Media: Unrecovered LBA FIFO Error |
| | | | F7F1 Media: Unrecovered Read Transfer Length Error |
| | | | F7F3 Media: Unrecovered DS RDC Burst Error |
| | | | F7F5 Media: Unrecovered SV RDC Burst Error |
| | | | F7F7 Media: Unrecovered Channel AE WG Error |
| | | | F7F9 Media: Unrecovered Dummy Error ERP MEAS |
| | | | F83B CMD: Unable Rebuild Assist |
| | | | F874 CMD: Unrecovered helium leak write abort |
| | | | FCxx Media: Unrecovered Unable to Read RID or FID Number xx |
| 4 | 44 | 0B | Vendor Unique - Internal Target Failure |
| | | | F310 Motor: Unrecovered Spindle Current error |
| | | | F318 Motor: Unrecovered Spin Sense timeout |
| | | | F320 Motor: Unrecovered System clock watchdog error |
| | | | F32A Motor: Unrecovered VCM DAC watchdog error |
| | | | F32C Motor: Unrecovered Module mid-die overtemp fault |
| | | | F32E Motor: Unrecovered Module Vcmp hi-side overtemp fault |
| | | | F330 Motor: Recovered Module Vcmn hi-side overtemp fault |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|----------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F332 Motor: Unrecovered Invalid standby RPM request |
| | | | F334 Motor: Unrecovered Invalid spin state request |
| | | | F336 Motor: Unrecovered Hardware retract timeout |
| | | | F338 Motor: Unrecovered thermal limit exceeded |
| | | | F33A Motor: Unrecovered Predriver fault |
| | | | F33C Motor: Unrecovered Predriver Watchdog Fsys error |
| | | | F33E Motor: Unrecovered Predriver Watchdog DAC error |
| | | | F340 Motor: Unrecovered Predriver Speed Low error |
| | | | F342 Motor: Unrecovered Predriver UV Vboost error |
| | | | F344 Motor: Unrecovered Predriver NREG UV error |
| | | | F346 Motor: Unrecovered Predriver Ext NPOR error |
| | | | F348 Motor: Unrecovered Predriver Reg UV error |
| | | | F34A Motor: Unrecovered Predriver Under Voltage 12 Volt Supply error |
| | | | F34C Motor: Unrecovered Predriver Under Voltage 5 Volt Supply error |
| | | | F34E Motor: Unrecovered Predriver Over Voltage 12 Volt Supply error |
| | | | F350 Motor: Unrecovered Predriver Under Voltage 1.8 Volt Supply error |
| | | | F352 Motor: Unrecovered Predriver Under Voltage 0.9 Volt Supply error |
| | | | F354 Motor: Unrecovered Predriver Under Voltage 1.5 Volt Supply error |
| | | | F356 Motor: Unrecovered Predriver Shock Detected error |
| | | | F358 Motor: Unrecovered Predriver Over Temperature error |
| | | | F35A Motor: Unrecovered Predriver Under Voltage 3.3 Volt Supply error |
| | | | F35C Motor: Unrecovered Predriver Under Voltage 5 and 12 Volt Supply error |
| | | | F35E Motor: Unrecovered Predriver Error in Enabling Power Saving Mode |
| | | | F360 Motor: Unrecovered Predriver Fault in Auto Retract |
| | | | F362 Motor: Unrecovered Predriver Error in Utilizing External Power Supply |
| | | | F364 Motor: Unrecovered Predriver Regulator Supply Fault |
| | | | F36C Motor: Unrecovered Predriver VCM Short Error |
| | | | F36E Motor: Unrecovered Predriver NREG disable error |
| 4 | 44 | F2 | Vendor Unique - Internal Target Failure |
| | | | F134 Head Health Check data compare error |
| 4 | 44 | F6 | Vendor Unique - Internal Target Failure |
| | | | F135 Head Health Check unrecovered media error |
| | | | F141 BATS#2 error Read/Write Test Compare Failed |
| 4 | 44 | F9 | Vendor Unique - Internal Target Failure |
| | | | F414 Servo: Unrecovered Sharp DRAM Parity Rate error |
| | | | F452 Servo: Unrecovered SHARP Parity Rate Error |
| | | | F456 Servo: Unrecovered SHARP Decode Rate Error |
| | | | F45A Servo: Unrecovered SHARP Timeout Rate Error |
| | | | F45E Servo: Unrecovered SHART Other Rate Error |
| 4 | 44 | FA | Vendor Unique - Internal Target Failure |
| | | | F412 Servo: Unrecovered Sharp DRAM Parity error |
| | | | F450 Servo: Unrecovered SHARP Parity Error |
| | | | F454 Servo: Unrecovered SHARP Decode Error |
| | | | F458 Servo: Unrecovered SHARP Timeout Error |
| | | | F45C Servo: Unrecovered SHARP Other Error |
| 4 | 45 | 00 | Helium leak alert |
| | | | F817 CMD: Overtime Helium leak alert |
| 4 | 85 | 00 | Vendor Unique - Internal Key Seed Error |
| | | | 1768 Media: Recovered Key Seed ID Mismatch Error |
| | | | F769 Media: Unrecovered Key Seed ID Mismatch Error |
| | | | Sense Key = Illegal Request |
| 5 | 00 | 16 | Operation in Progress |
| | | | F81F CMD: Operation in Progress |
| 5 | 15 | 00 | PHY Test In Progress Error |
| | | | F50D Host Interface: Phy Test Function in Progress |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| 5 | 1A | 00 | Parameter List Length Error F820 CMD: Unrecovered Parameter List Length Error |
| 5 | 20 | 00 | Invalid Command Operation Code F81E CMD: Reassign Not Allowed F821 CMD: Unrecovered Invalid Opcode in CDB Error |
| 5 | 20 | 02 | Drive locked F878 CMD: Unrecovered drive locked |
| 5 | 21 | 00 | Logical Block Address out of Range F822 CMD: Unrecovered LBA Out Of Range Error |
| 5 | 24 | 00 | Invalid Field in CDB F816 CMD: Incompatible PRDS Version F819 CMD: Unaligned Command Error F823 CMD: Unrecovered Invalid Field In CDB Error F83F CMD: NCQ Priority Error |
| 5 | 25 | 00 | Logical Unit Not Supported F824 CMD: Unrecovered Invalid LUN Error |
| 5 | 26 | 00 | Invalid Field in Parameter List F579 Host Interface: Data Checksum Error F825 CMD: Unrecovered Invalid Field In Parameter List Error F826 CMD: Unrecovered Unsupported Log Page Error F829 CMD: Invalid Tx Setting for Combo Chip Error |
| 5 | 26 | 01 | Command Param Not Support F81A CMD: Param Not Support |
| 5 | 26 | 02 | Parameter Value Invalid F120 BATS error: Code Compatibility Failure F126 BATS error: Code checksum error F127 BATS error: Invalid header F130 BATS error: Incorrect Customer Code F13D BATS error: Invalid Code Signature F830 CMD: Unrecovered Sequence Error |
| 5 | 26 | 04 | Invalid Release of Active Persistent Reservation F828 CMD: Unrecovered Invalid Release of Persistent Reservation Error |
| 5 | 26 | 06 | Command Too Many Target Descriptors F81B CMD: Too Many Target Descriptors |
| 5 | 26 | 07 | Command Unsupported TARG DESC Type Code F81C CMD: Unsupported TARG DESC Type Code |
| 5 | 26 | 08 | Command Too Many Segment Descriptors F81D CMD: Too Many Segment Descriptors |
| 5 | 26 | 53 | CMD: Invalid Programmable Inquiry template size for EMC F83C CMD: CMD: Invalid Programmable Inquiry template size for EMC |
| 5 | 2A | 03 | Reservation Conflict F536 Host Interface: Reservation conflict |
| 5 | 2C | 00 | Illegal Request Sequence Error F511 Host Interface: Illegal Request Sequence Error |
| 5 | 49 | 00 | Invalid Message Error F512 Host Interface: Invalid Message |
| 5 | 55 | 04 | Insufficient Registration Resources F567 Host Interface: Insufficient registration resources |
| Sense Key = Unit Attention | | | |
| 6 | 28 | 00 | Not Ready To Ready Transition (Format completed) F514 Host Interface: Not ready to ready transition |
| 6 | 29 | 01 | Unit Attention - POR Occurred F516 Host Interface: Power on reset |
| 6 | 29 | 02 | Unit Attention - SCSI Bus Reset Occurred F517 Host Interface: SAS Hard Reset (SAS) |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|------------------------------------------------------------------------|-------------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Key | Code | Qual | Description |
| 6 | 29 | 03 | Unit Attention - Bus Device Reset Occurred F518 Host Interface: LUN Reset (SAS) |
| 6 | 29 | 04 | Unit Attention - Self Initiated Reset Occurred F519 Host Interface: Self-initiated reset |
| 6 | 29 | 07 | I_T Nexus Loss Occurred F554 Host Interface: I_T_Nexus Loss Occurred (SAS) |
| 6 | 2A | 01 | Mode Parameters Changed F51C Host Interface: Mode parameters changed |
| 6 | 2A | 02 | Log Parameters Changed F51D Host Interface: Log parameters changed |
| 6 | 2A | 03 | Reservations Preempted F51E Host Interface: Reservations pre-empted |
| 6 | 2A | 04 | Reservations Released F51F Host Interface: Reservations released |
| 6 | 2A | 05 | Registrations Released F520 Host Interface: Registrations pre-empted |
| 6 | 2A | 09 | Capacity Data Changed F524 Host Interface: Capacity Data Changed |
| 6 | 2A | 10 | Timestamp Changed F525 Host Interface: Timestamp Changed |
| 6 | 2F | 00 | Commands Cleared by Another Initiator F521 Host Interface: Commands cleared by another initiator |
| 6 | 2F | 01 | Commands Cleared by Power Loss Notification F573 Host Interface: Commands cleared due to power failure event (SAS) |
| 6 | 3F | 01 | Microcode has been changed F522 Host Interface: Microcode changed |
| 6 | 3F | 02 | Primary FW image is degraded - booting from secondary F526 Primary FW image is degraded - booting from secondary |
| 6 | 3F | 05 | Device Identifier Changed F537 Host Interface: Device identifier changed |
| | | | Sense Key = Access Denied |
| 7 | 20 | 02 | Access Denied F509 Host Interface: In Self-Test - Band locked F827 CMD: Unrecovered Access Denied Error |
| 7 | 27 | 08 | Zone is read only F876 CMD: Unrecovered zone is read only |
| 7 | 2C | 0E | Zone is offline F877 CMD: Unrecovered zone is offline |
| | | | Sense Key = Aborted Command |
| B | 0C | 0E | Media Multiple WRITE Error F7BE Media: Multiple WRITE Error |
| B | 0E | 01 | Information Unit Too Short F561 Host Interface: Information unit too short (SAS) |
| B | 0E | 02 | Information Unit Too Long F562 Host Interface: Information unit too long (SAS) |
| B | 10 | 00 | Aborted Command - T10 Error F7BC Media: Unrecovered T10 error |
| B | 10 | 01 | Aborted Command - End-to-End Guard Check F568 Host Interface: End-to-End Data Protection Guard check F7BD Media: Unrecovered Guard Check Error |
| B | 10 | 02 | Aborted Command - End-to-End Application Tag Check F569 Host Interface: End-to-End Data Protection Application Tag check F7BB Media: Unrecovered Application Tag Error |
| B | 10 | 03 | Aborted Command - End-to-End Reference Tag Check F56A Host Interface: End-to-End Data Protection Reference Tag check |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|-------------------------------------------------------------|
| Key | Code | Qual | Description |
| | | | F7B9 Media: Unrecovered Reference Tag error |
| B | 11 | 03 | Aborted Command - OCT Timeout In Recovery |
| | | | F7BF Media: Multiple READ Error |
| B | 3F | 0F | Aborted Command - Echo Buffer Overwritten |
| | | | F544 Host Interface: Echo buffer overwritten |
| B | 44 | 00 | Internal Target Failure |
| | | | F250 WRITE Uncorrectable Flagged Limit |
| | | | F52D Host Interface: Buffer CRC error on read |
| | | | F52E Host Interface: Internal target failure |
| | | | F54A Host Interface: Xfer Ready credit exceeded |
| | | | F54B Host Interface: Transfer length error |
| | | | F56B Host Interface: ECC error in DRAM customer data area |
| | | | F56C Host Interface: Uncorrectable DRAM ECC error |
| | | | F570 Host Interface: Host interface Synchronous CRC error |
| | | | F57A Host Interface: Synchronous CRC Error on Write |
| | | | F57B Host Interface: Synchronous CRC LBA Error |
| | | | F62F Channel: Unrecovered Channel NRZ Clear Timeout Error |
| | | | F741 Media: OCT Timeout Not Dispatched |
| | | | F742 Media: OCT Timeout In Recovery |
| | | | F743 Media: OCT Timeout Executing |
| | | | F75C Media: Unrecovered Internal Media Access Timeout Error |
| | | | F772 Media: Unrecovered DASH starting timeout |
| | | | F773 Media: Unrecovered ID table timeout |
| | | | F774 Media: Unrecovered Servo timeout |
| | | | F775 Media: Unrecovered Buffers timeout |
| | | | F776 Media: Unrecovered DASH done timeout |
| | | | F777 Media: Unrecovered DASH unknown timeout |
| | | | F778 Media: DINIT2 timeout |
| | | | F779 Media: Unrecovered Mini Mode Timeout |
| | | | F77B Media: Unrecovered Abort EOS fail |
| | | | F77E Media: Write Error Recovery Timeout |
| | | | F77F Media: Read Error Recovery Timeout |
| | | | F7D0 Media: Unrecovered Pre-load Timeout Error |
| | | | F813 CMD: Insufficient Buffer Space Error |
| | | | F815 CMD: Aborted From Internal TMF Error |
| | | | F83D CMD: Quiesce not allowed |
| B | 47 | 01 | Data Phase CRC Error |
| | | | F54E Host Interface: Data Phase CRC Error |
| B | 4B | 00 | Data Phase Error |
| | | | F53E Host Interface: Data phase error |
| B | 4B | 02 | Too Much Write Data |
| | | | F560 Host Interface: Too much write data (SAS) |
| B | 4B | 03 | ACK/NAK Timeout |
| | | | F551 Host Interface: ACK NAK Timeout (SAS) |
| | | | F57D Host Interface: Break Received (SAS only) |
| B | 4B | 04 | NAK Received |
| | | | F550 Host Interface: NAK rcvd (SAS) |
| B | 4B | 05 | Data Offset Error |
| | | | F552 Host Interface: Bad parameter offset (SAS) |
| B | 4B | 06 | Initiator Response Timeout |
| | | | F555 Host Interface: Initiator Response Timeout (SAS) |
| B | 4B | FF | Internal Host forced |
| | | | F510 Host Interface: Host Interface Error forced |
| B | 4E | 00 | Overlapped Commands Attempted |
| | | | F534 Host Interface: Overlapped command attempted |

| Valid Sense Key, Code, Qualifier Combinations Used by the Drive | | | |
|-----------------------------------------------------------------|------|------|-----------------------------------------------|
| Key | Code | Qual | Description |
| B | 4F | 00 | Command Aborted Due To OOB |
| | | | F53F Host Interface: Abort by OOB (SAS) |
| B | 55 | 00 | Failed to reserve MFG slots |
| | | | F222 Failed to reserve MFG slots |
| | | | Sense Key = Miscompare |
| E | 1D | 00 | Miscompare During Verify Operation |
| | | | F535 Host Interface: Miscompare during verify |

12.2.9 FRU: Field Replaceable Unit (Byte 14)

The FRU (Field Replaceable Unit) field value will always be zero.

