ST3283N
SCSI Interface Drive
Product Manual

36184-001, Rev. A

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Seagate

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1.0 Specifications Summary

1.1 Formatted Capacity

Guaranteed megabytes	248.62
Guaranteed sectors	485,601
Bytes per sector	512
Interface	Fast SCSI-2
Recording method	RLL (1,7) (ZBR)
Spindle speed (RPM)	4,500 ± 0.5%
Discs	3
Servo heads	1
Read/write heads	5
Cylinders	1,691
Track density (TPI)	1,960
Recording density (BPI, max)	38,000
I/O data transfer rate (Mbytes/sec, max)	1.5 Asynchronous 10.0 Synchronous
Internal data transfer rate (Mbits/sec)	15.0 to 24.4
Auto-parking heads	Yes

The available capacity depends on the spare sector reallocation method selected. The capacities specified here accommodate one spare sector per cylinder and two spare cylinders per volume.

1.2 Drive Performance Specifications

1.2.1 Multi-Segment Read Look-Ahead Buffer

The Read Look-Ahead buffer improves performance by reading the next logical sector after the previously read sector into a buffer before those sectors are actually requested by the host. Since the data is read before it is requested, access read time is eliminated.

Read Look-Ahead stores data in the buffer from the start of a read until the buffer segment is full. The 128K RAM buffer can be divided into segments as follows:

Number of Segments	Size of Segment (in Kbytes)	Number of Segments	Size of Segment (in Kbytes)
1	128	8	16
2	64	16	8
4	32	32	4

Since each segment functions as an independent buffer, performance dramatically increases in a multi-tasking or multi-user environment.

Read Look-Ahead occurs in a segment when a Read command is issued that requests more data than is contained in one segment.

Caching occurs when a Read command requests less data than exists in one segment. All requested data remains in the segment and Read Look-Ahead will store more data in the buffer until it reaches the end of the cylinder or the buffer segment is full.

1.2.2 Seek Time Definition and Specifications

Seek time is a true statistical average (at least 5,000 measurements) of seek time less drive internal and external host overhead. All measurements are calculated under nominal conditions of temperature, voltage and horizontal orientation.

Track-to-track seek time is the average of all possible single-track seeks in both directions.

Average seek time is measured by executing seeks in both directions between random cylinders.

Full-stroke seek time is one-half the time needed to seek from the Logical Block (LBA) 0 to the maximum LBA and back to LBA 0.

Track-to-Track Seek Time	Average Seek Time	Full-Stroke Seek Time	Average Latency
3.5 msec typ 4.0 msec max	12.0 msec typ 14.0 msec max	30.0 msec typ 32.0 msec max	6.67 msec

Note: Host overhead varies between systems and cannot be specified. Drive internal overhead is measured by issuing a no-motion seek. Overhead is typically less than 1.0 msec.

1.2.2.1 Thermal Compensation

The Thermal Compensation operation compensates for thermal-related position offset on the selected head. Thermal Compensation is performed during startup and every 2 minutes thereafter. This periodic compensation coincides with a host command service operation. The last command execution time increases by 100 msec typical or 350 msec maximum.

1.2.3 Format Drive

The maximum execution time for a format command is 20 minutes.

1.2.4 Start/Stop Time

After DC power has been applied, the drive becomes ready within 20 seconds (unless the Motor Start option is disabled). During this time the drive responds to the SCSI interface. Stop time is 15 seconds, whether the drive is commanded to spin down or power is removed.

If the Motor Start option is enabled, the internal controller accepts a Motor Start, Inquiry or Request Sense command by the SCSI interface three seconds after DC power has been applied. After the Motor Start command has been received, the drive becomes ready for read/write operations within 15 seconds. During this time, the drive responds to the SCSI interface.

Note: Do not move the drive until the spindle motor has come to a complete stop.

1.2.5 Typical Power-Up/Power-Down Sequence

The following typical power-up/power-down sequence is provided to assist in evaluating drive performance. This information is for reference only.

Note: There is no power control switch on the drive.

1.2.5.1 Power-Up Sequence

1. Power is applied to the disc drive.

2. When power is applied, one of two sequences can occur:

   A. If the Motor Start jumper is not installed, the option is not selected. (See Figure 7.) In this case, the LED is on for about 2 seconds. Then, it turns off while the motor spins up. The drive does not respond to the SCSI interface until the LED is off.

   B. If the Motor Start jumper is installed, the option is selected. In this case, the LED glows when power is applied, and stops glowing after two seconds. Then, the drive controller responds to the SCSI interface. The host commands the motor to start. While the motor is coming up to speed, the LED is on.

3. The drive begins to lock in speed control circuits.

4. The actuator lock solenoid releases the actuator, producing an audible sound.

5. The spindle motor reaches operating speed in about 5 seconds. After 5 seconds, there are no speed variations.

6. The drive performs velocity adjustment seeks.

7. The drive seeks Track 0 and becomes ready.

1.2.5.2 Power-Down Sequence

1. The power cable is unplugged from the drive, or the drive is commanded to spin down.

2. Within 3 seconds after the motor begins to spin down, the actuator lock engages, producing an audible sound.

3. The spindle stops in 15 seconds, whether the power cable is unplugged from the drive or the drive receives the power-down command.

1.2.5.3 Read/Write Head Auto-Park

Upon power-down, the read/write heads automatically move to the shipping zone. All portions of the head/slider assembly park inboard of the maximum data cylinder. When power is applied, the heads recalibrate to Track 0.

1.3 Reliability

Read error rates are measured with automatic retries and data correction with ECC enabled and all flaws reallocated. MTBF is measured at nominal power, sea level, and 40 °C ambient temperature.

Nonrecoverable Read Errors	1 per 10^{13} bits transferred
Seek Errors	1 per 10^{7} physical seeks
MTBF	200,000 power-on hours
Preventative Maintenance	Not Required
Service Life	5 Years

1.4 Physical Dimensions

Height	1.00 inches (25.4 mm)
Width	4.02 inches (102.1 mm)
Depth	5.77 inches (146.6 mm)
Weight	1.5 lbs (0.68 Kg)

1.5 Environmental

1.5.1 Ambient Temperature

Operating	5 °C to 55 °C (41 °F to 131 °F)
Nonoperating	-40 °C to 70 °C (-40 °F to 158 °F)

1.5.2 Temperature Gradient

Operating	20 °C/hour (36 °F/hour)
Nonoperating	30 °C/hour (54 °F/hour)

1.5.3 Relative Humidity

Operating	8% to 80% Noncondensing
Maximum Wet Bulb	26 °C (79 °F)
Nonoperating	5% to 95% Noncondensing

1.5.4 Altitude

Operating	-1,000 ft to 10,000 ft (-305 m to 3,048 m)
Nonoperating	-1,000 ft to 40,000 ft (-305 m to 12,192 m)

1.6 Acoustics

34 dBA typical sound pressure at 1 meter, in Idle mode.
38 dBA maximum sound pressure at 1 meter, in Idle mode.

1.7 Shock and Vibration

All shock and vibration specifications assume that the drive is mounted in an approved orientation with the input levels measured at the drive mounting screws. Shock measurements are based on a 11 msec, half sine-wave shock pulse, not to be repeated more than two times per second.

During normal operating shock and vibration, there is no performance degradation or physical damage to the drive.

During abnormal operating shock and vibration, there is no physical damage to the drive, although performance may be degraded during the shock or vibration episode. When normal operating shock levels resume, the drive meets its performance specifications.

All nonoperating shock and vibration specifications assume that the read/write heads are positioned in the shipping zone.

	Normal Operating	Abnormal Operating	Nonoperating
Shock	2 Gs	10 Gs	75 Gs
5-22 Hz Vibration	0.020-inch displacement	0.020-inch displacement	0.020-inch displacement
22-500 Hz Vibration	0.50 Gs	1.50 Gs	4.00 Gs

1.8 DC Power

Except during the write procedure, power may be applied or removed in any sequence without loss of data or damage to the drive. If you turn off the power during the write procedure, you may lose the data currently being written. A voltage tolerance of ± 5% must be maintained under all conditions, including ripple.

In the table below, noise is specified as periodic and random distribution of frequencies from DC to 25 MHz.

	+5 VDC	+12 VDC
Voltage Regulation	±5%	±5%
Noise Immunity (Peak-to-Peak)	100 mV	240 mV

Interface commands and interface-selectable parameters are provided to allow custom configuration of the power management system. The available power modes are Standby, Spin-Up, Idle, Seeking, and Read/Write. Transitions between Standby mode and Idle Mode (via Spin Up mode) are controlled by both the power management configuration and the interface demands. Transitions between Idle mode, Read/Write mode, and Seeking mode are controlled solely by interface requests (seeks, reads and writes).

1.8.1 Power Mode Descriptions

The drive implements intelligent power management by automatically changing power modes based on interface activity. This feature reduces the average power consumption considerably from that required in a drive without this feature. The modes are described below:

Spin-Up: The drive is bringing the spindle and discs up to operating speed. Power in this mode is defined as the average power during the first 10 seconds after starting spin-up. This mode is entered from the Standby mode.

Seeking: The drive is moving the actuator to position the read/write heads to a specific location on the disc surface. Read/write electronics are powered-down and servo electronics are active. Power used during this mode is the average power measured while executing random seeks with a 2-revolution (26.6 msec) dwell between seek commands.

Read/Write: The drive is performing a read or write operation from or to the disc medium. Read/write electronics are active and the servo is in the track following mode. This mode is entered from the Idle mode.

Idle: The spindle is up to operating speed and ready to accept and execute any command with no delay to become ready. The servo electronics are active and the heads are in track following mode. The read/write electronics are in power down mode. This mode is entered from any mode except the Standby mode.

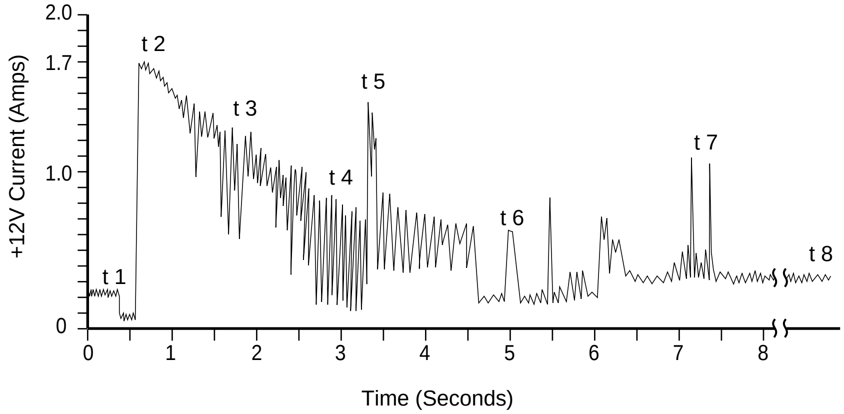
Standby: The drive is fully operational via the interface and will accept all commands. However, a ready latency will occur if any command is received which requires disc access or actuator movement. The spindle is at rest, and the servo and read/write electronics are powered-down. This mode is entered from the Idle mode.

1.8.2 Power Consumption

In the table below, the values apply at the drive power connector and assume that the terminating resistor packs are removed and terminator power is supplied through the SCSI connector. All values are typical and valid 10 minutes after the drive is spun up. Current is measured with an RMS DC ammeter.

	Spin Up	**Seeking**	**Read/ Write**	**Idle**	**Standby**
Current at +12 VDC					
Amps peak	1.9	N/A	N/A	N/A	N/A
RMS Amps typ	N/A	0.36	0.265	0.20	0.03
Watts typ	N/A	4.32	3.18	2.40	0.36
Current at +5 VDC					
RMS Amps typ	N/A	0.136	0.464	0.07	0.06
Watts typ	N/A	0.68	2.32	0.35	0.30
Power					
Total Watts typ	7.00	5.00	5.50	2.75	0.66

Figure 1: Typical Start-up Current Profile



t1 Voltage is applied to the drive.

t2 After a delay, the start-up current is applied and the spindle begins to turn.

t3 The accelerating current is applied, causing the spindle speed to increase.

t4 The spindle speed is close to the final, correct value. The drive begins to lock in speed control circuits.

t5 The arm lock solenoid releases arm.

t6 The final speed control lock is achieved.

t7 The servo is calibrated.

t8 The servo locks in on Track 0 and the drive is ready.

1.9 Agency Listings

1.9.1 UL Recognition

The ST3283N disc drive is recognized in accordance with UL 478 and UL 1950.

1.9.2 CSA Listing

The ST3283N disc drive is certified to CSA C22.2 No. 220-M1986.

1.9.3 VDE Listing

The ST3283N disc drive is certified to VDE 0806/8.81 and EN 60950/1.88, as tested by VDE.

1.9.4 FCC Verification

Note: This equipment has been tested with a Class B computing device and has been found to comply with Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in residential installations. This equipment generates, uses, and can radiate radio frequency energy, and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause interference to radio or television equipment reception, which can be determined by turning the equipment off and on, the user may attempt to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Move the equipment away from the receiver.
- Plug the equipment into an outlet on a circuit different from that to which the receiver is connected.
- If necessary, the user should consult the dealer or an experienced radio/television technician for additional suggestions.

Caution: Any changes or modifications to the equipment by the user not expressly approved by the grantee or manufacturer could void the user's authority to operate such equipment.

Note: This digital apparatus does not exceed the Class B limits for radio noise emissions from digital apparatus as set out in the radio interference regulations of the Canadian Department of Communications.

Le présent appareil numérique n′émet pas de bruits radioélectriques dépassant les limites applicables aux appareils numériques de Classe B prescrites dans le règlement sur le brouillage radioélectrique édicté par le Ministère des Communications du Canada.

Sicherheitsanleitung

1. Das Gerrät ist ein Einbaugerät, das für eine maximale Umegebungstemperatur von 55 °C vorgesehen ist.

2. Zur Befestigung des Laufwerks werden 4 Schrauben 6-32 UNC-2A benötigt. Bei seitlicher Befestigung darf die maximale Länge der Schrauben im Chassis nicht mehr als 3,3 mm und bei Befestigung an der Unterseite nicht mehr als 5,08 mm betragen.

3. Als Versorgungsspannugen werden benötigt:

+5 V ± 5% 0,6 A

+12 V ± 5 % 0,8 A (2,0 A fur ca. 30 Sek)

4. Die Versorgungsspannung muβ SELV entsprechen.

5. Alle Arbeiten dürfen nur von ausgebildetem Servicepersonal durchgeführt werden.

6. Der Einbau des Drives muβ den Anforderungen gemäβ DIN IEC 950V DC 0806/8.81 entsprechen.

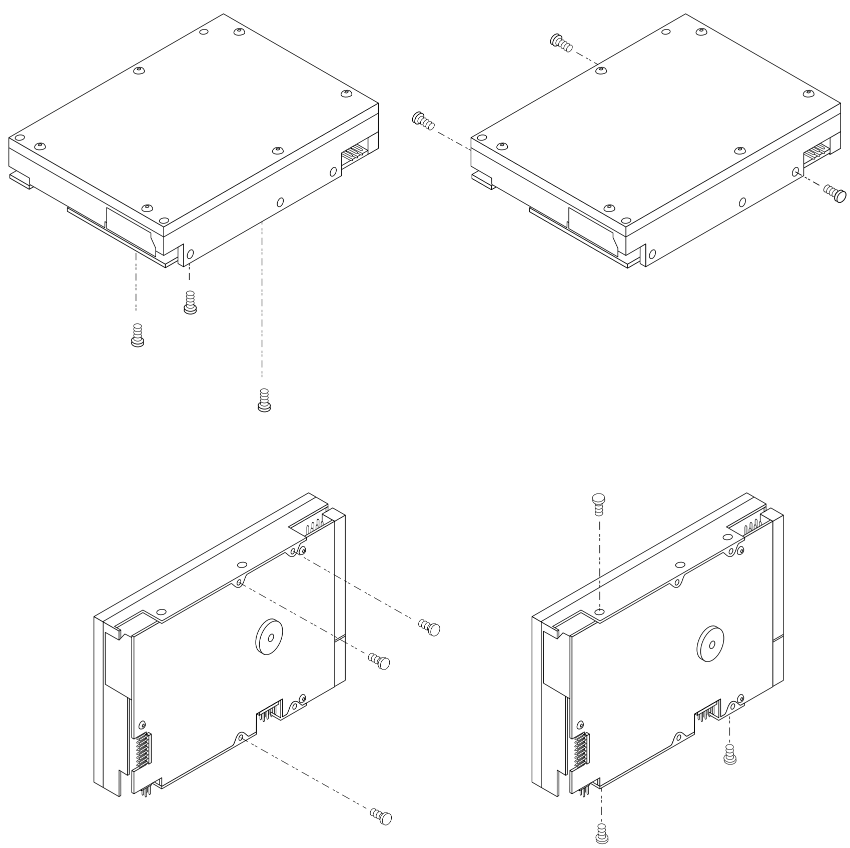
1.10 Drive Mounting

The drive may be mounted in any orientation using either the side or the bottom mounting holes; do not use side and bottom mounting holes in combination. Use only three of the four available mounting holes. Refer to Figure 2 for the recommended mounting orientations. Refer to Figure 3 for drive dimensions.

For optimum performance, the drive should be formatted in the same orientation as it will be mounted in the host system.

Caution: Seagate factory-installed labels must not be removed from the drive or covered with additional labels. Removing factory labels may void the warranty. Factory-installed labels contain information required when servicing the product.

Figure 2: Drive Mounting Orientations



1.10.1 Handling and Static Discharge Precautions

After unpacking the drive, and before you have installed the drive in the system, be careful not to expose the drive to handling or ESD hazards. Observe the following standard static-discharge precautions:

- Wear a grounded wrist-strap.
- Handle the drive by its edges.
- Do not put any pressure on the top or bottom of the drive.
- Do not touch the PC board.
- Always rest the drive on a padded surface until it is mounted in the host system.

1.10.2 Hot-plugging

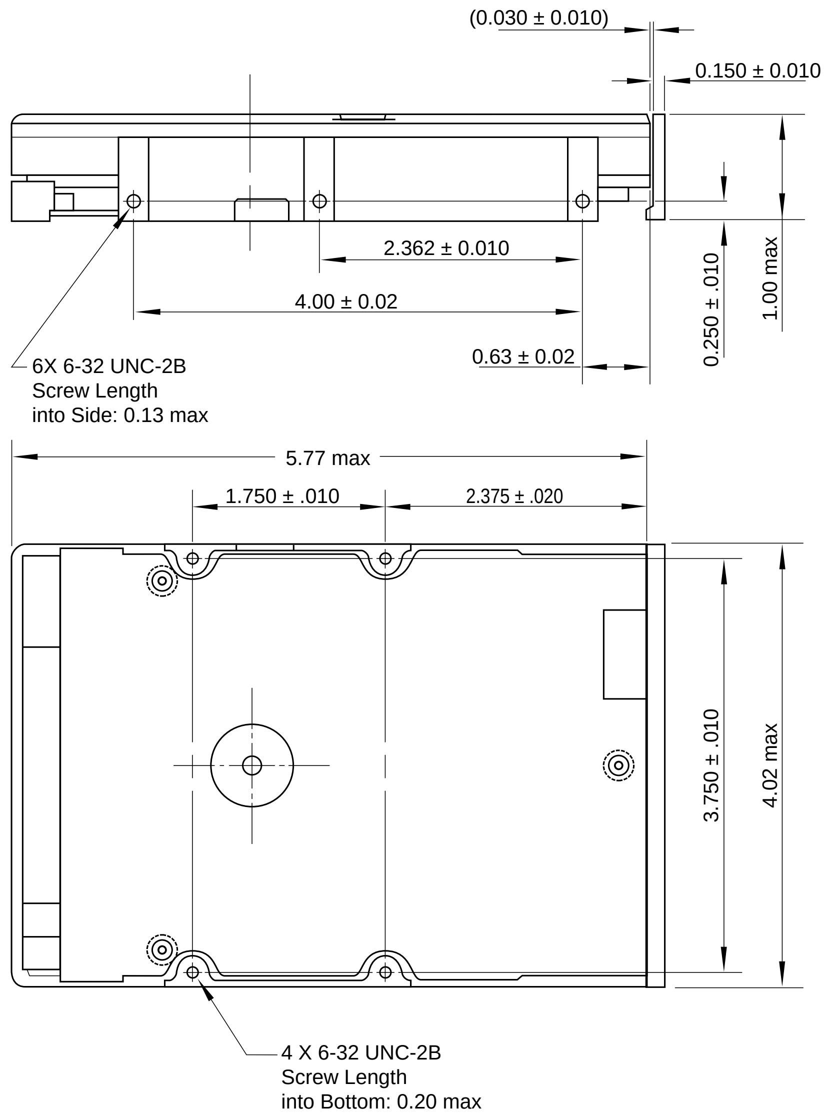
If there is more than one SCSI device daisy-chained on the bus, you can connect and disconnect the drive I/O and power connector if the following conditions are met:

- The drive you are disconnecting (or connecting) is not the device supplying terminator power or terminating resistance to the bus.
- Terminator power and resistance must not be added or removed from the bus during hot-plugging.
- The bus must not be used for I/O transactions during hot-plugging. If you are installing a drive on the bus, there must be no I/O transactions until the drive is connected and ready. If you are removing a drive from the bus, there must be no I/O transactions until the drive is completely disconnected.

To avoid damage to the disc and head, the spindle must be completely stopped and the heads must be parked before you remove the drive from the system. There are two ways to stop the spindle and park the heads:

- If the drive is not configured to use the remote start/stop feature, disconnect the DC power cable from the drive DC power connector and wait 30 seconds.
- If the drive is configured to use the remote start/stop feature, issue the SCSI stop command and wait 30 seconds.

Figure 3: Drive Dimensions



All Dimensions in Inches

2.0 Interface Description and Options

The SCSI-2 interface consists of a 9-bit bi-directional bus (8 data bits and 1 parity bit) plus 9 control signals supporting multiple initiators, disconnect/reconnect, and self-configuring host software. Logical block addressing is used.

The physical interface consists of single-ended drivers and receivers using asynchronous or synchronous communication protocols that support cable lengths of up to 6 meters (3 meters for Fast SCSI) and a bus interface transfer rate up to 1.5 Mbytes/sec asynchronous and 10.0 Mbytes/sec synchronous. The bus protocol supports multiple initiators, disconnect/reconnect, additional messages, and 6-byte and 10-byte Command Descriptor Blocks. The drive is always a target on the SCSI bus.