Note: The FRU field may be used to store vendor specific information in certain firmware builds.

12.2.10 Sense Key Specific (Byte 15 through 17)

The definition of this field is determined by the value of the sense key field.

12.2.10.1 Sense Key Specific - Illegal Request (Sense Key = 5h)

Error field pointer is returned.

Table 357 Field Pointer Bytes

| Byte | Bit | | | | | | | |
|-------|---------------------------------|-----|----------|---|-----|-------------|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 15 | SKSV | C/D | Reserved | | BPV | Bit Pointer | | |
| 16-17 | (MSB) Field Pointer (LSB) | | | | | | | |

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.

12.2.10.2 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 358 Actual Retry Count

| Byte | Bit | | | | | | | |
|------|--------------------|----------|---|---|----------|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 15 | SKSV | Reserved | | | | | | |
| 16 | Secondary Step | | | | ERP Type | | | |
| 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.

Secondary Step

Secondary error recovery step (valid for servo errors only).

ERP Type

Error recovery table branch for this error. Valid values are shown in the table below.

Table 359 Recovery Type

| Recovery Type | ERP Type |
|---------------------------------|----------|
| Read | 0x00 |
| Verify | 0x01 |
| Write | 0x02 |
| Seek | 0x03 |
| Read, Sync Byte branch | 0x04 |
| Read, Thermal Asperity branch | 0x05 |
| Read, Minus Mod branch | 0x06 |
| Verify, Sync Byte branch | 0x07 |
| Verify, Thermal Asperity branch | 0x08 |
| Verify, Minus Mod branch | 0x09 |

12.2.10.3 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 360 Progress Indication

| Byte | Bit | | | | | | | |
|-------|-------|---------------------|---|---|---|---|---|-------|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 15 | SKSV | Reserved | | | | | | |
| 16-17 | (MSB) | Progress Indication | | | | | | (LSB) |

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.

12.2.11 Reserved (Byte 18 through 19)

Reserved fields are filled with zero.

12.2.12 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.

12.2.13 Physical Error Record (Product Specific Information) (Byte 24 thru 29)

- ILI = 1 - This field contains zeros.
- ILI = 0 - These bytes contain the physical location of the error in cylinder, head, and sector. Bytes 24, 25, and 26 are cylinder high, middle, and low bytes respectively, of the cylinder number. Byte 27 is the head number. Bytes 28 and 29 are the high and low bytes, respectively of the sector number.

If the head is undetermined, bytes 24, 25, and 26 are set to 0FFFFFFh. If the head number is undetermined, byte 27 is set to 0FFh. If cylinder, head, and sector have no relevance 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.

Table 361 Log Only Errors

| Valid | ILI | Description |
|-------|-----|---------------------------------------------------------------------------------------|
| 1 | 0 | Cylinder Number (bytes 24-26) Head number (byte 27) Sector Number (bytes 28-29) |
| 1 | 1 | 0x000000000000 |
| 0 | x | 0x000000000000 - (not used/invalid) |

12.3 Descriptor Format Sense Data

The descriptor format sense data for response codes 72h (current errors) and 73h (deferred errors) is defined below.

Table 362 Descriptor Format Sense Data

| Byte | Bit | | | | | | | |
|-------|---------------------------------|----------------------------|---|---|-----------|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Reserved | Response Code (72h or 73h) | | | | | | |
| 1 | Reserved | | | | Sense Key | | | |
| 2 | Additional Sense Code | | | | | | | |
| 3 | Additional Sense Code Qualifier | | | | | | | |
| 4-6 | Reserved | | | | | | | |
| 7 | Additional Sense Length (n-7) | | | | | | | |
| 8-m | Sense Data Descriptor # 1 | | | | | | | |
| m...x | | | | | | | | |
| x -n | Sense Data Descriptor # K | | | | | | | |

Response Code: 72h Current Error. See Section 12.1.3 for more details.

73h Deferred Error. See Section 12.1.3 for more details.

The Sense Key definitions is the same as fixed format sense data.

The Additional Sense Code/Qualifier definitions is the same as fixed format sense data.

The Value of the Additional Sense Length indicates the remaining number of bytes in the sense data

Sense data descriptors (Byte 8 through n) provide specific sense information. The general format of a sense data descriptor is shown below:

Table 363 Sense Data Descriptor Format

| Byte | Bit | | | | | | | |
|------|--------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Descriptor Type | | | | | | | |
| 1 | Additional Length (n-1) | | | | | | | |
| 2-n | Sense Data Descriptor Specific | | | | | | | |

The Descriptor Type identifies the type of a sense data descriptor. (Supported types are listed below)

Table 364 Supported Descriptor Types

| Type Code | Description |
|-----------|-----------------------------------------------------------|
| 00h | Information Sense Data Descriptor |
| 01h | Command-specific Sense Data Descriptor |
| 02h | Sense Key Specific Sense Data Descriptor |
| 03h | Field Replaceable Unit Sense Descriptor |
| 05h | Block Command Sense Data Descriptor |
| 80h | Vendor Unique Unit Error Code Sense Data Descriptor |
| 81h | Vendor Unique Physical Error Record Sense Data Descriptor |

The ADDITIONAL LENGTH field indicates the number of sense data descriptor specific bytes that follow in the sense data descriptor.

12.3.1 Sense Data Descriptor Definitions

12.3.1.1 Information Sense Data Descriptor

The format of the Information Sense Data Descriptor is shown in Table 365

Table 365 Information Sense Data Descriptor Format

| Byte | Bit | | | | | | | |
|------|-------------------------|----------|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Descriptor Type (00h) | | | | | | | |
| 1 | Additional Length (0Ah) | | | | | | | |
| 2 | VALID | Reserved | | | | | | |
| 3 | Reserved | | | | | | | |
| 4-11 | Information | | | | | | | |

Descriptor Type Set to 00h for Information Sense Data Descriptor.

Additional Length Set to 0Ah for Information Sense Data Descriptor.

VALID This bit is set to 1 when content of the Information field is valid and set to 0 if the Information field is invalid.

Information This field contains an LBA or other information depending on the value of the ILI bit in the Block Command Sense Descriptor (See Section 12.3.1.5).

- ILI = 0 (or if the descriptor is not present): The Information 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.

Note: An LBA other than the command LBA may be reported on the Reassign Block (07h) command.

- ILI = 1: The Information field contains the difference (residue) of the requested length in bytes. Negative values are indicated by two's complement notation.

For ABORTED COMMAND/INTERNAL TARGET FAILURE cases, the LBA information returned are not directly related to media error (media error may be due to an indirect cause).

12.3.1.2 Command-specific Sense Data Descriptor

The format of the format of Command-specific Sense Data Descriptor is shown in Table 366.

Table 366 Command-specific Sense Data Descriptor Format

| Byte | Bit | | | | | | | |
|------|------------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Descriptor Type (01h) | | | | | | | |
| 1 | Additional Length (0Ah) | | | | | | | |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4-11 | Command-Specific Information | | | | | | | |

Descriptor Type Set to 01h for Command-specific Sense Data Descriptor.

Additional Length Set to 0Ah for Command-specific Sense Data Descriptor.

Command-specific Information The value of this field is set the same as Command Specific Information field in fixed format sense data (See Section 12.2.7)

12.3.1.3 Sense Key Specific Sense Data Descriptor

The format of Sense-key Specific Sense Data Descriptor is shown in Table 367.

Table 367 Information Sense Data Descriptor Format

| Byte | Bit | | | | | | | |
|------|--------------------------|-------------------------|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Descriptor Type (02h) | | | | | | | |
| 1 | Additional Length (06h) | | | | | | | |
| 2 | Reserved | | | | | | | |
| 3 | Reserved | | | | | | | |
| 4 | SKSV | Sense Key Specific Bits | | | | | | |
| 5-6 | Sense Key Specific Bytes | | | | | | | |
| 7 | Reserved | | | | | | | |

Descriptor Type Set to 02h for Command-specific Sense Data Descriptor.

Additional Length Set to 06h for Command-specific Sense Data Descriptor.

Fields in byte 4 through 6 (including the **SKSV** bit, **Sense-Key Specific Bits**, and **Sense-Key Specific Bytes**):

These fields are set the same as byte 15 - 17 in fixed format sense data (See Section 12.2.10 for details).

12.3.1.4 Field Replaceable Unit (FRU) Sense Data Descriptor

The format of Field Replaceable Unit (FRU) Sense Data Descriptor is shown in Table 368.

Table 368 Field Replaceable Unit Sense Data Descriptor Format

| Byte | Bit | | | | | | | |
|------|-----------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Descriptor Type (03h) | | | | | | | |
| 1 | Additional Length (02h) | | | | | | | |
| 2 | Reserved | | | | | | | |
| 3 | Field Replaceable Unit Code | | | | | | | |

Descriptor Type Set to 03h for Field Replaceable Unit Sense Data Descriptor.

Additional Length Set to 02h for Field Replaceable Unit Sense Data Descriptor.

Command-specific Information This field is set the same as the Field Replaceable Unit Code of fixed format sense data. (See Section 12.2.9).

12.3.1.5 Block Command Sense Descriptor

The format of the Block Command Sense Data Descriptor is shown in Table 369.

Table 369 Block Command Sense Data Descriptor Format

| Byte | Bit | | | | | | | |
|------|-------------------------|---|-----|---|------------|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Descriptor Type (05h) | | | | | | | |
| 1 | Additional Length (02h) | | | | | | | |
| 2 | Reserved | | | | | | | |
| 3 | Reserved=0 | | ILI | | Reserved=0 | | | |

Descriptor Type Set to 05h for Block Command Sense Data Descriptor.

Additional Length Set to 02h for Block Command Sense Data Descriptor.

ILI: Value of the ILI bit is set to indicate what type of value is stored in the Information field of the Information Sense Data Descriptor (See Section 12.3.1.1 for details).

12.3.1.6 Vendor Unique Unit Error Sense Data Descriptor

The format of the Vendor Unique Unit Error Code Sense Data Descriptor is shown in Table 370.

Table 370 Vendor Unique Unit Error Code Sense Data Descriptor

| Byte | Bit | | | | | | | |
|------|-------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Descriptor Type (80h) | | | | | | | |
| 1 | Additional Length (02h) | | | | | | | |
| 2-3 | Unit Error Code (UEC) | | | | | | | |

Descriptor Type Set to 80h for Vendor Unique Unit Error Code Sense Data Descriptor.

Additional Length Set to 02h for Vendor Unique Unit Error Code Sense Data Descriptor.

Unit Error Code: This field contains the same value as the Vendor Unique Error Information field in fixed format sense data which gives detailed information about the error (See Section 12.2.12). 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

12.3.1.7 Vendor Unique Physical Error Record Sense Data Descriptor

The format of the Vendor Unique Physical Error Record Sense Data Descriptor is shown in Table 371.

Table 371 Vendor Unique Physical Error Record Sense Data Descriptor

| Byte | Bit | | | | | | | |
|------|-------------------------|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | Descriptor Type (81h) | | | | | | | |
| 1 | Additional Length (06h) | | | | | | | |
| 2-7 | Physical Error Record | | | | | | | |

Descriptor Type Set to 81h for Vendor Unique Unit Physical Error Record Sense Data Descriptor.

Additional Length Set to 06h for Vendor Unique Unit Physical Error Record Sense Data Descriptor.

Unit Error Code: This field is set the same as the Physical Error Record in fixed format sense data. (See Section 12.2.13 for details).

13 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.

The list of Unit Error Codes and descriptions does not have a direct correlation to the error descriptions and Sense Key/Code/Qualifier descriptions in Section 10 "Additional information". These codes are used internally by Western Digital and may change without notice.

How to find a specific UEC

The second hex digit indicates the grouping, e.g., interface, media, servo, etc. types of errors. The table is sorted without regard to the first hex digit; instead, sorting is by the least significant three hex digits.