2.1 SCSI-2 Compatibility

The drive interface is compatible with the mandatory subset of the ANSI SCSI-2 Interface. The Fast SCSI-2 interface is based on the ANSI Small Computer System Interface-2 (SCSI-2): Document Number ANSI X3.131-1986 (X3T9.2/86-109 Rev. 10E).

2.2 SCSI Connector

The drive may be daisy-chained with other SCSI devices that have single-ended drivers and receivers using a common cable. All signals are common between all SCSI devices. The SCSI devices at both ends of the daisy-chain are to be terminated. Intermediate SCSI devices are not to be terminated.

A maximum of 8 SCSI devices (including the host) may be daisy-chained together. SCSI ID 7, by convention, is reserved for the host adapter. No drive can have the same SCSI ID as the host adapter.

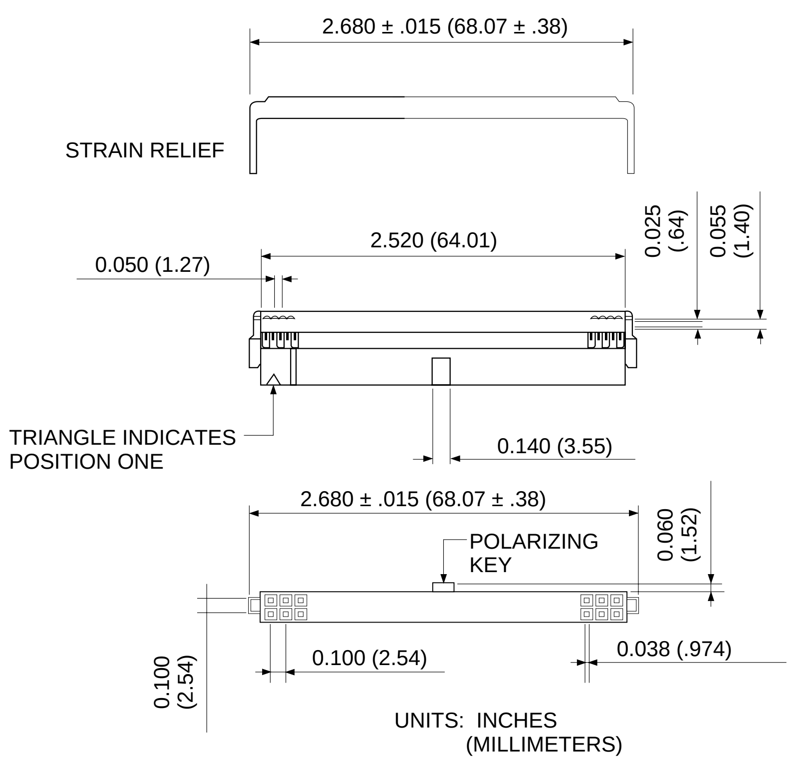
2.2.1 SCSI Connector Requirements

The drive connector is a nonshielded, 50-pin connector consisting of two rows of 25 pins with adjacent pins 0.100 inches apart. The connector is keyed with a slot. See Figure 4.

The nonshielded cable connector is a 50-conductor connector consisting of two rows of 25 female contacts with adjacent contacts 0.100 inches apart. The recommended cable connector part numbers are shown in the table below:

	Without Strain Relief	**With Strain Relief**	**With Strain Relief**
	Without Center Key	**Without Center Key**	**With Center Key**
Closed End (for cable ends)	3M 3425-7000	3M 3425-7050	Du Pont 66900-290
Open End (for daisy-chain)	3M 3425-6000	3M 3425-6050	Du Pont 66900-250

Figure 4: Nonshielded Cable Connector



2.2.1.1 SCSI Connector Pin Assignments

Pin Number	Signal (Minus Sign indicates Active Low)	Signal Ground Pin Number
2	-DB(0)	1
4	-DB(1)	3
6	-DB(2)	5
8	-DB(3)	7
10	-DB(4)	9
12	-DB(5)	11
14	-DB(6)	13
16	-DB(7)	15
18	-DB(P)	17
19 - 22	Ground	—
23 - 25	Reserved	—
26	Terminator Power	—
27 - 28	Reserved	—
29 - 30	Ground	—
32	-ATN	31
33 - 34	Ground	—
36	-BSY	35
38	-ACK	37
40	-RST	39
42	-MSG	41
44	-SEL	43
46	-C/D	45
48	-REQ	47
50	-I/O	49

Note: Do not connect Pin 25 to ground. Should the I/O connector be plugged in upside down, the terminator power on Pin 26 would be shorted to ground.

2.3 Cable Requirements

The characteristic impedance of the cable should be between 90 Ohms and 140 Ohms. However, most available cables have a somewhat lower characteristic impedance. To minimize discontinuities and signal reflections, do not use cables of different impedances in the bus.

Your design may require trade-offs in shielding effectiveness, cable length, the number of loads, and transfer rates. If your design uses both shielded and nonshielded cables within the same SCSI bus, you must allow for the effects of impedance mismatch.

A minimum conductor size of 28 AWG should be used to minimize noise effects. Use nonshielded cable connectors only. Use a 50-conductor flat cable or 25-conductor twisted-pair cable.

2.3.1 Single-Ended Cable

When using a single-ended SCSI cable, the following requirements must be met:

- The cable cannot be longer than 6.0 meters.
- A cable stub cannot be longer than 0.1 meter, from the mainline interconnection to any device.
- Stubs must be separated by at least 0.3 meter.

2.3.2 Fast Synchronous Data Transfer

When using a fast synchronous data transfer SCSI-2 cable, the following additional requirements must be met:

- The cable cannot be longer than 3.0 meters.
- A characteristic impedance of 90 Ohms to 132 Ohms is recommended for nonshielded flat cable or twisted-pair ribbon cable.
- The signal attenuation at 5 MHz must not be greater than 0.095 dB per meter.
- The DC resistance at 20 °C must not exceed 0.230 Ohms per meter.
- The propagation delay delta of a shielded, twisted-pair cable must not exceed 20 nsec per meter.

The recommended nonshielded flat cable part numbers are shown in the table below:

Part	Manufacturer	Part Number
Flat Cable	3M	3M-3365-50
Twisted Pair	Spectra	Twist-N-Flat 455-248-50

2.4 Terminators

Internal drive I/O termination consists of three SIP resistor modules that plug into sockets on the printed circuit board. You can order the drive with or without these terminators, depending on your application.

- All single initiator/single target applications require that the initiator and drive be terminated.
- Daisy-chain applications require that only the units at each end of the daisy-chain be terminated; all other peripherals on the chain should not be terminated.

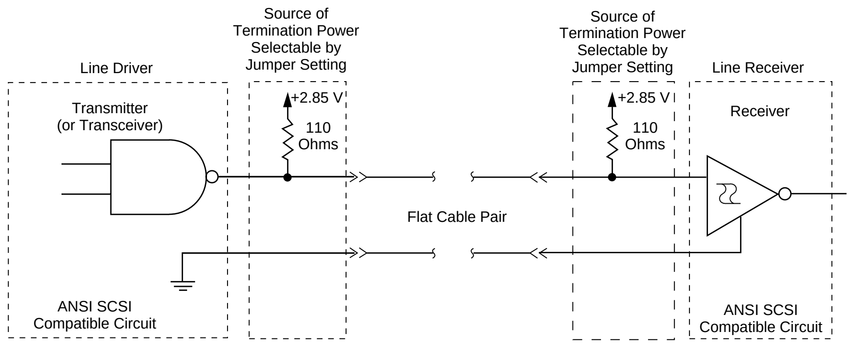
Note: If your application requires no terminators, remove the terminators from the circuit board. Merely removing the terminator power source selection jumper does not disconnect the terminator resistors from the circuit.

If Fast SCSI transfer rates are used, then the active termination options must be used. If the transfer rate is 5.0 MBytes/sec or less, either method of termination can be used. Although active and passive terminated devices can be installed on the same bus, both ends of the cable should be terminated in the same manner, either both active or both passive.

2.4.1 Active Termination

All interface signals are single-ended and must be terminated at the drive with a 110Ω resistor to +2.85 V.

Figure 5: Active Termination



2.4.2 Passive Termination

All interface signals with the drive are single-ended and must be terminated with 220Ω to +5 V and 330Ω to ground at each end of the cable. All signals use open-collector drivers or three-state drivers.

Single-ended SCSI devices providing termination power have the following characteristics:

Terminator Voltage (V)	4.0 to 5.25
Source Drive Capability (mA, min)	800

2.4.2.1 Single-Ended Drivers/Receivers

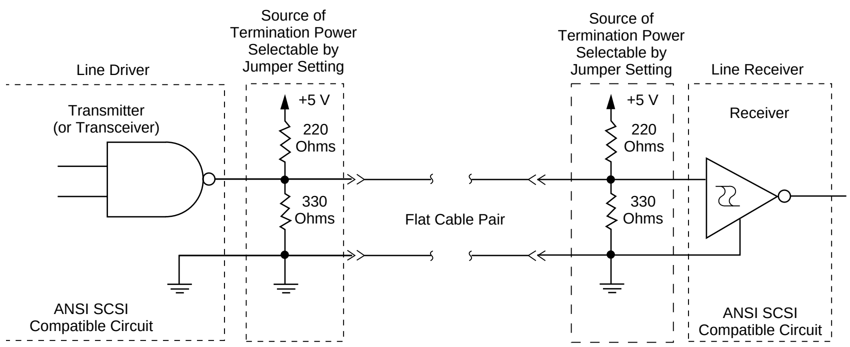
The drive uses single-ended drivers and receivers. Typical circuits are shown in Figures 5 and 6. Install terminator circuits only on the last drive in the daisy-chain.

- Transmitter Characteristics: The ST2383N uses an ANSI SCSI-compatible, open-collector, single-ended driver. This driver is capable of sinking a current of 48 mA with a low-level output voltage of 0.4 volts.
- Receiver Characteristics: The ST2383N uses an ANSI SCSI single-ended receiver with hysteresis gate or equivalent as a line receiver.

Figures 5 and 6 show part of the removable terminator resistor pack used on the last drive in the daisy-chain. The loss in the cable is defined as the difference between the voltages of the input and output signals, as shown below:

Logic Level	Driver Output	Receiver Input
Negated (0)	≥ 2.5 V; ≤ 5.25 V	≥ 2.0 V; ≤ 5.25 V
Asserted (1)	≤ 0.4 V; ≥ 0.0 V	≤ 0.8 V; ≥ 0.0 V

Figure 6: Single-Ended Transmitters and Receivers



2.5 Configuration Jumpers

The ST3283N has five jumper blocks. For each jumper block, several options are available. The jumper blocks and options are described in separate sections below. In addition to the jumper blocks, there are two connectors:

- Shrouded 50-pin SCSI connector with a key slot in the shroud
- 4-pin DC power connector

All jumper blocks and connectors are shown in Figure 7.

Note: This drive uses 2 mm-type connectors for the SCSI ID and 0.1 inch connectors for all other jumper blocks. The 2-mm jumpers should be Du Pont P/N 86730-001 or equivalent. The 0.1-inch jumpers should be Du Pont P/N 86214 or Molex P/N 87092-3013 or equivalent.

2.5.1 Parity/Remote Start Jumper Block

2.5.1.1 Parity Enable Option

This option is used to determine whether the parity bit is used. When a jumper is installed on Pins 1 and 2 of the Parity/Remote Start jumper block, the parity bit is used. The default is no jumper installed.

2.5.1.2 Start/Stop Option

When a jumper is installed on Pins 3 and 4 of the Remote Start/Parity jumper block, the drive waits for a Start/Stop Unit command from the Host before starting or stopping the spindle motor. The default is no jumper installed.

2.5.2 Active/Passive Termination Jumper Block

To select active termination, install a jumper on Pins 1 and 2 of the Active/Passive Termination jumper block. To select passive termination, install jumpers on Pins 5 and 6 and Pins 2 and 4 of the Active/Passive Termination jumper block.

2.5.3 Terminator Power Source Jumper Block

To select the termination power source install jumpers as follows:

- To select the SCSI connector as the termination power source, install a jumper on Pins 1 and 2 of the Terminator Power jumper block.
- To select the drive power connector as the termination power source for the resistor packs, install a jumper on Pins 1 and 3 of the Terminator Power jumper block.
- To provide terminator power to the SCSI connector from the drive power connector only, install a jumper on Pins 3 and 4 of the Terminator Power jumper block.
- To provide terminator power to the SCSI connector and the drive terminator packs, install jumpers on Pins 1 and 2 and Pins 3 and 4 of the Terminator Power jumper block.

2.5.4 SCSI ID Address Jumper Block

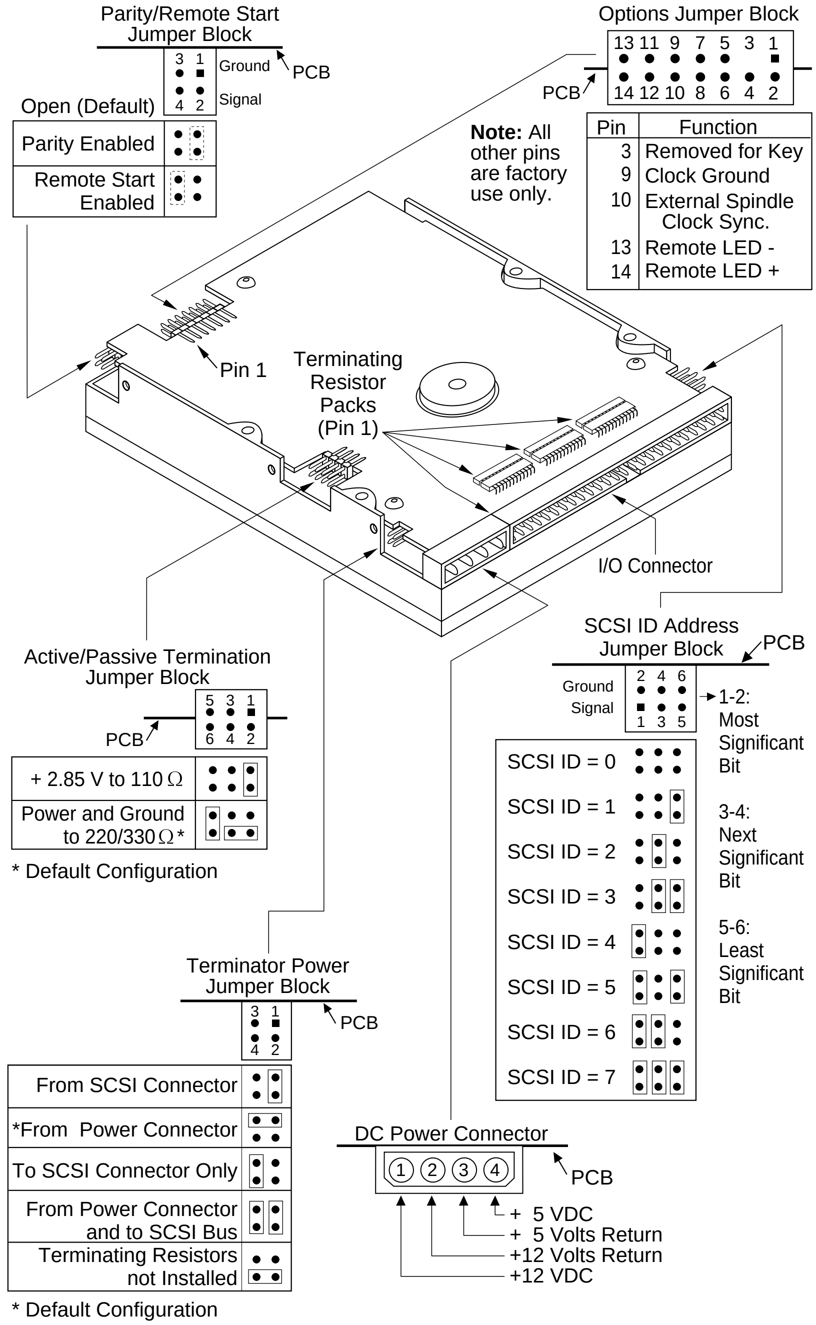
Select the SCSI ID of the drive by installing jumpers on the SCSI ID Address jumper block according to the table in Figure 7.

2.5.5 Options Jumper Block

To synchronize the drive spindles, connect a twisted pair to Pins 9 and 10 of the Options jumper block. External spindle synchronization implementation and timing is described in Section 2.6.

To power a remote LED, connect a twisted pair to Pins 13 and 14 of the Options jumper block.

Figure 7: Configuration Jumpers

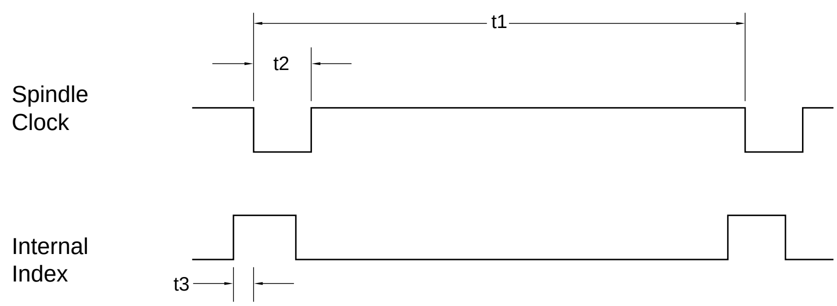


2.6 External Spindle Synchronization Option

The drive spindle can be synchronized to an external index signal so that several drives can be arrayed together to achieve a coordinated read/write capability. The ST3283 spindle synchronization is auto-detecting/auto-configuring and requires no jumpers or other reconfiguration except the installation of the cable providing (or supplying) the synchronization signal. This is a two-conductor cable, and the connections are single-ended. The drive connector is keyed, and is on 0.1-inch centers.

The SCSI interface version options that are programmable by the interface using the Mode Select command (Page 4, Byte 17, RPL options bits).

Figure 8: External Spindle Clock Timing Diagram



t1	spindle clock period	13.34 msec ± 0.5%
t2	duty cycle	0.5 µsec minimum to 500 µsec maximum
t3	spindle clock leading edge to index leading edge	0 µsec ± 250 µsec

3.0 SCSI Bus

Communication on the SCSI bus is allowed between only two SCSI devices at a time. There can be a maximum of eight SCSI devices, including the host computer, connected to the SCSI bus. The host adapter/initiator must be identified by one of the eight SCSI device addresses.

The host adapter, by convention, typically is set to SCSI ID 7. No drive can have the same SCSI ID as the host adapter. Each SCSI device has a SCSI ID bit assigned, as shown in Section 3.1.

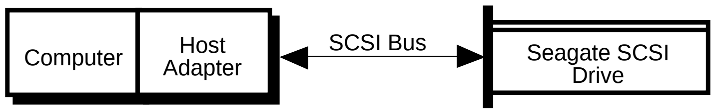
When two SCSI devices communicate on the SCSI bus, one acts as an initiator and the other acts as a target. The initiator, typically the host, starts an operation and the target performs the operation. The drive always operates as a target.

Certain SCSI bus functions are assigned to the initiator and certain SCSI bus functions are assigned to the target. The initiator selects a particular target. The target requests the transfer of Command, Data, Status or other information on the data bus.

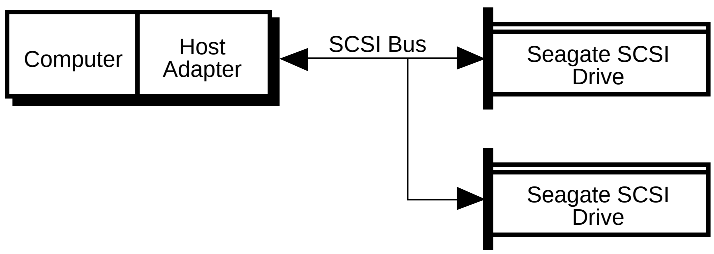
Information transfers on the data bus are asynchronous and follow a defined REQ/ACK handshake protocol. One byte of information is transferred with each handshake. The synchronous data transfer option is described in Section 4.5.3.1.

The drive supports single initiator/single target; single initiator/multiple target; or multiple initiator/multiple target bus configurations. See Figure 9.

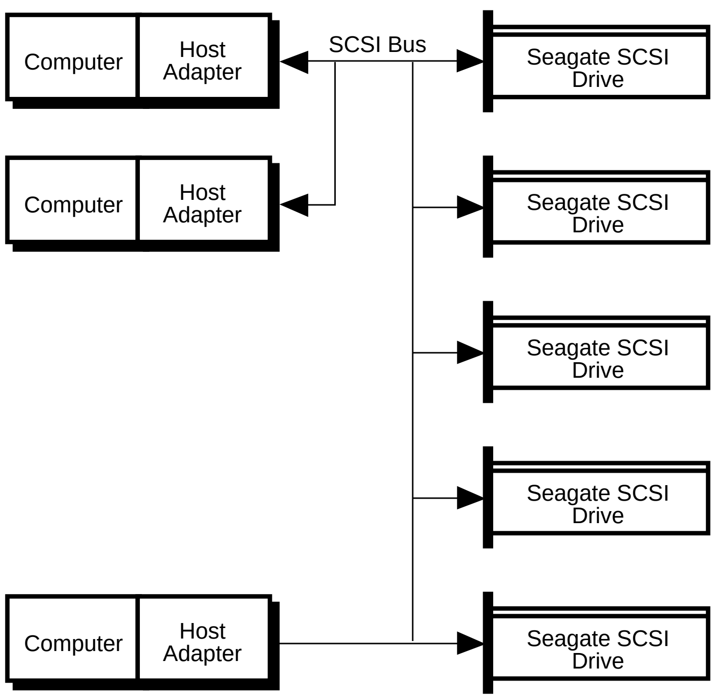
Figure 9: Sample SCSI Configurations



Single Initiator, Single Target



Single Initiator, Multi-Target



Multi-Initiator, Multi-Target

3.1 SCSI ID Bits

Data Bus	SCSI ID
DB(0)	SCSI ID = 0
DB(1)	SCSI ID = 1
DB(2)	SCSI ID = 2
DB(3)	SCSI ID = 3
DB(4)	SCSI ID = 4
DB(5)	SCSI ID = 5
DB(6)	SCSI ID = 6
DB(7)	SCSI ID = 7

3.2 SCSI Bus Signals

There are nine control and nine data signals, as described below:

BSY (BUSY): An OR-tied signal to indicate the bus is being used.