Table 372 Unit Error Codes

| UEC | Description |
|------|----------------------------------------------------------|
| 0000 | No Error |
| F101 | BATS error: Reserved Area - Invalid request |
| F102 | BATS error: Reserved Area - Broken |
| F103 | BATS error: Reserved Area - Invalid version |
| F104 | BATS error: Reserved Area - Invalid checksum |
| F105 | BATS error: Reserved Area - Invalid eyecatcher |
| F106 | BATS error: Reserved Area - Invalid main header checksum |
| F107 | BATS error: Reserved Area - Invalid read length |
| F108 | BATS error: Reserved Area - Address boundary error |
| 1109 | BATS error: Reserved Area - Error reading first copy |
| F10D | BATS error: Reserved Area - Write fix hard error |
| F10E | BATS error: Reserved Area - EPO Flash Log |
| F111 | BATS error: RAM code load error |
| F112 | BATS error: RAM code check |
| F113 | BATS error: Exception in primary FW image |
| F114 | BATS error: Reserved Area - Invalid request |
| F118 | BATS#2 error: Seek test error |
| F119 | BATS#2 error: Read/write test error |
| F11B | BATS#2 error: CRC test error |
| F11C | BATS#2 error: XOR test error |
| F11D | BATS error: Incorrect Disk Code |
| F11E | SoC compatibility failure |
| F11F | HI test: No command slot available |
| F120 | BATS error: Code Compatibility Failure |
| F121 | HI test: Loopback sector compare failure |
| F122 | HI test: Failed to gain word sync |
| F123 | BATS error: Reserved map index too large |
| F124 | Bring-up error |
| F125 | BATS error: Invalid RID/FID |
| F126 | BATS error: Code checksum error |
| F127 | BATS error: Invalid header |
| F12A | DRAM test error |
| F12B | BATS error: Reserved area - invalid model |
| F12C | Host Interface Test: Port active error |
| F12D | Format Reserved: FAT Size Exceeded Error |
| F12E | Format Reserved: Insufficient DIRS Good Error |
| F12F | Format Reserved: Insufficient FATS Good Error |
| F130 | BATS error: Incorrect Customer Code |
| F131 | Flash timeout |
| F132 | GEM FH track read error |
| F133 | BATS error: Vendor ID mismatch |

| UEC | Description |
|------------|--------------------------------------------------|
| F134 | Head Health Check data compare error |
| F135 | Head Health Check unrecovered media error |
| F136 | BATS#2 error: End-To-End Data Protection error |
| F137 | Flash ECC error |
| 1138 | BATS error: Primary Flash Not Ready |
| F139 | Format Reserved: Resize RID/FID Error |
| F13A | Format Reserved: Too many RDEF entries |
| F13C | BATS error: NCDE DRAM failure |
| F13D | BATS error: Invalid Code Signature |
| F13E | BATS#2 error: TCG Test Failed |
| F13F | BATS#2 error: Read/Write Test Compare Failed |
| F140 | Format Reserved: Too many Defects Error |
| F141 | BATS#2 error Read/Write Test Compare Failed |
| F142 | ATA Diagnostic Code: No Error |
| F143 | ATA Diagnostic Code: Formatter Error |
| F144 | ATA Diagnostic Code: Sector Buffer Error |
| F145 | BATS#2 error: EDC Compare Test error |
| F146 | BATS#2 error: EDC Encryption Test error |
| F147 | ATA Diagnostic Code: Read/Write Test Error |
| F148 | BATS error: Still broken after clear |
| F149 | BATS#2 error: Security: AES Error |
| F14A | BATS#2 error: Security: RSA Error |
| F14B | BATS#2 error: Security: DRGB Error |
| F14C | BATS#2 error: Security: SHA256 Error |
| F14D | BATS#2 error: Security: HMAC Error |
| F14E | BATS#2 error: Security: Hardware AES Error |
| F14F | BATS#2 error: Security: Hardware SHA256 Error |
| | |
| 1201 | Sanity: Error In UEC Class |
| 1202 | Sanity: Error In UEC Cause |
| F203 | Sanity: Sanity Check Failure |
| F204 | Reassign reserved area media error |
| F205 | G-list full - can't reassign any more sectors |
| F206 | No spares available |
| F208 | Mode Page Structure Mismatch |
| F209 | Miscompare of SBA in the P-List |
| F20B | DSLT: Invalid number of splits |
| F20C | DSLT: Invalid relaxed format |
| F20D | DSLT: First Fragment too large |
| F20E | DSLT: Invalid end offset |
| F20F | DSLT: Cycle not complete |
| F220 | MFG: Consistency Check failed |
| F221 | MFG: General Align Tables Missing |
| F222 | Failed to reserve MFG slots |
| F230 | SEC_MGR: AES Hardware Error |
| F231 | SEC_MGR: BDE Unwrap Error |
| F240 | SEC_MGR: PRNG Seed Error |
| F241 | SEC_MGR: PRNG General Error |
| F250 | WRITE Uncorrectable Flagged Limit |
| | |
| 1301 | Motor: Recovered internal error |
| F302 | Motor: Unrecovered internal error |
| 1303 | Motor: Recovered Open Loop Commutation failure |
| F304 | Motor: Unrecovered Open Loop Commutation failure |
| 1305 | Motor: Recovered No feedback detected error |
| F306 | Motor: Unrecovered No feedback detected error |

| UEC | Description |
|------------|-------------------------------------------------------|
| 1307 | Motor: Recovered Settle timeout |
| F308 | Motor: Unrecovered Settle timeout |
| 1309 | Motor: Recovered Gross speed error |
| F30A | Motor: Unrecovered Gross speed error |
| 130B | Motor: Recovered 12V OK error |
| F30C | Motor: Unrecovered 12V OK error |
| 130D | Motor: Recovered Speed error |
| F30E | Motor: Unrecovered Speed error |
| 130F | Motor: Recovered Spindle Current error |
| F310 | Motor: Unrecovered Spindle Current error |
| 1311 | Motor: Recovered Internal 12V not OK timeout |
| F312 | Motor: Unrecovered Internal 12V not OK timeout |
| 1313 | Motor: Recovered Inductive Sense measurement timeout |
| F314 | Motor: Unrecovered Inductive Sense speed error |
| 1315 | Motor: Recovered Spin Sense speed error |
| F316 | Motor: Unrecovered Spin Sense speed error |
| 1317 | Motor: Recovered Spin Sense timeout |
| F318 | Motor: Unrecovered Spin Sense timeout |
| 1319 | Motor: Recovered Target speed error |
| F31A | Motor: Unrecovered Target speed error |
| F31C | Motor: Unrecovered Power driver version error |
| 131D | Motor: Recovered Over current error |
| F31E | Motor: Unrecovered Over current error |
| 131F | Motor: Recovered System clock watchdog error |
| F320 | Motor: Unrecovered System clock watchdog error |
| 1321 | Motor: Recovered Negative regulator fault |
| F322 | Motor: Unrecovered Negative regulator fault |
| 1323 | Motor: Recovered Module overtemp error |
| F324 | Motor: Unrecovered Module overtemp error |
| 1325 | Motor: Recovered 12V or 5V OK error |
| F326 | Motor: Unrecovered 12V or 5V OK error |
| 1327 | Motor: Recovered unknown error |
| F328 | Motor: Unrecovered unknown error |
| 1329 | Motor: Recovered VCM DAC watchdog error |
| F32A | Motor: Unrecovered VCM DAC watchdog error |
| 132B | Motor: Recovered Module mid-die overtemp fault |
| F32C | Motor: Unrecovered Module mid-die overtemp fault |
| 132D | Motor: Recovered Module Vcmp hi-side overtemp fault |
| F32E | Motor: Unrecovered Module Vcmp hi-side overtemp fault |
| 132F | Motor: Recovered Module Vcmn hi-side overtemp fault |
| F330 | Motor: Recovered Module Vcmn hi-side overtemp fault |
| 1331 | Motor: Recovered Invalid standby RPM request |
| F332 | Motor: Unrecovered Invalid standby RPM request |
| 1333 | Motor: Recovered Invalid spin state request |
| F334 | Motor: Unrecovered Invalid spin state request |
| 1335 | Motor: Recovered Hardware retract timeout |
| F336 | Motor: Unrecovered Hardware retract timeout |
| 1337 | Motor: Recovered thermal limit exceeded |
| F338 | Motor: Unrecovered thermal limit exceeded |
| 1339 | Motor: Recovered Predriver fault |
| F33A | Motor: Unrecovered Predriver fault |
| 133B | Motor: Recovered Predriver Watchdog Fsys error |
| F33C | Motor: Unrecovered Predriver Watchdog Fsys error |
| 133D | Motor: Recovered Predriver Watchdog DAC error |
| F33E | Motor: Unrecovered Predriver Watchdog DAC error |
| 133F | Motor: Recovered Predriver Speed Low error |

| UEC | Description |
|------------|-----------------------------------------------------------------------|
| F340 | Motor: Unrecovered Predriver Speed Low error |
| 1341 | Motor: Recovered Predriver UV Vboost error |
| F342 | Motor: Unrecovered Predriver UV Vboost error |
| 1343 | Motor: Recovered Predriver NREG UV error |
| F344 | Motor: Unrecovered Predriver NREG UV error |
| 1345 | Motor: Recovered Predriver Ext NPOR error |
| F346 | Motor: Unrecovered Predriver Ext NPOR error |
| 1347 | Motor: Recovered Predriver Reg UV error |
| F348 | Motor: Unrecovered Predriver Reg UV error |
| 1349 | Motor: Recovered Predriver Under Voltage 12 Volt Supply error |
| F34A | Motor: Unrecovered Predriver Under Voltage 12 Volt Supply error |
| 134B | Motor: Recovered Predriver Under Voltage 5 Volt Supply error |
| F34C | Motor: Unrecovered Predriver Under Voltage 5 Volt Supply error |
| 134D | Motor: Recovered Predriver Over Voltage 12 Volt Supply error |
| F34E | Motor: Unrecovered Predriver Over Voltage 12 Volt Supply error |
| 134F | Motor: Recovered Predriver Under Voltage 1.8 Volt Supply error |
| F350 | Motor: Unrecovered Predriver Under Voltage 1.8 Volt Supply error |
| 1351 | Motor: Recovered Predriver Under Voltage 0.9 Volt Supply error |
| F352 | Motor: Unrecovered Predriver Under Voltage 0.9 Volt Supply error |
| 1353 | Motor: Recovered Predriver Under Voltage 1.5 Volt Supply error |
| F354 | Motor: Unrecovered Predriver Under Voltage 1.5 Volt Supply error |
| 1355 | Motor: Recovered Predriver Shock Detected error |
| F356 | Motor: Unrecovered Predriver Shock Detected error |
| 1357 | Motor: Recovered Predriver Over Temperature error |
| F358 | Motor: Unrecovered Predriver Over Temperature error |
| 1359 | Motor: Recovered Predriver Under Voltage 3.3 Volt Supply error |
| F35A | Motor: Unrecovered Predriver Under Voltage 3.3 Volt Supply error |
| 135B | Motor: Recovered Predriver Under Voltage 5 and 12 Volt Supply error |
| F35C | Motor: Unrecovered Predriver Under Voltage 5 and 12 Volt Supply error |
| 135D | Motor: Recovered Predriver Error in Enabling Power Saving Mode |
| F35E | Motor: Unrecovered Predriver Error in Enabling Power Saving Mode |
| 135F | Motor: Recovered Predriver Fault in Auto Retract |
| F360 | Motor: Unrecovered Predriver Fault in Auto Retract |
| 1361 | Motor: Recovered Predriver Error in Utilizing External Power Supply |
| F362 | Motor: Unrecovered Predriver Error in Utilizing External Power Supply |
| 1363 | Motor: Recovered Predriver Regulator Supply Fault |
| F364 | Motor: Unrecovered Predriver Regulator Supply Fault |
| 1365 | Motor: Recovered Predriver Voltage Offset Calibration Error |
| F366 | Motor: Unrecovered Predriver Voltage Offset Calibration Error |
| 1367 | Motor: Recovered Predriver BEMF Gain Calibration Error |
| F368 | Motor: Unrecovered Predriver BEMF Gain Calibration Error |
| 1369 | Motor: Recovered Predriver BEMF Unload Calibration Error |
| F36A | Motor: Unrecovered Predriver BEMF Unload Calibration Error |
| 136B | Motor: Recovered Predriver VCM Short Error |
| F36C | Motor: Unrecovered Predriver VCM Short Error |
| 136D | Motor: Recovered Predriver NREG disable error |
| F36E | Motor: Unrecovered Predriver NREG disable error |
| 136F | Motor: Recovered IDCS Calibration Measurement 1 Error |
| F370 | Motor: Unrecovered IDCS Calibration Measurement 1 Error |
| 1371 | Motor: Recovered IDCS Calibration Measurement 2 Error |
| F372 | Motor: Unrecovered IDCS Calibration Measurement 2 Error |
| 1373 | Motor: Recovered IDCS Calibration Saturation Error |
| F374 | Motor: Unrecovered IDCS Calibration Saturation Error |
| 1375 | Motor: Recovered IDCS Calibration Adjustment Error |
| F376 | Motor: Unrecovered IDCS Calibration Adjustment Error |
| 1377 | Motor: Recovered Predriver VDUAL over current |