SEL (SELECT): A signal used by an initiator to select a target, or by a target to reselect an initiator.

C/D (CONTROL/DATA): A signal driven by the drive to indicate whether Control or Data information is on the Data Bus. Assertion indicates Control.

I/O (INPUT/OUTPUT): A signal driven by a drive to control the direction of data movement on the Data Bus with respect to an initiator. Assertion indicates input to the initiator. This signal is also used to distinguish between Selection and Reselection phases.

MSG (MESSAGE): A signal driven by the drive during the Message phase.

REQ (REQUEST): A signal driven by a target to indicate a request for REQ/ACK data transfer handshake.

ACK (ACKNOWLEDGE): A signal driven by an initiator to indicate an acknowledgment for a REQ/ACK data transfer handshake.

ATN (ATTENTION): A signal driven by an initiator to indicate the Attention condition.

RST (RESET): An OR-tied signal that indicates the Reset condition.

DB(7-0,P) (DATA BUS): Eight data bit signals, plus a parity bit signal form a Data Bus. DB(7) is the most significant bit and has the highest priority during the Arbitration phase. Bit number significance, and priority decrease downward to DB(0). A data bit is defined as one when the signal is asserted and zero when the signal is negated. Data parity DB(P) is odd. The use of parity is a system option. The drive always generates parity, but can be configured to enable/disable parity detection. (See Figure 7.) Parity is not valid during the Arbitration phase.

3.2.1 Signal Values

Signals may assume true or false values. There are two methods of driving these signals. In both cases, the signal is actively driven true, or asserted. In the case of OR-tied drivers, the driver does not drive the signal to the false state, rather the bias circuitry of the bus terminators pulls the signal false whenever it is released by the drivers at every SCSI device. If any driver is asserted, then the signal is true. In the case of non-OR-tied drivers, the signal may be actively driven false, or negated. Negated means that the signal may be actively driven false, or may simply be released (in which case the bias circuitry pulls it false), at the option of the implementor.

3.2.2 OR-Tied Signals

The BSY and RST signals are OR-tied only. In the ordinary operation of the bus, these signals are simultaneously driven true by several drivers. No signals other than BSY, RST, and DB(P) are simultaneously driven by two or more drivers, and any signal other than BSY and RST may employ OR-tied or non-OR-tied drivers. DB(P) are not driven false during the Arbitration phase. There is no operational problem in mixing OR-tied and non-OR-tied drivers on signals other than BSY and RST.

3.2.3 Signal Sources

The table that follows indicates which type of SCSI device is allowed to source each signal. All SCSI device drivers that are not active sources must be in the passive state. Note that the RST signal may be sourced by any SCSI device at any time. The drive functions as a target, never as an initiator, and is capable of performing only the reselection function.

Bus Phase	BSY	SEL	C/D, I/O, MSG, REQ	ACK/ATN	DB(7-0,P)
Bus Free	None	None	None	None	None
Arbitration	All	Winner	None	None	SCSI ID
Selection	I&T	Initiator	None	Initiator	Initiator
Reselection	I&T	Target	Target	Initiator	Target
Command	Target	None	Target	Initiator	Initiator
Data In	Target	None	Target	Initiator	Target
Data Out	Target	None	Target	Initiator	Initiator
Status	Target	None	Target	Initiator	Target
Message In	Target	None	Target	Initiator	Target
Message Out	Target	None	Target	Initiator	Initiator

ALL: The signal is driven by all actively arbitrating SCSI devices.

SCSI ID: A unique data bit (the SCSI ID) is driven by each actively arbitrating SCSI device: the other seven data bits are not driven by this SCSI device. The parity bit [DB(P)] may be undriven or driven to the true state, but will never be driven to the false state during this phase.

I&T: The signal is driven by the initiator, target, or both, as specified in the Selection phase and Reselection phase.

Initiator: If this signal is driven, it shall be driven only by the active initiator.

None: The signal is released; that is, not driven by any SCSI device. The bias circuitry of the bus terminators pulls the signal to the false state.

Winner: The signal is driven by the one SCSI device that wins arbitration.

Target: If the signal is driven, it is driven only by the active target.

3.3 SCSI Bus Timing

Unless otherwise indicated, the delay time measurements for each SCSI device are calculated from signal conditions existing at that SCSI device’s own SCSI bus connection. Thus, these measurements (except skew delay) can be made without considering delays in the cable.

Arbitration Delay (2.2 µsec min, no max): The minimum time a SCSI device waits between the time BSY is asserted for arbitration until the time the data bus can be examined to see if arbitration is won.

Assertion Period (90 nsec min): The minimum time a target asserts REQ while using synchronous data transfers. Also, the minimum time an initiator asserts ACK during synchronous data transfers.

Bus Clear Delay (800 nsec max): The maximum time for a SCSI device to stop driving all bus signals after:

1. The Bus Free phase is detected (BSY and SEL are both negated for a bus settle delay).
2. The maximum time for a SCSI device to clear the bus is 1200 nsec from the time BSY and SEL are both negated. If a SCSI device requires more than a bus settle delay to detect the Bus Free phase, it clears the bus within a duration equal to the Bus Clear delay minus the excess time.
3. SEL is received from another SCSI device during the Arbitration phase.
4. The transition of RST to assertion.

Bus Free Delay (800 nsec min): The minimum time that a SCSI device will wait from its detection of the Bus Free phase (BSY and SEL both negated for a bus settle delay) until its assertion of BSY when going to the arbitration phase.

Bus Set Delay (1.8 µsec max): The maximum time for a SCSI device to assert BSY and its SCSI ID bit on the Data Bus after it detects Bus Free phase (BSY and SEL both negated for a bus settle delay) for the purpose of entering the Arbitration phase.

Bus Settle Delay (400 nsec min): The time taken for the bus to settle after changing certain control signals as specified in the protocol definitions.

Cable Skew Delay (10 nsec max): The maximum difference in propagation time allowed between any two SCSI bus signals when measured between any two SCSI bus signals.

Data Release Delay (400 nsec max): The maximum time for an initiator to release the Data Bus signals following the transition of the I/O signal from negation to assertion.

Deskew Delay (45 nsec min): The minimum time required for deskew of certain signals.

Disconnection Delay (200 µsec min): The minimum time a target waits after releasing BSY before participating in an Arbitration phase when honoring a Disconnect message from the initiator.

Hold Time (45 nsec min): The minimum time added between the assertion of REQ or ACK and the changing of the data lines to provide hold time in the initiator or target, respectively, while using synchronous data transfers.

Negation Period (90 nsec min): The minimum time that a target negates REQ while using synchronous data transfers. Also, the minimum time that an initiator negates ACK while using synchronous data transfers.

Reset Hold Time (25 µsec min, no max): The minimum time that RST is asserted.

Selection Abort Time (200 µsec max): The maximum time between the moment a target (or initiator) most recently detects being selected (or reselected) and the moment BSY is asserted. This timeout ensures that a target (or initiator) does not assert BSY after a Selection (or Reselection) phase has been aborted. This is not the selection timeout period; see Sections 4.1.3.5 and 4.1.4.2 for a complete description.

Selection Timeout Delay (250 msec min recommended): The minimum time an initiator (or target) should wait for a BSY response during the Selection (or Reselection) phase before starting the timeout procedure. Note that this is only a recommended time period. The drive implements this 250 msec selection timeout delay.

3.4 Fast Synchronous Transfer Rates

When devices negotiate a synchronous data transfer period of less than 200 nsec they are said to be using “fast synchronous transfer rates.” Devices that negotiate a synchronous data transfer period greater than 200 nsec use timing parameters specified in Section 3.3.

When the drive is being used as a fast SCSI device, the transfer periods in this section are applicable, in lieu of previously specified periods. Transfer periods not mentioned in this section remain the same as those previously defined. The minimum synchronous data transfer period is 100 nsec.

Period	Fast SCSI Rates (nsec)
Fast Assertion Period	30
Fast Cable Skew Delay	5
Fast Deskew Delay	20
Fast Hold Time	10
Fast Negation Period	30

4.0 Logical Characteristics

All the operations of the SCSI bus described in this chapter are supported by the drive, unless otherwise stated. The drive always functions as the target, never the initiator.

4.1 SCSI Bus Phases

The SCSI architecture includes eight distinct bus phases. The SCSI bus can never be in more than one phase at a time.

1. Bus Free phase
2. Arbitration phase
3. Selection phase
4. Reselection phase
5. Command phase*
6. Data (In and Out) phase*
7. Status (In Only) phase*
8. Message (In and Out) phase*

* These phases are collectively termed the Information Transfer Phase.

4.1.1 Bus Free Phase

The Bus Free phase indicates that no SCSI device is actively using the SCSI bus and it is available for subsequent users.

SCSI devices detect the Bus Free phase after SEL and BSY are both false for at least a bus settle delay.

SCSI devices must release all SCSI bus signals within a bus clear delay after BSY and SEL are continuously negated for a bus settle delay. If a SCSI device requires more than a bus settle delay to detect the Bus Free phase, it must release all SCSI bus signals within a bus clear delay minus the excess time to detect the Bus Free phase. The total time to clear the SCSI bus must not exceed a bus settle delay plus a bus clear delay.

If the initiator detects the Bus Free phase (except as a result of a Reset condition, an Abort message, or a Bus Device Reset message) without first receiving a Disconnect or Command Complete message, it is considered to be an error condition. If the target intentionally creates this condition, the target:

1. Clears the current I/O process, if any, for that initiator.
2. Sets up Request Sense data with the appropriate Sense Key and Error Code if the LUN is known.

Whenever an initiator detects an unexpected Bus Free, it should attempt to select and issue Request Sense to determine if the previous I/O process was:

1. Aborted with valid Request Sense data, or
2. Aborted without any valid Request Sense data.

4.1.2 Arbitration Phase

The Arbitration phase allows one SCSI device to gain control of the SCSI bus so that it can assume the role of an initiator or target. The drive arbitrates for the bus only as a target implementing reselection. The drive supports arbitration by multiple SCSI devices.

The procedure for a SCSI device to obtain control of the SCSI bus is as follows:

1. The SCSI device waits for Bus Free phase. The Bus Free phase is detected when BSY and SEL are simultaneously and continuously negated for a minimum of a bus settle delay.

   Note: This bus settle delay is necessary because a transmission line phenomenon known as a “wired-OR glitch” may cause BSY to briefly appear negated, even though it is being asserted.

2. The SCSI device waits a minimum of a bus free delay after detection of the Bus Free phase (i.e. after BSY and SEL are both negated for a bus settle delay) before driving any signal.
3. The SCSI device may arbitrate for the SCSI bus by asserting both BSY and its own SCSI ID, however the SCSI device does not arbitrate (i.e. assert BSY and its SCSI ID) if more than a bus set delay has passed since the Bus Free phase was last observed.

Note: There is no maximum delay before asserting BSY and the SCSI ID following the bus free delay as long as the bus remains in the Bus Free phase. However, SCSI devices that delay longer than a bus settle delay plus a bus set delay from the time when BSY and SEL are first negated may fail to participate in arbitration when competing with faster SCSI devices.