| UEC | Description |
|------------|---------------------------------------------------------|
| F378 | Motor: Unrecovered Predriver VDUAL over current |
| 1379 | Motor: Recovered Predriver NEG Chargepump Fault |
| F37A | Motor: Unrecovered Predriver NEG Chargepump Fault |
| 137B | Motor: Recovered Predriver VGH Fault |
| F37C | Motor: Unrecovered Predriver VGH Fault |
| 137D | Motor: Recovered Predriver Ext Interrupt |
| F37E | Motor: Unrecovered Predriver Ext Interrupt |
| 137F | Motor: Recovered Predriver Ext Fault |
| F380 | Motor: Unrecovered Predriver Ext Fault |
| 1381 | Motor: Recovered PMIC Not Detected |
| F382 | Motor: Unrecovered PMIC Not Detected |
| 1383 | Motor: Recovered Get MA Error |
| F384 | Motor: Unrecovered Get MA Error |
| 1385 | Motor: Recovered Unexpected HD on Ramp |
| F386 | Motor: Unrecovered Unexpected HD on Ramp |
| 1387 | Motor: Recovered VCPDSA Driver Failure |
| F388 | Motor: Unrecovered VCPDSA Driver Failure |
| 1389 | Motor: Recovered Motor Start Timeout |
| F38A | Motor: Unrecovered Motor Start Timeout |
| 138B | Motor: Recovered Motor PMIC UV12 |
| F38C | Motor: Unrecovered Motor PMIC UV12 |
| 138D | Motor: Recovered Motor PMIC UV5 |
| F38E | Motor: Unrecovered Motor PMIC UV5 |
| 138F | Motor: Recovered Motor PMIC UV09 |
| F390 | Motor: Unrecovered Motor PMIC UV09 |
| 1391 | Motor: Recovered Motor PMIC OT12 |
| F392 | Motor: Unrecovered Motor PMIC OT12 |
| 1393 | Motor: Recovered Motor PMIC OT5 |
| F394 | Motor: Unrecovered Motor PMIC OT5 |
| 1395 | Motor: Recovered Motor PMIC EOTW12 |
| F396 | Motor: Unrecovered Motor PMIC EOTW12 |
| 1397 | Motor: Recovered Motor PMIC EOTW5 |
| F398 | Motor: Unrecovered Motor PMIC EOTW5 |
| 1399 | Motor: Recovered Motor PMIC OC12 |
| F39A | Motor: Unrecovered Motor PMIC OC12 |
| 139B | Motor: Recovered Motor PMIC OC5 |
| F39C | Motor: Unrecovered Motor PMIC OC5 |
| 139D | Motor: Recovered Motor PMIC OC09 |
| F39E | Motor: Unrecovered Motor PMIC OC09 |
| 139F | Motor: Recovered Motor PMIC OV12 |
| F3A0 | Motor: Unrecovered Motor PMIC OV12 |
| 13A1 | Motor: Recovered Motor PMIC OV5 |
| F3A2 | Motor: Unrecovered Motor PMIC OV5 |
| 13A3 | Motor: Recovered I2C READ Error |
| F3A4 | Motor: Unrecovered I2C READ Error |
| 13A5 | Motor: Recovered I2C WRITE Error |
| F3A6 | Motor: Unrecovered I2C WRITE Error |
| 13A7 | Motor: Recovered PMIC not supported |
| F3A8 | Motor: Unrecovered PMIC not supported |
| | |
| 1401 | Servo: Recovered Requested rezero head does not exist |
| F402 | Servo: Unrecovered Requested rezero head does not exist |
| 1403 | Servo: Recovered Back EMF movement in progress |
| F404 | Servo: Unrecovered Back EMF movement in progress |
| 1405 | Servo: Recovered Back EMF timeout error |
| F406 | Servo: Unrecovered Back EMF timeout error |

| UEC | Description |
|------------|----------------------------------------------------|
| 1407 | Servo: Recovered ADC conversion timeout |
| F408 | Servo: Unrecovered ADC conversion timeout |
| 1409 | Servo: Recovered Load/unload calibration error |
| F40A | Servo: Unrecovered Load/unload calibration error |
| 140B | Servo: Recovered Invalid 5 volts |
| F40C | Servo: Unrecovered Invalid 5 volts |
| 140D | Servo: Recovered Invalid 12 volts |
| F40E | Servo: Unrecovered Invalid 12 volts |
| 140F | Servo: Recovered Invalid harmonic requested |
| F410 | Servo: Unrecovered Invalid harmonic requested |
| 1411 | Servo: Recovered Sharp DRAM Parity error |
| F412 | Servo: Unrecovered Sharp DRAM Parity error |
| 1413 | Servo: Recovered Sharp DRAM Parity Rate error |
| F414 | Servo: Unrecovered Sharp DRAM Parity Rate error |
| 1415 | Servo: Recovered Invalid temperature |
| F416 | Servo: Unrecovered Invalid temperature |
| 1417 | Servo: Recovered Truncated rezero |
| F418 | Servo: Unrecovered Truncated rezero |
| 1419 | Servo: Recovered Heads not loaded |
| F41A | Servo: Unrecovered Heads not loaded |
| 141B | Servo: Recovered Current error |
| F41C | Servo: Unrecovered Current error |
| 141D | Servo: Recovered Seek timeout |
| F41E | Servo: Unrecovered Seek timeout |
| 141F | Servo: Recovered Seek error |
| F420 | Servo: Unrecovered Seek error |
| 1421 | Servo: Recovered Track following error |
| F422 | Servo: Unrecovered Track following error |
| 1423 | Servo: Recovered Track follow timeout |
| F424 | Servo: Unrecovered Track follow timeout |
| 1425 | Servo: Recovered KT Seek out of range |
| F426 | Servo: Unrecovered KT Seek out of range |
| 1427 | Servo: Recovered DAC Offset calibration error |
| F428 | Servo: Unrecovered DAC Offset calibration error |
| 1429 | Servo: Recovered Load speed error |
| F42A | Servo: Unrecovered Load speed error |
| 142B | Servo: Recovered RRO Calibration timeout |
| F42C | Servo: Unrecovered RRO Calibration timeout |
| 142D | Servo: Recovered ADC Calibration error |
| F42E | Servo: Unrecovered ADC Calibration error |
| 142F | Servo: Recovered ADC Offset error |
| F430 | Servo: Unrecovered ADC Offset error |
| 1431 | Servo: Recovered ADC Limit error |
| F432 | Servo: Unrecovered ADC Limit error |
| 1433 | Servo: Recovered Balancer Resistance error |
| F434 | Servo: Unrecovered Balancer Resistance error |
| 1435 | Servo: Recovered Balancer Resistance Limit error |
| F436 | Servo: Unrecovered Balancer Resistance Limit error |
| 1437 | Servo: Recovered First Cylinder error |
| F438 | Servo: Unrecovered First Cylinder error |
| 1439 | Servo: Recovered Valid Cylinder error |
| F43A | Servo: Unrecovered Valid Cylinder error |
| 143B | Servo: Recovered ADC Saturation error |
| F43C | Servo: Unrecovered ADC Saturation error |
| 143D | Servo: Recovered Latch Break timeout |
| F43E | Servo: Unrecovered Latch Break timeout |

| UEC | Description |
|------------|--------------------------------------------------------|
| 143F | Servo: Recovered MR Resistance out of range error |
| F440 | Servo: Unrecovered MR Resistance out of range error |
| 1441 | Servo: Recovered VCM Retract error |
| F442 | Servo: Unrecovered VCM Retract error |
| 1443 | Servo: Recovered Load Retry error |
| F444 | Servo: Unrecovered Load Retry error |
| 1445 | Servo: Recovered DFT Sharp error |
| F446 | Servo: Unrecovered DFT Sharp error |
| 1447 | Servo: Recovered Load/Unload state error |
| F448 | Servo: Unrecovered Load/Unload state error |
| 1449 | Servo: Recovered TFCR out-of-range error |
| F44A | Servo: Unrecovered TFCR out-of-range error |
| 144B | Servo: Recovered Measure GMR Timeout |
| F44C | Servo: Unrecovered Measure GMR Timeout |
| 144D | Servo: Recovered Coil Resistance Measurement Failure |
| F44E | Servo: Unrecovered Coil Resistance Measurement Failure |
| 144F | Servo: Recovered SHARP Parity Error |
| F450 | Servo: Unrecovered SHARP Parity Error |
| 1451 | Servo: Recovered SHARP Parity Rate Error |
| F452 | Servo: Unrecovered SHARP Parity Rate Error |
| 1453 | Servo: Recovered SHARP Decode Error |
| F454 | Servo: Unrecovered SHARP Decode Error |
| 1455 | Servo: Recovered SHARP Decode Rate Error |
| F456 | Servo: Unrecovered SHARP Decode Rate Error |
| 1457 | Servo: Recovered SHARP Timeout Error |
| F458 | Servo: Unrecovered SHARP Timeout Error |
| 1459 | Servo: Recovered SHARP Timeout Rate Error |
| F45A | Servo: Unrecovered SHARP Timeout Rate Error |
| 145B | Servo: Recovered SHARP Other Error |
| F45C | Servo: Unrecovered SHARP Other Error |
| 145D | Servo: Recovered SHARP Other Rate Error |
| F45E | Servo: Unrecovered SHARP Other Rate Error |
| 145F | Servo: Recovered WCS Hang Error |
| F460 | Servo: Unrecovered WCS Hang Error |
| 1461 | Servo: Recovered DFT Timeout Error |
| F462 | Servo: Unrecovered DFT Timeout Error |
| 1463 | Servo: Recovered SDM Timeout Error |
| F464 | Servo: Unrecovered SDM Timeout Error |
| 1465 | Servo: Recovered RRO Write Error |
| F466 | Servo: Unrecovered RRO Write Error |
| 1467 | Servo: Recovered Velocity Error |
| F468 | Servo: Unrecovered Velocity Error |
| 1469 | Servo: Recovered Start SID Incorrect Error |
| F46A | Servo: Unrecovered Start SID Incorrect Error |
| 146B | Servo: Recovered End Sid Incorrect Error |
| F46C | Servo: Unrecovered End Sid Incorrect Error |
| 146D | Servo: Recovered Measure GMR SDM Failure |
| F46E | Servo: Unrecovered Measure GMR SDM Failure |
| 146F | Servo: Recovered VCM Free Speed Error |
| F470 | Servo: Unrecovered VCM Free Speed Error |
| 1471 | Servo: Recovered Emergency Brake Timeout Error |
| F472 | Servo: Unrecovered Emergency Brake Timeout Error |
| 1473 | Servo: Recovered Excessive Current Error |
| F474 | Servo: Unrecovered Excessive Current Error |
| 1475 | Servo: Recovered Excessive Velocity Error |
| F476 | Servo: Unrecovered Excessive Velocity Error |

| UEC | Description |
|------------|---------------------------------------------------|
| F477 | Servo: Unrecovered Invalid SDM CDB Error |
| F478 | Servo: Unrecovered Invalid SDM Descriptor Error |
| F479 | Servo: Unrecovered Invalid DFT Descriptor Error |
| F47A | Servo: Unrecovered SDM or DFT Allocation Error |
| F47B | Servo: Unrecovered SDM OR DFT Transfer Error |
| F47C | Servo: Unrecovered SDM Physical Parameter Error |
| 147D | Servo: Recovered RROF SDM Timeout Error |
| F47E | Servo: Unrecovered RROF SDM Timeout Error |
| 147F | Servo: Recovered RROF Over Limit Error |
| F480 | Servo: Unrecovered RROF Over Limit Error |
| F481 | Servo: Unrecovered Self-Test Failed |
| 1482 | Servo: Recovered Measure Asymmetry SDM Failure |
| F483 | Servo: Unrecovered Measure Asymmetry SDM Failure |
| F484 | Servo: Unrecovered Measure Overwrite SDM Failure |
| F485 | Servo: Unrecovered TFC Utility SDM Failure |
| 1486 | Servo: Recovered Milli-Calibration Error |
| F487 | Servo: Unrecovered Milli-Calibration Error |
| F488 | Servo: Unrecovered SIDSAT Timeout Error |
| F489 | Servo: Unrecovered SDM Load-And-Drop-Anchor Error |
| F48A | Servo: Unrecovered Filter Table Full Error |
| F48B | Servo: Unrecovered Filter Table Invalid Error |
| 148C | Servo: Recovered Measure Qsamp SDM Failure |
| F48D | Servo: Unrecovered Measure Qsamp SDM Failure |
| 148E | Servo: Recovered Tilt Calibration Error |
| F48F | Servo: Unrecovered Tilt Calibration Error |
| 1490 | Servo: Recovered Tilt Numerical Error |
| F491 | Servo: Unrecovered Tilt Numerical Error |
| F492 | Servo: Unrecovered Milli Table Load Error |
| F493 | Servo: Unrecovered TFCR DAC Out of Range |
| F494 | Servo: Unrecovered MRR DAC Out of Range |
| F495 | Servo: Unrecovered TFCR Open/Short |
| 1496 | Servo: Recovered DTID Inhibit Error |
| F497 | Servo: Unrecovered DTID Inhibit Error |
| 1498 | Servo: Recovered Waketime Error |
| F499 | Servo: Unrecovered Waketime Error |
| 149A | Servo: Recovered SHARP Pulse TFC Entry Error |
| F49B | Servo: Unrecovered SHARP Pulse TFC Entry Error |
| 149C | Servo: Recovered Heads Not Loaded FFSULI |
| F49D | Servo: Unrecovered Heads Not Loaded FFSULI |
| 149E | Servo: Recovered Load Abort FFSULI |
| F49F | Servo: Unrecovered Load Abort FFSULI |
| 14A0 | Servo: Recovered IDLEA Grab Error |
| F4A1 | Servo: Unrecovered IDLEA Grab Error |
| 14A2 | Servo: Recovered IDLEA Seek Error |
| F4A3 | Servo: Unrecovered IDLEA Seek Error |
| 14A4 | Servo: Recovered AVEDAC Error |
| F4A5 | Servo: Unrecovered AVEDAC Error |
| 14A6 | Servo: Recovered IDLEA Exit Timeout Error |
| F4A7 | Servo: Unrecovered IDLEA Exit Timeout Error |
| 14A8 | Servo: Recovered IDLEA Long Seek Error |
| F4A9 | Servo: Unrecovered IDLEA Long Seek Error |
| 14AA | Servo: Recovered IDLEA SID ACQ Error |
| F4AB | Servo: Unrecovered IDLEA SID ACQ Error |
| 14AC | Servo: Recovered ODCS Detect Error |
| F4AD | Servo: Unrecovered ODCS Detect Error |
| 14AE | Servo: Recovered Unexpected Motion Error |