4. After waiting at least an arbitration delay (measured from its assertion of BSY) the SCSI device examines the Data Bus. If a higher priority SCSI ID bit is true on the Data Bus [DB(7) is the highest], the SCSI device has lost the arbitration and must release its signals and return to the first step. If no higher priority SCSI ID bit is true on the Data Bus, the SCSI device has won the arbitration and it will assert SEL. Any other SCSI device that is participating in the Arbitration phase has lost the arbitration and releases BSY and its SCSI ID bit within a bus clear delay after SEL becomes true. A SCSI device that loses arbitration may return to the first step.

The SCSI device that wins arbitration waits at least a bus clear delay plus a bus settle delay after asserting SEL before changing any signals.

Note: The SCSI ID bit is a single bit on the Data Bus that corresponds to the SCSI device's unique SCSI address. The other seven data bus bits are released by the SCSI device. Parity is not valid during the Arbitration phase, DB(P) may be undriven, or driven true, but not driven false.

4.1.3 Selection Phase

The Selection phase allows an initiator to select a target for the purpose of initiating some target function, for example a Read or a Write command.

Note: During the Selection phase, the I/O signal is negated so this phase can be distinguished from the Reselection phase.

4.1.3.1 Nonarbitrating Systems

In systems that do not implement the Arbitration phase, the initiator detects the Bus Free phase, and then waits a minimum of a bus clear delay. Then, except in certain single initiator environments with initiators employing the single initiator option, the initiator asserts the desired target's SCSI ID and its own initiator SCSI ID on the data bus. After two deskew delays, the initiator asserts SEL.

4.1.3.2 Arbitrating Systems

In systems with the Arbitration phase implemented, the SCSI device that won the arbitration has both BSY and SEL asserted and has delayed at least a bus clear delay plus a bus settle delay before ending the Arbitration phase.

The SCSI device that won the arbitration becomes an initiator by releasing I/O. Except in certain single initiator environments with initiators employing the single initiator option (see Section 4.1.3.4), the initiator sets the Data Bus signal to a value that is the OR of its SCSI ID bit and the target's SCSI ID bit. The initiator waits at least two deskew delays and release BSY. The initiator then waits at least a bus settle delay before looking for a response from the target.

4.1.3.3 All Systems

In all systems, the target determines that it is selected when SEL and its SCSI ID bit are true and BSY and I/O are false for at least a bus settle delay. The selected target examines the Data Bus to determine the SCSI ID of the selecting initiator unless the initiator employed the single initiator option. The selected target then asserts BSY before the selection abort expires; this is required for correct operation of the time-out procedure.

In systems with parity implemented, the target does not respond to a selection if bad parity is detected. Also, if more than two SCSI ID bits are on the data bus, the target does not respond to selection. If at least two deskew delays transpire before the initiator asserts BSY, it releases SEL and changes the Data Bus signal.

4.1.3.4 Single Initiator Option

Initiators that do not implement the Reselection phase, and do not operate in the multiple initiator environment, are allowed to set only the target's SCSI ID bit during the Selection phase. This makes it impossible for the target to determine the initiator's SCSI ID.

4.1.3.5 Selection Time-out Procedure

A selection time-out procedure is specified for clearing the SCSI bus:

- If the initiator waits a minimum of a selection time-out delay and there has been no BSY response from the target, the initiator continues asserting SEL and releases the data bus.
- If the initiator has not detected BSY to be asserted after at least a selection abort time plus two deskew delays, the initiator releases SEL and ATN, allowing the SCSI bus to go to the Bus Free phase. SCSI devices ensure, when responding to selection, that the selection was still valid within a selection abort time of their assertion of BSY.

  Note: Failure to comply with this requirement could result in an improper selection, for example: two targets connected to the same initiator; wrong target connected to an initiator; or a target that is not connected to an initiator.

4.1.4 Reselection Phase

Reselection is a phase that allows a target to reconnect to an initiator for the purpose of continuing some operation that was previously started by the initiator but was suspended by the target. For example, the target disconnected by allowing a Bus Free phase to occur before the operation was complete.

Reselection can be used only in systems that have the Arbitration phase implemented.

The drive implements the Reselection phase if the host system is capable of supporting Reselection.

4.1.4.1 Reselection Procedure

Upon completing the Arbitration phase, the winning SCSI device has both BSY and SEL asserted and has delayed at least a bus clear delay plus a bus settle delay. The winning SCSI device becomes a target by asserting the I/O signal. That device also sets the Data Bus to a value that is the OR of its SCSI ID bit and the initiator's SCSI ID bit. The target waits at least two deskew delays and releases BSY. The target then waits at least a bus settle delay before looking for a response from the initiator.

The initiator determines that it is reselected when SEL, I/O, and its SCSI ID bit are true and BSY is false for at least a bus settle delay. The reselected initiator may examine the Data Bus to determine the SCSI ID of the reselecting target.

The reselected initiator then asserts BSY within a selection abort time of its most recent detection of being reselected; this is required for correct operation of the time-out procedure. In systems with parity implemented, the initiator does not respond to Reselection if bad parity is detected. The initiator does not respond to a Reselection if more than two SCSI ID bits are on the Data Bus.

After the target detects the BSY signal is true, it asserts BSY and waits at least two deskew delays and then releases SEL. The target may then change the I/O signal and the Data Bus. When the reselected initiator detects SEL false, it releases BSY. The target continues asserting BSY until the target is ready to relinquish the SCSI bus.

Note: When the target is asserting BSY, a transmission line phenomenon known as a “wired-OR glitch” may cause BSY to appear false for up to a round trip propagation delay following the release of BSY by the initiator. Therefore, the Bus Free phase is recognized only after both BSY and SEL are continuously false for a minimum of a bus settle delay.

Note: Do not use a cable longer than previously specified, even if the chosen driver, receiver, and cable provide adequate noise margins. The increased length increases the duration of the wired-OR glitch and could cause SCSI devices to inadvertently detect the Bus Free phase.

4.1.4.2 Reselection Time-out Procedure

The Reselection time-out procedure is specified for clearing the SCSI bus during a Reselection phase:

- If the target waits a minimum of a selection time-out period and there has been no BSY response from the initiator, the target continues asserting SEL and I/O and releases all Data Bus signals.
- If the target has not detected BSY to be true after at least a selection abort time plus two deskew delays, the target releases SEL and I/O allowing the SCSI bus to go to the Bus Free phase.

SCSI devices that respond to reselection must ensure that the reselection was still valid within a selection abort time of their assertion of BSY. If not, an improper reselection may result. For example, two initiators may be connected to the same target or the wrong initiator may be connected to a target.

If reselection fails, the current command is aborted. If an initiator times out while waiting to be reselected, the initiator should attempt to select and issue Request Sense to determine if the previous I/O process is:

- Still in process (Busy Status will be returned)
- Aborted with valid Request Sense data
- Aborted without valid Request Sense data

4.1.5 Information Transfer Phases

Note: The Command, Data, Status, and Message phases are grouped together as information transfer phases because they are used to transfer data or control information via the Data Bus. The actual contents of the information is beyond the scope of this section.

The C/D, I/O, and MSG signals are used to distinguish between the different information transfer phases. The target drives these three signals and therefore controls all changes from one phase to another. The initiator can request a Message Out phase by asserting ATN, while the target can cause the Bus Free phase by releasing MSG, C/D, I/O, and BSY.

The information transfer phases use one or more REQ/ACK handshakes to control transfers. Each REQ/ACK handshake allows the transfer of one byte of information. During the information transfer phases:

- BSY must remain true and SEL must remain false.
- The target must continuously envelope the REQ/ACK handshake(s) with C/D, I/O, and MSG so that these control signals are valid for a bus settle delay before the assertion of REQ of the first handshake, and remain valid until the negation of ACK at the end of the last handshake.

4.1.5.1 Asynchronous Data Transfer

The target use the I/O signal to control the direction of data transfer:

- When I/O is true, information is transferred from the target to the initiator.

  The target drives DB(7-0,P) to their desired values, delays at least one deskew delay plus a cable skew delay, then asserts REQ. DB(7-0,P) must remain valid until ACK is true at the target. The initiator reads DB(7-0,P) after REQ is true, and then signals its acceptance of the data by asserting ACK.

  When ACK becomes true at the target, the target may change or release DB(7-0,P) and negate REQ. After REQ is false the initiator negates ACK. After ACK is false, the target may continue the transfer by driving DB(7-0,P) and asserting REQ, as described above.

- When I/O is false, information is transferred from the initiator to the target.

  The target requests information by asserting REQ. The initiator drives DB(7-0,P) to their desired values, delays at least one deskew delay plus a cable skew delay, and asserts ACK. The initiator continues to drive the DB(7-0,P) until REQ is false.

  When ACK becomes true at the target, the target reads DB(7-0,P), then negate REQ. When REQ becomes false at the initiator, the initiator may change or release DB(7-0,P) and negate ACK. The target may continue the transfer by asserting REQ, as described above.

4.1.5.2 Synchronous Data Transfer

Synchronous data transfer may be used only in the data phase if previously agreed to by the initiator and the target through the message system. The messages determine the use of synchronous mode by both devices and establishes a REQ/ACK offset and a transfer period. See Section 4.5.3.1 for an explanation of synchronous extended messages.

The REQ/ACK offset specifies the maximum number of REQ pulses that can be sent by the target in advance of the number of ACK pulses received from the initiator, establishing a pacing mechanism. If the number of REQ pulses exceeds the number of ACK pulses by the REQ/ACK offset, the target does not assert REQ until the next ACK pulse is received. To successfully complete the data phase, the number of ACK and REQ pulses must be equal.

Before asserting the REQ signal, the drive waits at least:

- the greater of a transfer period from the last transition of the REQ signal to true,
- or a minimum of a negation period from the last transition of the REQ signal to false.

The initiator must send one pulse on the ACK signal for each REQ pulse received. The initiator asserts the ACK pulse for a minimum of an assertion period. Before asserting the ACK signal, the initiator waits at least the greater of a transfer period from the last transition of ACK to true or a minimum of a negation period from the transition of ACK to false.

- When I/O is true, information is transferred from the target to the initiator.

  The target drives DB (7-0,P) to their desired values, and then waits at least one deskew delay plus one cable skew delay plus one hold time after the assertion of REQ. The target must assert REQ for a minimum of an assertion period. The target may then negate REQ and change or release DB (7-0,P). The initiator reads the value of DB (7-0,P) within one hold time of the transition of REQ to true. The initiator then responds with an ACK pulse.

- When I/O is false, information is transferred from the initiator to the target.

  The initiator transfers one byte for each REQ pulse received. After receiving the REQ pulse, the initiator drives DB (7-0,P) to their desired values, and then delays at least one deskew delay plus one cable delay before asserting ACK. The initiator must hold DB (7-0,P) valid for at least one deskew delay plus one cable skew delay plus one hold time after the assertion of ACK. The initiator asserts ACK for a minimum of an assertion period. The initiator may then negate ACK and change or release DB (7-0,P). The target reads the value of DB (7-0,P) within one hold time of the transition of the ACK signal to true.

4.1.6 Command Phase

The Command phase allows the target to request command information from the initiator. The target must assert the C/D signal and negate the I/O and MSG signals during the REQ/ACK handshake(s) of this phase.

4.1.7 Data Phases

The Data Phase is a term that encompasses both the Data In and the Data Out phase.

4.1.7.1 Data In Phase

The Data In phase allows the target to request that it send data to the initiator. The target must assert the I/O signal and negate the C/D and MSG signals during the REQ/ACK handshake.

4.1.7.2 Data Out Phase

The Data Out phase allows the target to request that data be sent to it from the initiator. The drive negates the C/D, I/O, and MSG signals during the REQ/ACK handshake.

4.1.8 Status Phase

The Status phase allows the target to request that it send status information to the initiator. See Section 5.5 for a detailed table of the available status information. The target must assert C/D and I/O and negate the MSG signal during the REQ/ACK handshake.

4.1.9 Message Phases

Multiple-byte messages can be sent during a single phase of Message In and Message Out phases. The first byte transferred is either a single-byte message or the first byte of a multiple-byte message.

4.1.9.1 Message In Phase

The Message In phase allows the target to request that it send messages to the initiator. The target must assert C/D, I/O, and MSG during the REQ/ACK handshake.

4.1.9.2 Message Out Phase

The Message Out phase allows the target to request that message(s) be sent from the initiator to the target. The target can invoke this phase in response to the Attention condition created by the initiator. The drive asserts C/D and MSG and negates I/O during the REQ/ACK handshake. The drive handshakes bytes in this phase until ATN goes false, unless an error occurs.

If the target detects a parity error on the message bytes received, it can attempt to retry the message by asserting REQ after detection ATN has gone false and before changing to any other phase. In response, the initiator resends all of the previous message bytes sent during this phase. When resending more than one message byte, the initiator asserts ATN at least two deskew delays before asserting ACK on the first byte and maintains ATN asserted until the last byte is sent.

If the target receives all of the message bytes without parity errors, it indicates that it does not wish to retry by changing to any information transfer phase other than the Message Out phase and transfers at least one byte. The target may also indicate that it has successfully received the message bytes by changing to the Bus Free phase, for example, Abort or Bus Device Reset messages.

The first message sent by the initiator after the selection phase must be an Identify, Abort, or Bus Device Reset message. If the target receives any other message, it goes to the Bus Free phase.

4.1.10 Signal Restrictions Between Phases

When the SCSI bus is between two information transfer phases, the following restrictions apply to the SCSI bus signals:

1. The BSY, SEL, REQ, and ACK signals must not change.

2. The C/D, I/O, MSG, and Data Bus signals may change. When switching the Data Bus signal direction from Out (initiator driving) to In (target driving), the target delays driving the Data Bus by at least a data release delay plus the bus settle delay after asserting the I/O signal, and the initiator releases the Data Bus signal no later than a data release delay after the transition of the I/O signal to true. When switching the Data Bus direction from In (target driving) to Out (initiator driving), the target releases the Data Bus signal no later than a deskew delay after negating the I/O signal.

3. The ATN and RST signals may change as defined under the descriptions for the Attention condition (Section 4.2.1) and Reset condition (Section 4.2.2).

4.2 SCSI Bus Conditions

The SCSI bus has two asynchronous conditions: the Attention condition and the Reset condition. These conditions cause the SCSI device to perform certain actions and can alter the phase sequence.

4.2.1 Attention Condition

The initiator uses the Attention condition to tell the target that the initiator has a message ready. The target gets this message by performing a Message Out phase.

The initiator creates the Attention condition by asserting ATN at any time, except during the Arbitration or Bus Free phase.

The initiator must assert the ATN signal before negating ACK for the last byte transferred in a bus phase for the Attention condition to be honored before transition to a new bus phase. An ATN asserted later may not be honored until a later bus phase. The drive responds with the Message Out phase as follows:

1. If ATN occurs during a Data phase, Message Out occurs at a convenient time. It may not occur until several logical blocks after ATN is first asserted.
2. If ATN occurs during a Command phase, Message Out occurs after transfer of all Command Descriptor Block bytes has been completed.
3. If ATN occurs during a Status phase, Message Out occurs after the status byte has been acknowledged by the initiator.
4. If ATN occurs during a Message In phase, Message Out occurs after the last byte of the current message has been acknowledged by the initiator.
5. If ATN occurs during a Selection phase, Message Out occurs immediately after that Selection phase.
6. If ATN occurs during a Reselection phase, Message Out occurs immediately after the Identify message.

The initiator must keep ATN asserted if more than one byte is to be transferred. The initiator may negate the ATN signal at any time except while the ACK signal is asserted during a Message Out phase. Recommended practice is that the initiator negates ATN while REQ is true and ACK is false during the last REQ/ACK handshake of the Message Out phase.

4.2.2 Reset Condition

The Reset condition is used to clear all SCSI devices from the bus. Reset takes precedence over all other phases and conditions. During the Reset condition, the states of all SCSI bus signals, except RST, are not defined. After the Reset condition, the bus always goes to the Bus Free phase.

All SCSI devices must release all bus signals (except RST) within a bus clear delay of the transition of RST to true. The drive never asserts the Reset signal. The drive implements only the “hard” Reset option. Upon receipt, the drive:

1. Clears all uncompleted commands.
2. Releases all SCSI device reservations.
3. Returns any SCSI device operating modes to default conditions. The mode parameters will be returned to their saved values if the saved value can be retrieved. Otherwise, the mode values will be returned to their default values.
4. Activates Unit Attention Condition for all initiators.

4.3 SCSI Bus Phases

SCSI bus phases follow a prescribed sequence. The Reset condition can abort any phase and is always followed by the Bus Free phase. Also, any other phase can be followed by the Bus Free phase.

4.3.1 Arbitration Transfer Phases

The arbitration transfer phases can be in any sequence. A phase of a specific type can be followed by any phase, even of the same type.

4.3.1.1 Systems with Arbitration

For systems with Arbitration, the allowable sequences are shown in Figure 10 The normal progression is from the Bus Free phase to Arbitration, from Arbitration to Selection or Reselection, and from Selection or Reselection to one or more of the information transfer phases: Command, Data, Status, or Message.

4.3.1.2 Systems without Arbitration

For systems without Arbitration, the allowable sequences are shown in Figure 11. The normal progression is from the Bus Free phase to Selection, and from Selection to an information transfer phase: Command, Data, Status, or Message.

4.4 SCSI Pointers

The SCSI architecture provides for two sets of three pointers for each I/O process within each initiator. The pointers are part of the initiator path control. The first set of pointers are known as the active pointers. These pointers represent the state of the interface and point to the next command, data, or status byte to be transferred between the initiator's memory and the target. There is only one set of pointers in each initiator. The active pointers are used by the target currently connected to the initiator.

The second set of pointers are known as the saved pointers. There is one set of saved pointers for each command that is currently active (whether or not it is currently connected). The saved command pointer always points to the start of the Command Descriptor Block (see Section 5.2) for the current command. The saved status pointer always points to the start of the status area for the current command. At the beginning of each command, the saved data pointer points to the start of the data area. It remains at this value until the target sends a Save Data Pointer message (see Section 4.5.2) to the initiator. In response to this message, the initiator stores the value of the active data pointer into the saved data pointer. The target may restore the active pointers to their saved values by sending a Restore Pointer Message to the initiator. (See

Section 4.5.2.) The initiator moves the saved value of each pointer into the corresponding active pointer. Whenever a SCSI device disconnects from the bus, only the saved pointer values are retained. The active pointer values are restored from the saved values upon the next reconnection

Figure 10: Phase Sequences with Arbitration

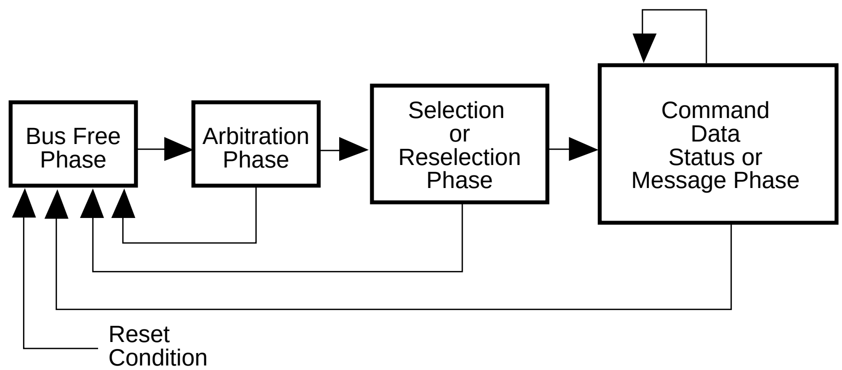
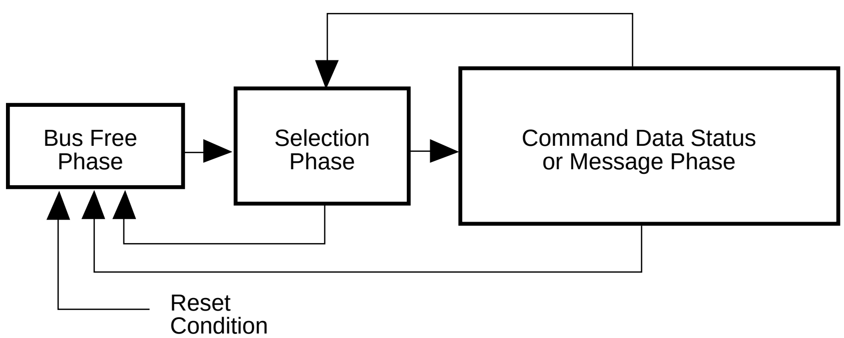


Figure 11: Phase Sequences without Arbitration



4.5 Message System Specification

The message system allows communication between an initiator and target for the purpose of physical path management.

4.5.1 Message Protocol

The drive supports systems that accommodate the Command Complete message or systems that accommodate additional messages. The drive is always Logical Unit (LUN) address zero.

SCSI devices indicate their ability to accommodate more than the Command Complete message by asserting or responding to the ATN signal. The initiator indicates this in the Selection phase by asserting ATN before the SCSI bus condition of SEL true, and BSY false. If the target has not received ATN by this point, it will assume that the initiator does not support disconnection or messages other than Command Complete. If the ATN signal is asserted later, it is ignored until after the next Bus Free phase. The target indicates its ability to accommodate more messages by responding to the Attention condition with the Message Out phase after going through the Selection phase.

For SCSI devices that support messages other than Command Complete, the first message sent by the initiator after the Selection phase must be the Identify, Abort or Bus Device Reset message. This allows the establishment of the physical path for a particular logical unit specified by the initiator.

The first message sent by the target after the Reselection phase is the Identify message. This allows the physical path to be reestablished for the target's specified logical unit number (always zero).

Whenever a physical path is established in an initiator that can accommodate disconnection and reconnection, the initiator must ensure that the active pointers of the physical path are equal to the save pointers for that particular logical unit number. (An implied restore pointers operation occurs as a result of connect or reconnect.)

4.5.2 Single-Byte Messages

The single-byte messages are listed below. Any Message Out not listed is answered with a Message Reject message by the drive.