| UEC | Description |
|------------|------------------------------------------------------------------------|
| F4AF | Servo: Unrecovered Unexpected Motion Error |
| 14B0 | Servo: Recovered BEMF Loop Error |
| F4B1 | Servo: Unrecovered BEMF Loop error |
| 14B2 | Servo: Recovered BEMF DTID Error |
| F4B3 | Servo: Unrecovered BEMF DTID Error |
| 14B4 | Servo: Recovered BEMF Lock Error |
| F4B5 | Servo: Unrecovered BEMF Lock Error |
| 14B6 | Servo: Recovered BEMF Fail Error |
| F4B7 | Servo: Unrecovered BEMF Fail Error |
| 14B8 | Servo: Recovered BEMF Speed Error |
| F4B9 | Servo: Unrecovered BEMF Speed Error |
| 14BA | Servo: Recovered Measure GTM SDM Failure |
| F4BB | Servo: Unrecovered Measure GTM SDM Failure |
| 14BC | Servo: Recovered SAM2SG SDM Failure |
| F4BD | Servo: Unrecovered SAM2SG SDM Failure |
| 14BE | Servo: Recovered Invalid MULTRG Descriptor Error |
| F4BF | Servo: Unrecovered Invalid MULTRG Descriptor Error |
| 14C0 | Servo: Recovered Filter COEF Overflow |
| F4C1 | Servo: Unrecovered Filter COEF Overflow |
| 14C2 | Servo: Recovered WCS Watchdog Expire |
| F4C3 | Servo: Unrecovered WCS Watchdog Expire |
| F4C4 | Servo: Unrecovered DFTSQZ Timeout Error |
| F4C6 | Servo: Unrecovered Measure HS SDM Failure |
| 14C7 | Servo: Recovered HD on RAMP SWCAL Unload |
| F4C8 | Servo: Unrecovered HD on RAMP SWCAL Unload |
| 14C9 | Servo: Recovered HD on RAMP SWCAL IDsearch |
| F4CA | Servo: Unrecovered HD on RAMP SWCAL IDsearch |
| 14CB | Servo: Recovered IDLEA Check CMPLT Error |
| F4CC | Servo: Unrecovered IDLEA Check CMPLT Error |
| 14CD | Servo: Recovered IDLEA Time Base Duration |
| F4CE | Servo: Unrecovered IDLEA Time Base Duration |
| 14CF | Servo: Recovered Emergency Brake Duration |
| F4D0 | Servo: Unrecovered Emergency Brake Duration |
| 14D1 | Servo: Recovered VCM Free Duration |
| F4D2 | Servo: Unrecovered VCM Free Duration |
| 14D5 | Servo: Recovered Search Mode Duration |
| F4D6 | Servo: Unrecovered Search Mode Duration |
| 14D7 | Servo: Recovered Invalid Seek Target |
| F4D8 | Servo: Unrecovered Invalid Seek Target |
| 14D9 | Servo: Recovered safe zone seek error |
| F4DA | Servo: Unrecovered safe zone seek error |
| 14DB | Servo: Recovered head switch at safe zone fail |
| F4DC | Servo: Unrecovered head switch at safe zone fail |
| F4DE | Servo: Seek Length histogram bin order error |
| | |
| F501 | Host Interface: Logical unit not ready |
| F502 | Host Interface: Logical unit becoming ready |
| F503 | Host Interface: Logical unit not ready - initializing command required |
| F504 | Host Interface: Not ready - format in progress |
| F505 | Host Interface: Not ready - self-test in progress |
| F506 | Host Interface: Reassign failed |
| F507 | Host Interface: Format failed |
| F508 | Host Interface: Not Ready - Session opened |
| F509 | Host Interface: In Self-Test - Band locked |
| F50B | Host Interface: Not Ready - Sanitize in progress |
| F50C | Host Interface: Sanitize Command failed |

| UEC | Description |
|------------|----------------------------------------------------------------------|
| F50D | Host Interface: Phy Test Function in Progress |
| F510 | Host Interface: Host Interface Error forced |
| F511 | Host Interface: Illegal Request Sequence Error |
| F512 | Host Interface: Invalid Message |
| F513 | Host Interface: No ready microcode activation required |
| F514 | Host Interface: Not ready to ready transition |
| F516 | Host Interface: Power on reset |
| F517 | Host Interface: SAS Hard Reset (SAS) |
| F518 | Host Interface: LUN Reset (SAS) |
| F519 | Host Interface: Self-initiated reset |
| F51C | Host Interface: Mode parameters changed |
| F51D | Host Interface: Log parameters changed |
| F51E | Host Interface: Reservations pre-empted |
| F51F | Host Interface: Reservations released |
| F520 | Host Interface: Registrations pre-empted |
| F521 | Host Interface: Commands cleared by another initiator |
| F522 | Host Interface: Microcode changed |
| F524 | Host Interface: Capacity Data Changed |
| F525 | Host Interface: Timestamp Changed |
| F526 | Primary FW image is degraded - booting from secondary |
| F52D | Host Interface: Buffer CRC error on read |
| F52E | Host Interface: Internal target failure |
| F534 | Host Interface: Overlapped command attempted |
| F535 | Host Interface: Miscompare during verify |
| F536 | Host Interface: Reservation conflict |
| F537 | Host Interface: Device identifier changed |
| F53E | Host Interface: Data phase error |
| F53F | Host Interface: Abort by OOB (SAS) |
| F544 | Host Interface: Echo buffer overwritten |
| F54A | Host Interface: Xfer Ready credit exceeded |
| F54B | Host Interface: Transfer length error |
| F54E | Host Interface: Data Phase CRC Error |
| F550 | Host Interface: NAK rcvd (SAS) |
| F551 | Host Interface: ACK NAK Timeout (SAS) |
| F552 | Host Interface: Bad parameter offset (SAS) |
| F553 | Host Interface: LUN Not ready, Notify (Enable Spinup) required (SAS) |
| F554 | Host Interface: I_T Nexus Loss Occurred (SAS) |
| F555 | Host Interface: Initiator Response Timeout (SAS) |
| F556 | LUN Not ready, Power Grant required (SAS) |
| F560 | Host Interface: Too much write data (SAS) |
| F561 | Host Interface: Information unit too short (SAS) |
| F562 | Host Interface: Information unit too long (SAS) |
| F567 | Host Interface: Insufficient registration resources |
| F568 | Host Interface: End-to-End Data Protection Guard check |
| F569 | Host Interface: End-to-End Data Protection Application Tag check |
| F56A | Host Interface: End-to-End Data Protection Reference Tag check |
| F56B | Host Interface: ECC error in DRAM customer data area |
| F56C | Host Interface: Uncorrectable DRAM ECC error |
| F570 | Host Interface: Host interface Synchronous CRC error |
| F572 | Host Interface: LUN not ready; manual intervention required |
| F573 | Host Interface: Commands cleared due to power failure event (SAS) |
| F579 | Host Interface: Data Checksum Error |
| F57A | Host Interface: Synchronous CRC Error on Write |
| F57B | Host Interface: Synchronous CRC LBA Error |
| F57D | Host Interface: Break Received (SAS only) |
| | |

| UEC | Description |
|------------|-------------------------------------------------------|
| 1601 | Channel/AE: Recovered Internal Logic Error |
| 1602 | AE: Recovered IVC fault error |
| F603 | AE: Unrecovered IVC fault error |
| F604 | Channel/AE: Unrecovered Internal Calibration Error |
| F605 | Channel/AE: Unrecovered Internal MR Calibration Error |
| 1606 | AE: Recovered AE Last Data Read Error |
| F607 | Channel/AE: Unrecovered data with PPM or precomp load |
| 1609 | AE: Recovered TFC Short Error |
| F60A | AE: TFC Short Error |
| 160B | AE: Recovered Shorted MR Element Error |
| F60C | AE: Unrecovered Shorted MR Element Error |
| F60D | Unsupported Read Channel Command Error |
| F60E | Init: RRCIk Dead Error |
| F60F | Init: RRCIk Unlock Error |
| 1610 | AE: Recovered ECS Shorted Fault |
| F611 | AE: Unrecovered ECS Shorted Fault |
| 1612 | AE: Recovered ECS Open Fault |
| F613 | AE: Unrecovered ECS Open Fault |
| 1614 | AE: Recovered ECS Fault |
| F615 | AE: Unrecovered ECS Fault |
| 1616 | Channel: Recovered Channel Error |
| F617 | Channel: Unrecovered Channel Error |
| 1618 | AE: Recovered STO current fault error |
| F619 | Init: SVCLK Unlock Error |
| 161A | AE: Recovered Open MR Element Error |
| F61B | AE: Unrecovered Open MR Element Error |
| 161C | AE: Recovered IC Over Temperature Error |
| F61D | AE: Unrecovered IC Over Temperature Error |
| 161E | AE: Recovered IP Clock Count Error |
| F61F | AE: Unrecovered IP Clock Count Error |
| 1620 | AE: Recovered DLC SVCLK Error |
| F621 | AE: Unrecovered DLC SVCLK Error |
| 1622 | AE: Recovered Write Data BLS Error |
| F623 | AE: Unrecovered Write Data BLS Error |
| 1624 | AE: Recovered STO short fault error |
| F625 | AE: Unrecovered ECSR Dac Out of Range |
| 1626 | AE: Recovered Power Supply Error |
| F627 | AE: Unrecovered Power Supply Error |
| 1628 | AE: Recovered Open Write Head Error |
| F629 | AE: Unrecovered Open Write Head Error |
| 162A | AE: Recovered Write Transition Error |
| F62B | AE: Unrecovered Write Transition Error |
| F62C | AE: Unrecovered I2C Command Error |
| F62D | AE: Unrecovered I2C Memory Read Error |
| 162E | Channel: Recovered Channel NRZ Clear Timeout Error |
| F62F | Channel: Unrecovered Channel NRZ Clear Timeout Error |
| 1630 | AE: Recovered SPE Low In Write Fault |
| F631 | AE: Unrecovered SPE Low In Write Fault |
| 1632 | AE: Recovered STO Open fault error |
| F633 | Channel: Unrecovered Write Synth Unlock error |
| F635 | Unrecovered CH WPTP Timeout |
| 1636 | AE: Recovered Short Write Head Error |
| F637 | AE: Unrecovered Short Write Head Error |
| F638 | AE: Unrecovered I2C 5V Register Data Error |
| F639 | AE: Unrecovered I2C 12V Register Data Error |
| F63A | AE: Unrecovered I2C Memory Checksum Error |

| UEC | Description |
|------------|------------------------------------------------------------|
| 163C | AE: Recovered TFC Open Error |
| F63D | AE: Unrecovered TFC Open Error |
| 163E | AE: Recovered SoC DIE Temperature Dropped Below Warning |
| 163F | AE: Recovered SoC DIE Temperature Above Fatal |
| F640 | AE: Unrecovered DCR Location Error |
| F641 | AE: Unrecovered AE Burst overlapped Error |
| F642 | AE: Unrecovered Software Readback Error |
| F643 | AE: Unrecovered Readback Error |
| F645 | AE: Unrecovered Latch Fault Error |
| 1646 | AE: Recovered CHN Power Sequence Error |
| F647 | AE: Unrecovered CHN Power Sequence Error |
| 1648 | Channel: Recovered Reset Flag Error |
| F649 | Channel: Unrecovered Reset Flag Error |
| 164A | Channel: Recovered Gate Command Queue Underflow Error |
| F64B | Channel: Unrecovered Gate Command Queue Underflow Error |
| 164C | Channel: Recovered Sector Size Fault Error |
| F64D | Channel: Unrecovered Sector Size Fault Error |
| 164E | Channel: Recovered Last Split Fault Error |
| F64F | Channel: Unrecovered Last Split Fault Error |
| 1650 | Channel: Recovered Servo-Servo Overlap Error |
| F651 | Channel: Unrecovered Servo-Servo Overlap Error |
| 1652 | Channel: Recovered Read Gate Fault Error |
| F653 | Channel: Unrecovered Read Gate Fault Error |
| 1654 | Channel: Recovered RWBI Out Fault Error |
| F655 | Channel: Unrecovered RWBI Out Fault Error |
| 1656 | Channel: Recovered No Write Clock Error |
| F657 | Channel: Unrecovered No Write Clock Error |
| 1658 | Channel: Recovered No NRZ Clock Error |
| F659 | Channel: Unrecovered No NRZ Clock Error |
| 165A | Channel: Recovered Calibration Block Fault Error |
| F65B | Channel: Unrecovered Calibration Block Fault Error |
| 165C | Channel: Recovered Mode Overlap Read Fault Error |
| F65D | Channel: Unrecovered Mode Overlap Read Fault Error |
| 165E | Channel: Recovered Gate Command Queue Overflow Error |
| F65F | Channel: Unrecovered Gate Command Queue OverflowError |
| 1660 | Channel: Recovered Ending Write Splice Fault Error |
| F661 | Channel: Unrecovered Ending Write Splice Fault Error |
| 1662 | Channel: Recovered Write Gate Overlap Fault Error |
| F663 | Channel: Unrecovered Write Gate Overlap Fault Error |
| 1664 | Channel: Recovered Write Gate Fault Error |
| F665 | Channel: Unrecovered Write Gate Fault Error |
| 1666 | Channel: Recovered Buffer Overflow Write Error |
| F667 | Channel: Unrecovered Buffer Overflow Write Error |
| 1668 | Channel: Recovered Buffer Underflow Write Error |
| F669 | Channel: Unrecovered Buffer Underflow Write Error |
| 166A | Channel: Recovered Write Parity Error |
| F66B | Channel: Unrecovered Write Parity Error |
| 166C | Channel: Recovered Buffer Overflow Read Error |
| F66D | Channel: Unrecovered Buffer Overflow Read Error |
| 166E | Channel: Recovered CTG Wedge Slip Fault Error |
| F66F | Channel: Unrecovered CTG Wedge Slip Fault Read Error |
| 1670 | Channel: Recovered CTG Packet Late Fault Error |
| F671 | Channel: Unrecovered CTG Packet Late Fault Error |
| 1672 | Channel: Recovered Baseline Instability Count Late Error |
| F673 | Channel: Unrecovered Baseline Instability Count Late Error |
| 1674 | Channel: Recovered Preamp Count Fault Error |

| UEC | Description |
|------------|-------------------------------------------------------------|
| F675 | Channel: Unrecovered Preamp Count Fault Error |
| 1676 | Channel: Recovered Pfault Read Error |
| F677 | Channel: Unrecovered Pfault Read Error |
| 1678 | Channel: Recovered Pfault Write Error |
| F679 | Channel: Unrecovered Pfault Write Error |
| 167A | Channel: Recovered Last Data Fault Error |
| F67B | Channel: Unrecovered Last Data Fault Error |
| 167C | Channel: Recovered WRPO Fault Error |
| F67D | Channel: Unrecovered WRPO Fault Error |
| 167E | Channel: Recovered Forced Channel Fault Error |
| F67F | Channel: Unrecovered Forced Channel Fault Error |
| 1680 | Channel: Recovered PLLFloor Error |
| F681 | Channel: Unrecovered PLLFloor Error |
| 1682 | Channel: Recovered Loss lock Error |
| F683 | Channel: Unrecovered Loss lock Error |
| 1684 | Channel: Recovered VGA Floor Error |
| F685 | Channel: Unrecovered VGA Floor Error |
| 1686 | Channel: Recovered Buffer EVGA Floor Error |
| F687 | Channel: Unrecovered Buffer EVGA Floor Error |
| 1688 | Channel: Recovered TA Detector Error |
| F689 | Channel: Unrecovered TA Detector Error |
| 168A | Channel: Recovered NPLD Error |
| F68B | Channel: Unrecovered NPLD Error |
| 168C | Channel: Recovered ZGR Flag Error |
| F68D | Channel: Unrecovered ZGR Flag Error |
| 168E | Channel: Recovered DPLL Freq Flag Error |
| F68F | Channel: Recovered DPLL Freq Flag Error |
| 1690 | Channel: Recovered Massive Drop Out Detection Error |
| F691 | Channel: Unrecovered Massive Drop Out Detection Error |
| 1692 | Channel: Recovered CTG Parameter Out of Bounds Error |
| F693 | Channel: Unrecovered CTG Parameter Out of Bounds Flag Error |
| 1694 | Channel: Recovered Flaw Signal Sync Error |
| F695 | Channel: Unrecovered Flaw Signal Sync Error |
| 1696 | Channel: Recovered ACQ Flag Error |
| F697 | Channel: Unrecovered ACQ Flag Error |
| 1698 | Channel: Recovered No Clock Error |
| F699 | Channel: Unrecovered No Clock Error |
| 169A | Channel: Recovered PLL Loss lock Error |
| F69B | Channel: Unrecovered PLL Loss lock Error |
| F69D | Channel: Unrecovered ESNR Timeout Error |
| 169E | Channel: Recovered ADC Sample Not Ready Error |
| F69F | Channel: Unrecovered ADC Sample Not Ready Error |
| F6A0 | AE: Unrecovered Fuse Load Fail Error |
| F6A1 | AE: Unrecovered Configuration Error |
| 16A2 | Channel: Recovered Auto RST NRZ-Clock Error |
| F6A3 | Channel: Unrecovered Auto RST NRZ-Clock Error |
| 16A4 | Channel: Recovered Write CRC Fault Error |
| F6A5 | Channel: Unrecovered Write CRC Fault Error |
| 16A6 | Channel: Recovered Read Synthesizer Loss of Lock Error |
| F6A7 | Channel: Unrecovered Read Synthesizer Loss of Lock Error |
| 16A8 | Channel: Recovered RLL Parameter Error |
| F6A9 | Channel: Unrecovered RLL Parameter Error |
| 16AA | Channel: Recovered FIFO Underflow Error |
| F6AB | Channel: Unrecovered FIFO Underflow Error |
| 16AC | Channel: Recovered FIFO Overflow Error |
| F6AD | Channel: Unrecovered FIFO Overflow Error |

| UEC | Description |
|------------|-----------------------------------------------------------|
| 16AE | Channel: Recovered Iterative Decoder Error |
| F6AF | Channel: Unrecovered Iterative Decoder Error |
| 16B0 | Channel: Recovered Iterative Read Error |
| F6B1 | Channel: Unrecovered Iterative Read Error |
| 16B2 | Channel: Recovered Encoder Overflow Error |
| F6B3 | Channel: Unrecovered Encoder Overflow Error |
| 16B4 | Channel: Recovered Encoder Underflow Error |
| F6B5 | Channel: Unrecovered Encoder Underflow Error |
| 16B6 | Channel: Recovered Encoder RAM CRC Error |
| F6B7 | Channel: Unrecovered Encoder RAM CRC Error |
| 16B8 | Channel: Recovered Interface Fault |
| F6B9 | Channel: Unrecovered Interface Fault |
| F6BB | Channel: Unrecovered QMM EVDump Parse Error |
| 16BC | Channel: Recovered DiBit Timeout Error |
| F6BD | Channel: Unrecovered DiBit Timeout Error |
| 16BE | Channel: Recovered MXP Write Fault |
| F6BF | Channel: Unrecovered MXP Write Fault |
| 16C0 | Channel: Recovered Data Jam Error |
| F6C1 | Channel: Unrecovered Data Jam Error |
| 16C2 | Channel: Recovered Code-Word Out Of Order Error |
| F6C3 | Channel: Unrecovered Code-Word Out Of Order Error |
| 16C4 | Channel: Recovered Read RLL Buffer CRC Flag Error |
| F6C5 | Channel: Unrecovered Read RLL Buffer CRC Flag Error |
| 16C6 | Channel: Recovered Write RLL Buffer CRC Flag Error |
| F6C7 | Channel: Unrecovered Write RLL Buffer CRC Flag Error |
| 16C8 | Channel: Recovered CTG No SAM Detected Fault Error |
| F6C9 | Channel: Unrecovered CTG No SAM Detected Fault Error |
| 16CA | Channel: Recovered ITI Adjust Preload Fault Track Error |
| F6CB | Channel: Unrecovered ITI Adjust Preload Fault Track Error |
| 16CC | Channel: Recovered WTG SRV Fault Error |
| F6CD | Channel: Unrecovered WTG SRV Fault Error |
| 16CE | Channel: Recovered CTG Engine Not Ready Fault Error |
| F6CF | Channel: Unrecovered CTG Engine Not Ready Fault Error |
| 16D0 | Channel: Recovered LLI Abort Fault Error |
| F6D1 | Channel: Unrecovered LLI Abort Fault Error |
| 16D2 | Channel: Recovered Retry Fault Error |
| F6D3 | Channel: Unrecovered Retry Fault Error |
| 16D4 | Channel: Recovered WTG Timeout Fault Error |
| F6D5 | Channel: Unrecovered WTG Timeout Fault Error |
| 16D6 | Channel: Recovered ITI Fault TS Transfer All Error |
| F6D7 | Channel: Unrecovered ITI Fault TS Transfer All Error |
| 16D8 | Channel: Recovered ITI Data Fault Error |
| F6D9 | Channel: Unrecovered ITI Data Fault Error |
| F6DA | Channel: Unrecovered Insufficient TFC Preheat Error |
| F6DB | Channel: Unrecovered AE And FAEP Do Not Match |
| 16DC | Channel: Recovered Data Jam Fault Error |
| F6DD | Channel: Unrecovered Data Jam Fault Error |
| 16DE | Channel: Recovered Code-Word Out of Order Error |
| F6DF | Channel: Unrecovered Code-Word Out of Order Error |
| 16E0 | Channel: Recovered RLL Initialization Timeout Error |
| F6E1 | Channel: Unrecovered RLL Initialization Timeout Error |
| F6E2 | Channel: Unrecovered AEQ Timeout Error |
| F6E3 | Channel: Unrecovered AEQ NLD Initialization Error |
| 16E4 | Channel: Recovered DLC out of criteria |
| F6E5 | Channel: Unrecovered DLC out of criteria |
| 16E7 | Channel: Recovered Mode Overlap Write Error |

| UEC | Description |
|------------|-------------------------------------------------------------------|
| F6E8 | Channel: Unrecovered Mode Overlap Write Error |
| 16E9 | Channel: Recovered Ready Fault Error |
| F6EA | Channel: Unrecovered Ready Fault Error |
| 16EB | Channel: Recovered Synchronous Abort Done Error |
| F6EC | Channel: Unrecovered Synchronous Abort Done Error |
| 16ED | Channel: Recovered NRZ Clear Fault Error |
| F6EE | Channel: Unrecovered NRZ Clear Fault Error |
| 16EF | Channel: Recovered Collision Fault Error |
| F6F0 | Channel: Unrecovered Collision Fault Error |
| 16F1 | Channel: Recovered Read Synthesizer Precharge Fail Fault Error |
| F6F2 | Channel: Unrecovered Read Synthesizer Precharge Fail Fault Error |
| 16F3 | Channel: Recovered Servo Synthesizer Precharge Fail Fault Error |
| F6F4 | Channel: Unrecovered Servo Synthesizer Precharge Fail Fault Error |
| 16F5 | Channel: Recovered Read Synthesizer Loss of Lock Error |
| F6F6 | Channel: Unrecovered Read Synthesizer Loss of Lock Error |
| 16F7 | Channel: Recovered Fragment Number Fault Error |
| F6F8 | Channel: Unrecovered Fragment Number Fault Error |
| 16F9 | Channel: Recovered Preamble Quality Monitor Fault Error |
| F6FA | Channel: Unrecovered Preamble Quality Monitor Fault Error |
| F6FC | Channel: Unrecovered RTM Configuration Error |
| F6FD | Channel: Unrecovered RTM Failure Error |
| F6FE | Channel: Unrecovered RTM Timeout Error |
| | |
| F701 | Format corrupted |
| F702 | Too many notches |
| D703 | Media: Auto Reallocated Write Error |
| 1704 | Media: Recovered Write Error - Recommend reassign |
| D705 | Media: Error With OTF Correction - Reassigned |
| E706 | Media: Error With OTF Correction - Recommend Reassign |
| E707 | Media: Error With OTF Correction - Recommend Rewrite |
| E708 | Media: Error With OTF Correction - Rewritten |
| 1709 | Media: Recovered Error With Offline Correction |
| D70A | Media: Error With Offline Correction - Reassigned |
| E70B | Media: Error With Offline Correction - Recommend Reassign |
| E70C | Media: Error With Offline Correction - Recommend Rewrite |
| 170D | Media: IWV Verify Soft error |
| E70D | Media: Error With Offline Correction - Rewritten |
| E70E | Media: Recovered Data Address Mark Error - Rewritten |
| E70F | Media: Recovered Data Address Mark Error - Recommend Rewrite |
| D710 | Media: Recovered Data Address Mark Error - Reassigned |
| E711 | Media: Recovered Data Address Mark Error - Recommend Reassign |
| 1712 | Media: Recovered LBA MEDC Error |
| F713 | Media: Unrecovered LBA MEDC Error |
| 1714 | Media: Recovered Sector Overflow Error |
| F715 | Media: Unrecovered Sector Overflow Error |
| 1716 | Media: Recovered Write Overrun Error |
| F717 | Media: Unrecovered Write Overrun Error |
| 1718 | Media: Recovered Sync Mark Retry Timeout |
| F719 | Media: Unrecovered Sync Mark Retry Timeout |
| 171A | Media: Recovered Sector miss cause watchdog expire |
| F71B | Media: Unrecovered Sector miss cause watchdog expire |
| D71C | Media: Internal rewrite skipped |
| F71D | Media: Unrecovered DRAM CRC Error |
| 171E | Media: Recovered Read Latency Error |
| F71F | Media: Unrecovered Read Latency Error |
| F720 | Media: RC Dump Overflow Error |

| UEC | Description |
|------------|---------------------------------------------------------|
| F721 | Media: Format Configuration Invalid |
| 1722 | Media: Recovered WRITE Overrun Servo Gate Active |
| F723 | Media: Unrecovered WRITE Overrun Servo Gate Active |
| 1724 | Media: Recovered READ Overrun Servo Gate Active |
| F725 | Media: Unrecovered READ Overrun Servo Gate Active |
| 1726 | Media: Recovered Internal Write Catch Error |
| F727 | Media: Unrecovered Internal Write Catch Error |
| 1728 | Media: Recovered S2S MAX Flag Fault |
| F729 | Media: Unrecovered S2S MAX Flag Fault |
| 172A | Media: Recovered track ecc unrecoverable error |
| 172B | Media: physical element status change |
| 172C | Media: Recovered Data |
| F72D | Media: Unrecovered Uncorrectable Read Data error |
| 172E | Media: Recovered Error on Last Data Read |
| F72F | Media: Unrecovered Error on Last Data Read |
| F730 | Media: Recommend targeted scan |
| 1731 | Media: Recovered Write Fault |
| F732 | Media: Unrecovered Write Fault |
| 1733 | Media: Recovered Read Write Abort Error |
| F734 | Media: Unrecovered Read Write Abort Error |
| 1735 | Channel: Recovered No Sync Detected Error |
| F736 | Channel: Unrecovered No Sync Detected Error |
| 1737 | Media: Recovered Post Write Abort Error |
| F738 | Media: Unrecovered Post Write Abort |
| 1739 | Media: Recovered Post PES Check Write Abort Error |
| F73A | Media: Unrecovered Post PES Check Write Abort Error |
| 173B | Media: Recovered Data Address Mark Error |
| F73C | Media: Unrecovered Data Address Mark Error |
| 173D | Media: Recovered Sector Miss Error |
| F73E | Media: Unrecovered Sector Miss Error |
| F73F | Media: NFZ Table Full |
| F740 | Media: Defect SID Table Full Error |
| F741 | Media: OCT Timeout Not Dispatched |
| F742 | Media: OCT Timeout In Recovery |
| F743 | Media: OCT Timeout Executing |
| 1744 | Media: Recovered Sudden Stop Error |
| F745 | Media: Unrecovered Sudden Stop Error |
| 1746 | Media: Recovered Defect List Format Not Supported Error |
| 1747 | Media: Recovered Primary Defect List Not Found Error |
| 1748 | Media: Recovered Grown Defect List Not Found Error |
| 1749 | Media: Recovered Partial Defect List Transferred Error |
| F74A | Media: Unrecovered Alternate Track Table Full Error |
| F74B | Media: Unrecovered Primary Defect List Error |
| F74C | Media: Unrecovered Grown Defect List Error |
| F74D | Media: Unrecovered Too Many Heads Error |
| F74E | Media: Unrecovered Skew Table Size Error |
| F74F | Media: Unrecovered Too Many Zones Error |
| F750 | Media: Unrecovered Too Many SIDs Error |
| F751 | Media: Unrecovered Alternate Track Table Full Error |
| F752 | Media: Unrecovered Drive Capacity Too Small |
| F753 | Media: Unrecovered G-list Full (Format command) |
| F754 | Media: Unrecovered G-list Full (2) (Format command) |
| F755 | Media: Unrecovered Pointer Repeat Size Error |
| F756 | Media: Unrecovered DST Slot Size Error |
| F757 | Media: Unrecovered P-list Full Error |
| F758 | Media: Unrecovered Invalid NFZ Table Error |

| UEC | Description |
|------------|------------------------------------------------------------------|
| 1759 | Media: Recovered Unknown Error |
| F75A | Media: Unrecovered Unknown Error |
| F75B | Media: Unrecovered Too Many Sectors Error |
| F75C | Media: Unrecovered Internal Media Access Timeout Error |
| F75D | Media: Unrecovered Self-Test Failed Error |
| F75E | Media: Unrecovered Maximum Servo Cylinder Number Too Small Error |
| F75F | Media: Unrecovered SAT No Buffer Overflow Error |
| F760 | Media: Unrecovered SAT Buffer Overflow Error |
| F761 | Media: Unrecovered Wrong TDC MIN Number Sector Per Track EST |
| F762 | Media: Unrecovered Self-Test Hard-Cache Test Fail |
| F763 | Media: Unrecovered Self-Test OTF-Cache Fail |
| F764 | Media: Unrecovered Merge G-List Failed - No P-List Exists |
| F765 | Media: Unrecovered Wrong TDC MAX Number Sector Per SID |
| 1768 | Media: Recovered Key Seed ID Mismatch Error |
| F769 | Media: Unrecovered Key Seed ID Mismatch Error |
| F76B | Media: Unrecovered No NRZ Clock Error |
| 176C | Media: Recovered MEDC Correctable Error |
| F76D | Media: Unrecovered MEDC Uncorrectable Error |
| 176E | Media: Correctable Channel Ready Error |
| F76F | Media: Uncorrectable Channel Ready Error |
| 1770 | Media: Recovered SID Timeout Error |
| F771 | Media: Unrecovered SID Timeout Error |
| F772 | Media: Unrecovered DASH starting timeout |
| F773 | Media: Unrecovered ID table timeout |
| F774 | Media: Unrecovered Servo timeout |
| F775 | Media: Unrecovered Buffers timeout |
| F776 | Media: Unrecovered DASH done timeout |
| F777 | Media: Unrecovered DASH unknown timeout |
| F778 | Media: DINIT2 timeout |
| F779 | Media: Unrecovered Mini Mode Timeout |
| F77A | Media: BUFCNT Timeout Error |
| F77B | Media: Unrecovered Abort EOS fail |
| 177C | Media: Recovered Servo Area Timeout |
| F77D | Media: Unrecovered Servo Area Timeout |
| F77E | Media: Write Error Recovery Timeout |
| F77F | Media: Read Error Recovery Timeout |
| 1780 | Media: Recovered DLC SID Delay Timeout |
| F781 | Media: Unrecovered DLC SID Delay Timeout |
| 1782 | Media: Recovered Force Soft Error |
| F783 | Media: Unrecovered Force Soft Error |
| 1784 | Media: Recovered Channel Sector Marginal Error |
| F785 | Media: Unrecovered Channel Sector Marginal Error |
| 1786 | Media: Recovered LLI Underrun Error |
| F787 | Media: Unrecovered LLI Underrun Error |
| 178C | Media: Recovered FFSULI Timeout |
| F78D | Media: Unrecovered FFSULI Timeout |
| F78E | Media: Unrecovered SAT No Buffer Overflow With ECS Fault |
| F78F | Media: Unrecovered SAT Buffer Overflow With ECS Fault |
| F790 | Media: Unrecovered SAT No Buffer Overflow Reset Media |
| F791 | Media: Unrecovered SAT No Buffer Overflow Reset with ECS Fault |
| 1792 | Media: Recovered MEDC Write Data Not Ready Error |
| F793 | Media: Unrecovered MEDC Write Data Not Ready error |
| 1794 | Media: Recovered DMA Timeout Error |
| F795 | Media: Unrecovered DMA Timeout Error |
| F797 | Media: SAT Write Abort |
| 1798 | Media: Recovered ID Not Found Error |

| UEC | Description |
|------------|-----------------------------------------------------------------------|
| F799 | Media: Unrecovered ID Not Found Error |
| F79A | Media: Unrecovered HS Measure Target Mismatch |
| F79B | Media: Unrecovered Hard Clock Stop until the RDWTCLK is running again |
| 179C | Media: Recovered Channel Read Timeout Error |
| F79D | Media: Unrecovered Channel Read Timeout Error |
| 179E | Media: Recovered End Sector PHSN Error on READ |
| F79F | Media: Unrecovered End Sector PHSN Error on READ |
| F7A2 | Media: Unrecovered Write Dcatch OCT Error |
| F7A6 | Media: Unrecovered LBA ECC Last Data Read Error |
| F7A7 | Media: Unrecovered Committed Write Hard Error |
| F7A8 | Media: Unrecovered Committed Write Correction Disabled Error |
| F7A9 | Media: Unrecovered Committed Write Uncorrectable Error |
| 17AA | Media: Recovered Read Overrun Error |
| F7AB | Media: Unrecovered Read Overrun Error |
| 17AE | Media: Recovered ECC Correctable Error |
| F7AF | Media: Unrecovered Sector Missing Error |
| F7B0 | Media: Unrecovered Sector Overflow |
| 17B1 | Media: Recovered track ECC recovery |
| 17B2 | Media: Recovered Abort Window Error |
| F7B3 | Media: Unrecovered Abort Window Error |
| 17B4 | Media: Recovered Shock Sensor Error |
| F7B5 | Media: Unrecovered Shock Sensor Error |
| 17B8 | Media: Recovered Reference Tag Error |
| F7B9 | Media: Unrecovered Reference Tag error |
| 17BA | Media: Recovered Application Tag Error |
| F7BB | Media: Unrecovered Application Tag Error |
| F7BC | Media: Unrecovered T10 error |
| F7BD | Media: Unrecovered Guard Check Error |
| F7BE | Media: Multiple WRITE Error |
| F7BF | Media: Multiple READ Error |
| F7C1 | Media: Unrecovered End Sector Check Error |
| F7C3 | Media: Unrecovered Read CRC Error |
| 17C4 | Media: Recovered DRAM ECC Error |
| F7C5 | Media: Unrecovered DRAM ECC Error |
| 17C6 | Media: Recovered DRAM ECC LBA Error |
| F7C7 | Media: Unrecovered DRAM ECC LBA Error |
| 17C8 | Media: Recovered End Sector PHSN Error on WRITE |
| F7C9 | Media: Unrecovered End Sector PHSN Error on WRITE |
| F7CA | Media: Unrecovered LBA Correction Disabled Error |
| 17CB | Media: Recovered LBA Write Correctable Error |
| F7CC | Media: Unrecovered LBA Write Uncorrectable Error |
| F7CD | Media: Unrecovered LBA Encryption Error |
| F7CE | Media: Unrecovered Offline Already TAR Error |
| F7D0 | Media: Unrecovered Pre-load Timeout Error |
| 17D1 | Media: Recovered DCHW Hang |
| F7D2 | Media: Unrecovered DCHW Hang |
| F7D3 | Media: Unrecovered SG Drive Error |
| 17D4 | Media: Recovered Parity PTR FIFO Error |
| F7D5 | Media: Unrecovered Parity PTR FIFO Error |
| 17D6 | Media: Recovered Parity LBA FIFO Error |
| F7D7 | Media: Unrecovered Parity LBA FIFO Error |
| 17D8 | Media: Recovered Parity Uncorrectable FIFO Error |
| F7D9 | Media: Unrecovered Parity Uncorrectable FIFO Error |
| 17DA | Media: Recovered Status Uncorrectable FIFO Error |
| F7DB | Media: Unrecovered Status Uncorrectable FIFO Error |
| 17DC | Media: Recovered Parity EDC SRAM Error |

| UEC | Description |
|------------|------------------------------------------------------------------|
| F7DD | Media: Unrecovered Parity EDC SRAM Error |
| 17DE | Media: Recovered REQ/ACK Handshake Error |
| F7DF | Media: Unrecovered REQ/ACK Handshake Error |
| 17E0 | Media: Recovered Write Splice Error |
| F7E1 | Media: Unrecovered Write Splice Error |
| 17E2 | Media: Recovered Read Parity Error |
| F7E3 | Media: Unrecovered Read Parity Error |
| 17E4 | Media: Recovered EPO Error |
| F7E5 | Media: Unrecovered EPO Error |
| 17E6 | Media: Recovered NRZ Sector Marginal Error |
| F7E7 | Media: Unrecovered NRZ Sector Marginal Error |
| 17E8 | Media: Recovered AE Access Inhibit Error |
| F7E9 | Media: Unrecovered AE Access Inhibit Error |
| 17EA | Media: Recovered PTR FIFO Error |
| F7EB | Media: Unrecovered PTR FIFO Error |
| 17EC | Media: Recovered LBA FIFO Error |
| F7ED | Media: Unrecovered LBA FIFO Error |
| 17EE | Media: Recovered Sector Number Cylinder Error |
| F7EF | Media: Unrecovered Sector Number Cylinder Error |
| 17F0 | Media: Recovered Read Transfer Length Error |
| F7F1 | Media: Unrecovered Read Transfer Length Error |
| 17F2 | Media: Recovered DS RDC Burst Error |
| F7F3 | Media: Unrecovered DS RDC Burst Error |
| 17F4 | Media: Recovered SV RDC Burst Error |
| F7F5 | Media: Unrecovered SV RDC Burst Error |
| 17F6 | Media: Recovered Channel AE WG Error |
| F7F7 | Media: Unrecovered Channel AE WG Error |
| 17F8 | Media: Recovered Dummy Error ERP MEAS |
| F7F9 | Media: Unrecovered Dummy Error ERP MEAS |
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| F813 | CMD: Insufficient Buffer Space Error |
| F815 | CMD: Aborted From Internal TMF Error |
| F816 | CMD: Incompatible PRDS Version |
| F817 | CMD: Ontime Helium leak alert |
| F819 | CMD: Unaligned Command Error |
| F81A | CMD: Param Not Support |
| F81B | CMD: Too Many Target Descriptors |
| F81C | CMD: Unsupported TARG DESC Type Code |
| F81D | CMD: Too Many Segment Descriptors |
| F81E | CMD: Reassign Not Allowed |
| F81F | CMD: Operation in Progress |
| F820 | CMD: Unrecovered Parameter List Length Error |
| F821 | CMD: Unrecovered Invalid Opcode in CDB Error |
| F822 | CMD: Unrecovered LBA Out Of Range Error |
| F823 | CMD: Unrecovered Invalid Field In CDB Error |
| F824 | CMD: Unrecovered Invalid LUN Error |
| F825 | CMD: Unrecovered Invalid Field In Parameter List Error |
| F826 | CMD: Unrecovered Unsupported Log Page Error |
| F827 | CMD: Unrecovered Access Denied Error |
| F828 | CMD: Unrecovered Invalid Release of Persistent Reservation Error |
| F829 | CMD: Invalid Tx Setting for Combo Chip Error |
| F830 | CMD: Unrecovered Sequence Error |
| 1831 | CMD: Power Mode Idle_A By Timer |
| 1832 | CMD: Power Mode Idle_B By Timer |
| 1833 | CMD: Power Mode Idle_C By Timer |
| 1834 | CMD: Power Mode Standby_Z By Timer |

| UEC | Description |
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| 1835 | CMD: Power Mode Idle_A By Command |
| 1836 | CMD: Power Mode Idle_B By Command |
| 1837 | CMD: Power Mode Idle_C By Command |
| 1838 | CMD: Power Mode Standby_Z By Command |
| 1839 | CMD: Power Mode Standby_Y By Timer |
| 183A | CMD: Power Mode Standby_Y By Command |
| F83B | CMD: Unable Rebuild Assist |
| F83C | CMD: CMD: Invalid Programmable Inquiry template size for EMC |
| F83D | CMD: Quiesce not allowed |
| F83F | CMD: NCQ Priority Error |
| F870 | CMD: Unrecovered attempt to read invalid data |
| F873 | CMD: Unrecovered write boundary violation |
| F874 | CMD: Unrecovered helium leak write abort |
| F875 | CMD: Unrecovered insufficient zone resource |
| F876 | CMD: Unrecovered zone is read only |
| F877 | CMD: Unrecovered zone is offline |
| F878 | CMD: Unrecovered drive locked |
| F879 | CMD: Unrecovered zone command not ready |
| F87A | CMD: Unrecovered unaligned write command |
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| 1A02 | SMART: Temperature Warning (No Sense) |
| 2A02 | SMART: Temperature Warning (Recovered Sense) |
| 3A02 | SMART: Temperature Warning (Unit Attention) |
| 1A03 | SMART: Background Self-Test Failure (No Sense) |
| 2A03 | SMART: Background Self-Test Failure (Recovered Sense) |
| 3A03 | SMART: Background Self-Test Failure (Unit Attention) |
| 1A04 | SMART: Background Pre-Scan Failure (No Sense) |
| 2A04 | SMART: Background Pre-Scan Failure (Recovered Sense) |
| 3A04 | SMART: Background Pre-Scan Failure (Unit Attention) |
| 1A05 | SMART: Background Media Scan Failure (No Sense) |
| 2A05 | SMART: Background Media Scan Failure (Recovered Sense) |
| 3A05 | SMART: Background Media Scan Failure (Unit Attention) |
| 1A14 | SMART: Spare Sector Availability Warning (No Sense) |
| 2A14 | SMART: Spare Sector Availability Warning (Recovered Sense) |
| 3A14 | SMART: Spare Sector Availability Warning (Unit Attention) |
| 1A21 | SMART: Milli-Actuator Error (No Sense) |
| 2A21 | SMART: Milli-Actuator Error (Recovered Sense) |
| 3A21 | SMART: Milli-Actuator Error (Unit Attention) |
| 1A22 | SMART: Extreme Over-Temperature Warning (No Sense) |
| 2A22 | SMART: Extreme Over-Temperature Warning (Recovered Sense) |
| 3A22 | SMART: Extreme Over-Temperature Warning (Unit Attention) |
| 1A32 | SMART: Read Error Rate Warning (No Sense) |
| 2A32 | SMART: Read Error Rate Warning (Recovered Sense) |
| 3A32 | SMART: Read Error Rate Warning (Unit Attention) |
| 1A43 | SMART: Seek Error Rate Warning (No Sense) |
| 2A43 | SMART: Seek Error Rate Warning (Recovered Sense) |
| 3A43 | SMART: Seek Error Rate Warning (Unit Attention) |
| 1A4A | SMART: Write Error Rate Warning (No Sense) |
| 2A4A | SMART: Write Error Rate Warning (Recovered Sense) |
| 3A4A | SMART: Write Error Rate Warning (Unit Attention) |
| 1A50 | SMART: Start/Stop Load/Unload Cycle Count Warning (No Sense) |
| 2A50 | SMART: Start/Stop Load/Unload Cycle Count Warning (Recovered Sense) |
| 3A50 | SMART: Start/Stop Load/Unload Cycle Count Warning (Unit Attention) |
| 1A56 | SMART: Spinup Time Warning (No Sense) |
| 2A56 | SMART: Spinup Time Warning (Recovered Sense) |
| 3A56 | SMART: Spinup Time Warning (Unit Attention) |

| UEC | Description |
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| 1A5B | SMART: Spinup Retry Count Warning (No Sense) |
| 2A5B | SMART: Spinup Retry Count Warning (Recovered Sense) |
| 3A5B | SMART: Spinup Retry Count Warning (Unit Attention) |
| FA81 | Self-Test: Unrecoverable Error Count Threshold Exceeded |
| 2A83 | Self-Test: GLIST Error Count Threshold Reached |
| 1A85 | Self-Test: Recovery Error |
| 2A85 | Self-Test: Servo Error |
| 4A85 | Self-Test: Command Timeout Error |
| FA85 | Self-Test: Unrecoverable Error |
| FA8D | SMART: Disk shift exceeded threshold |
| 1AFD | SMART: Internal Environment Status Error (No Sense) |
| 2AFD | SMART: Internal Environment Status Error (Recovered Sense) |
| 3AFD | SMART: Internal Environment Status Error (Unit Attention) |
| 1AFF | SMART: Test Warning Threshold Reached (No Sense) |
| 2AFF | SMART: Test Warning Threshold Reached (Recovered Sense) |
| 3AFF | SMART: Test Warning Threshold Reached (Unit Attention) |
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| FCxx | Media: Unrecovered Unable to Read RID or FID Number xx |
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| 1EC0 | Media: Recovered R/W Abort Due to SSW Calibration Track |
| FEC1 | Media: Unrecovered R/W Abort Due to SSW Calibration Track |
| 1EC2 | Media: Recovered R/W Abort Due to RAW TID |
| FEC3 | Media: Unrecovered R/W Abort Due to RAW TID |
| 1EC4 | Media: Recovered R/W Abort Due to Burst In Progress |
| FEC5 | Media: Unrecovered R/W Abort Due to Burst In Progress |
| 1EC6 | Media: Recovered R/W Abort Due to DSW Not Settled |
| FEC7 | Media: Unrecovered R/W Abort Due to DSW Not Settled |
| 1EC8 | Media: Recovered R/W Abort Due to Preheat |
| FEC9 | Media: Unrecovered R/W Abort Due to Preheat |
| 1ECA | Media: Recovered R/W Abort Due to HMA R/W Offset |
| FECB | Media: Unrecovered R/W Abort Due to HMA R/W Offset |
| 1ECC | Media: Recovered R/W Abort Due to WCSBUSY Pro Check |
| FECD | Media: Unrecovered R/W Abort Due to WCSBUSY Pro Check |
| 1ECE | Media: Recovered R/W Abort Due to Vibration Condition (Other) |
| FECF | Media: Unrecovered R/W Abort Due to Vibration Condition (Other) |
| 1ED0 | Media: Recovered R/W Abort Due to Vibration Condition (Estimator) |
| FED1 | Media: Unrecovered R/W Abort Due to Vibration Condition (Estimator) |
| 1ED2 | Media: Recovered R/W Abort Due to Vibration Condition (Predictor) |
| FED3 | Media: Unrecovered R/W Abort Due to Vibration Condition (Predictor) |
| 1ED4 | Media: Recovered R/W Abort Due to Vibration Condition (PES Error) |
| FED5 | Media: Unrecovered R/W Abort Due to Vibration Condition (PES Error) |
| 1ED6 | Media: Recovered R/W Abort Off Track Write Error |
| FED7 | Media: Unrecovered R/W Abort Off Track Write Error |
| 1ED8 | Media: Recovered R/W Abort RRO Field Misread Error |
| FED9 | Media: Unrecovered R/W Abort RRO Field Misread Error |
| 1EDA | Media: Recovered R/W Abort RRO Field Missing Error |
| FEDB | Media: Unrecovered R/W Abort RRO Field Missing Error |
| 1EDC | Media: Recovered R/W Abort Idle Seek Error |
| FEDD | Media: Unrecovered R/W Abort Idle Seek Error |
| 1EDE | Media: Recovered R/W Abort Seek Timeout Error |
| FEDF | Media: Unrecovered R/W Abort Seek Timeout Error |
| 1EE0 | Media: Recovered R/W Abort Estimator Error |
| FEE1 | Media: Unrecovered R/W Abort Estimator Error |
| 1EE2 | Media: Recovered R/W Abort Predictor Error |
| FEE3 | Media: Unrecovered R/W Abort Predictor Error |
| 1EE4 | Media: Recovered R/W Abort PES Error |

| UEC | Description |
|------------|-------------------------------------------------------------|
| FEE5 | Media: Unrecovered R/W Abort PES Error |
| 1EE6 | Media: Recovered R/W Abort RPC Resync Error |
| FEE7 | Media: Unrecovered R/W Abort RPC Resync Error |
| 1EE8 | Media: Recovered R/W Abort PES Reset Error |
| FEE9 | Media: Unrecovered R/W Abort PES Reset Error |
| 1EEA | Media: Recovered R/W Abort SID Unlock Error |
| FEEB | Media: Unrecovered R/W Abort SID Unlock Error |
| 1EEC | Media: Recovered R/W Abort WCS Error |
| FEED | Media: Unrecovered R/W Abort WCS Error |
| 1EEE | Media: Recovered R/W Abort Hard Reset Error |
| FEEF | Media: Unrecovered R/W Abort Hard Reset Error |
| 1EF0 | Media: Recovered R/W Abort Shock Error |
| FEF1 | Media: Unrecovered R/W Abort Shock Error |
| 1EF2 | Media: Recovered R/W Abort Unlock Macro Error |
| FEF3 | Media: Unrecovered R/W Abort Unlock Macro Error |
| 1EF4 | Media: Recovered R/W Abort Sharp Error |
| FEF5 | Media: Unrecovered R/W Abort Sharp Error |
| 1EF6 | Media: Recovered R/W Abort Aggressive Error |
| FEF7 | Media: Unrecovered R/W Abort Aggressive Error |
| 1EF8 | Media: Recovered R/W Abort VWI Limit Error |
| FEF9 | Media: Unrecovered R/W Abort VWI Limit Error |
| 1EFA | Media: Recovered R/W Abort Gray Code Error |
| FEFB | Media: Unrecovered R/W Abort Gray Code Error |
| 1EFC | Media: Recovered R/W Abort Linger Error |
| FEFD | Media: Unrecovered R/W Abort Linger Error |
| 1EFE | Media: Recovered R/W Abort No STM Error |
| FEFF | Media: Unrecovered R/W Abort No STM Error |
| | |
| FF01 | IndSys: Drive Not Loaded |
| FF02 | IndSys: Drive Not Loaded - Format Invalid |
| FF03 | IndSys: Indirection System Not Online |
| FF04 | IndSys: Drive Not Loaded - Old Version Mismatch |
| FF05 | IndSys: Drive Not Loaded - Heap Pointer Mismatch |
| FF06 | IndSys: Drive Not Loaded - Heap size Mismatch |
| FF07 | IndSys: Drive Not Loaded - Rid Heap Size Mismatch |
| FF08 | IndSys: Drive Not Loaded - Heap Version Mismatch |
| FF09 | IndSys: Drive Not Loaded - Incompatible Rid |
| FF0A | IndSys: Drive Not Loaded - Corrupt Rid |
| FF0B | IndSys: Drive Not Loaded - Rid Num Objects Mismatch |
| FF0C | IndSys: Drive Not Loaded - Rid Version Mismatch |
| FF0D | IndMgr: Drive Not Loaded - Rid Version Mismatch |
| FF0E | IndSys: Drive Not Loaded - Layout Rid Version Mismatch |
| FF0F | IndSys: Drive Not Loaded - W2C Rid Version Mismatch |
| FF10 | IndSys: Drive Not Loaded - Layout Manager Restore Failed |
| FF11 | IndSys: Drive Not Loaded - W2C Manager Restore Failed |
| FF12 | IndSys: Drive Not Loaded - Layout Failed |
| FF13 | IndSys: Drive Not Loaded - DMM Format Failed |
| FF14 | IndSys: Drive Not Loaded - IM Format Failed |
| FF15 | IndSys: Drive Not Loaded - Pseudo Write Failed |
| FF16 | IndSys: Drive Not Loaded - Full drop Failed |
| FF17 | IndSys: Drive Not Loaded - EPO Format Failed |
| FF18 | IndSys: Drive Not Loaded - Set IM Valid Failed |
| FF19 | IndSys: Drive Not Loaded - Bring Online failed |
| FF1A | IndSys: Drive Not Loaded - Metadata First Primary |
| FF1B | IndSys: Drive Loaded - Metadata First Primary and Secondary |
| FF1C | IndSys: Drive Loaded - IBA Out of Range |

| UEC | Description |
|------------|-----------------------------------------------------|
| FF1E | IndSys: Drive Loaded - Context Sequence ID Mismatch |
| FF20 | IndSys: Drive Not Loaded - EPD Flash Entry Invalid |
| FF21 | LayoutMgr: All Flash Entries Erased |
| FF22 | IndSys: Drive Loaded - Replay Failed |
| FF23 | Out of Order EPO SRAM Copy Object |
| FF24 | Showstop During EPO |
| FF25 | Error While Loading Object |
| FF26 | Missing NVC SPEC |
| FF27 | Showstop during EPO replay |
| FF28 | IndSys: Full context drop write overflow |
| FF29 | IndSys: Interruptible full context drop not started |
| FF2A | EPD num EPO pages exceeded |
| FF2B | IndSys: IFCD repopulate invalid spec |
| FF41 | LayoutMgr: Format Capacity Not Met |
| FF43 | IndSys: Drive Not Loaded - Metadata ATI |
| FF44 | IndSys: Drive Loaded - Replay Fail |
| FF45 | Format Too Many Regions |
| FF46 | Format No Tracks in Region |
| FF47 | Format Not Enough Tracks For Spares |
| FF48 | Format Too Many Data Tracks |
| FF50 | IndMgr: IM Demand Split Too Deep Failure |
| FF51 | IndMgr: Allocate Failed Delta Group |
| FF52 | IndMgr: Allocate Failed Split Spec |
| FF53 | IndMgr: Allocate Failed Split Delta |
| FF54 | IndMgr: Allocate Failed Unsplit Delta Group |
| FF55 | IndMgr: Generic Insert Exception Failed |
| FF56 | IndMgr: Commit write LBA out of range |
| FF57 | IndMgr: Format insufficient heap size |
| FF60 | EpoMgr: Flash Read RS Syndrome Gen Timeout |
| FF61 | EpoMgr: Uncorrectable Flash RS ECC Error |
| FF62 | EpoMgr: Correctable EPO Timeout |
| FF63 | EpoMgr: ARM FPS Engine and Not Spinning |
| FF66 | EpoMgr: Flash Header Not Pre Erased |
| FF67 | EpoMgr: Flash Data Not Pre Erased |
| FF68 | EpoMgr: Flash Header Not Written |
| FF70 | NVC Not Loaded |
| FF71 | NVC Command Spec Too Large |
| FF72 | ESL Command Spec Mismatch |
| FF73 | NVC Non Meta Data Error |