Code	Description	Direction	
00_H	Command Complete	In	
01_H	Extended	In	Out
02_H	Save Data Pointer	In	
03_H	Restore Pointers	In	
04_H	Disconnect	In	Out
05_H	Initiator Detected Error		Out
06_H	Abort		Out
07_H	Message Reject	In	Out
08_H	No Operation		Out
09_H	Message Parity Error		Out
$0A_H$	Linked Command Complete	In	
$0B_H$	Linked Command Complete (with Flag)	In	
$0C_H$	Bus Device Reset		Out
$0D_H$	Abort Tag		Out
$0E_H$	Clear Queue		Out
$0F_H$ - $7F_H$	(not supported)		
80_H - FF_H	Identify	In	Out

In = Drive to Initiator; Out = Initiator to Drive

Command Complete (00_H): Tells the initiator that the I/O process has been successfully or unsuccessfully completed. Valid status is sent to the initiator. After successfully sending this message, the target goes to the Bus Free phase by releasing BSY.

Extended (01_H): The first byte of a multiple-byte message. (See Section 4.5.3 for descriptions of extended messages.)

Save Data Pointer (02_H): Tells the initiator to copy the currently active data pointer to the saved data pointer for the current I/O process. (See Section 4.4 for a definition of pointer.)

Restore Pointers (03_H): Directs the initiator to restore the active pointers from the most recently saved pointers for the currently attached drive. Pointers to the command, data, and status locations for the logical unit are restored to the active pointers. Command and status pointers are restored to the beginning of the present command and status areas. The data pointer is restored to the value at the beginning of the data area in the absence of a Save Data Pointer message or to the value at the point at which the last Save Data Pointer message occurred for the currently attached drive.

Disconnect (04_H): Tells the initiator that the present physical path is broken, causing the target to disconnect by releasing BSY. Later, a reconnect is required to complete the current I/O process.

If the initiator detects the Bus Free phase (other than as a result of a Reset condition) without first receiving a Disconnect, Command Complete or after sending Abort, Abort Tag, Bus Device Reset or a Clear Queue message, the initiator considers this a catastrophic error. The initiator does not save the data pointer.

If Disconnect messages are used to break a long data transfer into two or more shorter transfers, then a Save Data Pointer message is issued before each Disconnect message. The drive disconnects when a substantial delay is anticipated. These situations occur after receipt of a Command Descriptor Block or during a data transfer. The initiator may send this message to the target to tell it to disconnect from the SCSI bus.

After the target receives the Disconnect message, it switches to the Message In phase, sends the Save Data Pointer and Disconnect messages to the initiator, and disconnects by releasing BSY. After releasing the BSY signal, the target does not participate in another arbitration phase for at least a disconnection delay.

Initiator Detected Error (05_H): Tells the target that an error (for example, a parity error) has occurred that does not preclude the target from retrying the I/O process. Since present pointer integrity is not assured, a Restore Pointers message is sent by the target to cause the pointers to be restored to their defined prior state. An initiator should not issue this message unless it will accept the Restore Pointers message. If the target is not sure it can recover properly, Check Condition status will be created with Sense Key of Aborted Command.

Abort (06_H): Tells the target to clear all I/O processes for the current initiator:

- If a logical unit has been identified, all pending data and status for the initiator from the affected logical unit is aborted and target goes to the Bus Free phase. Pending data and status for other initiators are not cleared.
- If a logical unit has not been identified, the target goes to the Bus Free phase. No status or ending message is sent for the I/O process.

Message Reject (07_H): Tells the initiator that the last message that it sent was inappropriate or has not been implemented.

Tells the target that the last message it sent was inappropriate or has not been implemented. (The target does not retry the message.) Messages and responses are listed in table below.

Message	Recovery Action
Command Complete	Go to “unexpected” Bus Free phase, no sense data available.
Save Data Pointer	Go to “unexpected” Bus Free phase, no sense data available.
Restore Pointers	Go to “unexpected” Bus Free phase, no sense data available.
Disconnect	Don’t disconnect: continue command normally.
Message Reject	Go to “unexpected” Bus Free phase, no sense data available.
Linked Command Complete	Go to “unexpected” Bus Free phase, no sense data available.
Identify	Go to “unexpected” Bus Free phase, no sense data available.
Synchronous Data Transfer Request	Set transfer parameters for asynchronous data transfers.

No Operation (08_H): Tells the target, in response to its request for a message, that the initiator does not currently have any other valid messages to send.

Message Parity Error (09_H): Tells the target that one or more bytes in the last message it received had a parity error. The drive retries the original message once. If the retry also results in a parity error, the target goes to Bus Free phase.

The initiator indicates its intention to send this message by asserting the ATN signal before it releases ACK for the REQ/ACK handshake of the message that has the parity error. This provides an interlock, allowing the target to determine which message has the parity error.

Linked Command Complete ($0A_H$): Tells the initiator that a linked command is completed and that the status has been sent. Then, the initiator sets the pointers to the initial state for the next linked command.

Linked Command Complete (with flag) ($0B_H$): Tells the initiator that a linked command has been completed (with the flag bit set to one) and that the status has been sent. Then, the initiator sets the pointers to the initial state for the next linked command. Typically, this message would be used to cause an interrupt in the initiator between two linked commands.

Bus Device Reset ($0C_H$): Tells the target to clear all I/O processes and drives it to an initial state with no operations pending for any initiator. When received, the target goes to the Bus Free phase. This message forces a hard reset condition on the drive. The drive then creates a unit attention condition for all initiators.

Abort Tag ($0D_H$): Tells the target to abort the current I/O process without any ending message, status, or sense data, though the data on the disc may have been modified. The target goes to Bus Free phase. No other I/O processes are affected. Mode parameters, extended contingent allegiance, and reservations are not affected.

Clear Queue ($0E_H$): Tells the target to abort the current I/O process without any ending message, status, or sense data, though the data on the disc may have been modified. The target goes to Bus Free phase. All other queued I/O processes, from all initiators for the specified LUN, are cleared. Unit Attention is set for any initiators having active or queued I/O processes for the specified LUN with an additional sense of commands cleared by another initiator.

Identify (80_H to FF_H): Establishes the physical connection between initiator and target:

- Sent by the initiator after Selection phase. If an initiator specifies an invalid LUN in the Identify message, the drive accepts the Identify message but rejects the next command. (See Section 5.2.2.)

- Sent by the target after Reselection phase. If sent during reconnection, an implied Restore Pointers message is performed by the initiator before completion of this message.

Bit	Function
7	Always set to one to distinguish Identify messages from the other messages.
6	The initiator sets this bit to one to tell the drive that it can disconnect and reconnect. When set to zero, the drive cannot disconnect.
5 - 3	Reserved
2 - 0	Specify a logical unit number in a target. Only 0 supported.

4.5.3 Extended Messages

Extended messages are implemented as listed below. The drive responds with a Message Reject message after any unsupported extended message is received.

Byte	Value	Description
0	01_H	Extended Message
1	03_H	Extended Message Length
2	01_H	Synchronous Data Transfer Request Code
3	m	Transfer Period (nsec) = 4m
4	x	REQ/ACK offset

4.5.3.1 Synchronous Data Transfer Request Message

A pair of synchronous data transfer request messages are exchanged between an initiator and a target whenever a SCSI device capable of synchronous data transfer recognizes that it has not communicated with the other SCSI device since receiving the last hard reset condition or a bus device reset message. The SCSI devices may also exchange messages to establish synchronous data transfer upon request. Any problem that precludes the successful exchange of the synchronous data transfer request message shall cause the initiator and drive to default to asynchronous data transfers.

The message exchange establishes the transfer period and the REQ/ACK offset:

- The transfer period is the minimum time between leading edges of successive REQ and ACK pulses. This value, times four nsec, is the data transfer period. The minimum value supported by the drive is 25 (100 nsec).
- The REQ/ACK offset is the maximum number of REQ pulses that may be outstanding before its corresponding ACK pulse is received at the target. A REQ/ACK offset value of zero indicates asynchronous mode. The maximum offset supported by the drive is six.

If the initiator recognizes that negotiation is required, it asserts ATN and sends a synchronous data transfer request message indicating a REQ/ACK offset and minimum transfer period. The REQ/ACK offset is chosen to prevent initiator buffer overflows, while the minimum transfer period is chosen to meet the data handling requirements of the initiator. The drive responds with a REQ/ACK offset of zero, which indicates an asynchronous transfer only.

5.0 SCSI Commands

This section defines the SCSI command structure and describes a typical SCSI bus procedure involving a command, status return, and message interchange.

The command structure provides a contiguous set of logical blocks of data to be transferred across the interface. The number of logical data blocks to be transferred are defined in the command. Initiator commands to the drive are structured in accordance with the requirements imposed by the drive's physical characteristics. These physical characteristics are reported to the initiator in response to an Inquiry command or Mode Sense command.

A single command may transfer one or more logical blocks of data. The drive may disconnect from the SCSI bus to allow activity by other SCSI devices while the drive performs its own operations.

When the drive has successfully or unsuccessfully completed a command, it returns a status byte to the initiator. Because most error and exception conditions cannot be adequately described with a single status byte, the drive issues the Check Condition status byte, which indicates that additional information is available. The initiator may issue a Request Sense command to request additional information as part of the Data-In phase of the Request Sense command.

5.1 Command Implementation Requirements

The first byte of any SCSI command contains an operation code as defined in this document. Three bits (bits 7 - 5) of the second byte of each SCSI command specify the logical unit if it is not specified using the Identify Message command. (See Section 4.5.2.) Only a logical unit number of zero is valid for the drive. The last byte of all SCSI commands always contains a control byte as defined in Section 5.2.6.

5.1.1 Reserved Addresses

Reserved bits, bytes, fields, and code values are set aside for future use. A reserved bit, field, or byte is always set to zero. If the drive receives a reserved code value other than zero, it terminates the command with a Check Condition status.

5.1.2 Unit Attention Condition

The Unit Attention condition begins for each initiator if a power-on sequence occurs, if there is an internally generated reset (caused by a power failure), if the drive is reset by a bus device reset message or a hard reset condition, if a microcode download operation occurs, or if one or more Mode Select parameters affecting the initiator were changed by another initiator or if spindle synchronization is enabled and the spindle goes into or out of synchronization. The Unit Attention condition persists for each initiator until that initiator clears the condition.

If an Inquiry command is received from an initiator with a pending Unit Attention condition before the drive reports the Unit Attention Check Condition status, the drive performs the command and does not clear the Unit Attention condition for that initiator. If a Request Sense command is received from an initiator with a pending Unit Attention condition, the drive discards any pending sense data, reports the Unit Attention conditions and then clears the Unit Attention condition for that initiator.

If an initiator issues a command other than Inquiry or Request Sense while a Unit Attention condition exists for that initiator, the drive shall not perform the command and shall report Check Condition status and set up the sense data to report the Unit Attention Check Condition for an anticipated Request Sense command. If a Request Sense command is issued next, the Unit Attention condition will be reported in the sense data. If a command other than Request Sense is issued following the reporting of the Unit Attention Check Condition, the drive shall perform the command and return the appropriate status for the completion of the command. The Unit Attention condition sense data for that initiator is cleared or overwritten by the results of the last command causing the Unit Attention condition to be lost.

5.1.3 Command Queuing

The drive supports untagged command queuing which means the drive is capable of accepting and queuing one command from each initiator for up to seven possible initiators. When commands are queued, after the drive is selected it will accept the message and command bytes, send a Disconnect message, go to Bus Free phase, and continue command execution. If the command cannot be queued, the drive will allow itself to be selected and will accept the command bytes for this command. The drive will then go to the Status Phase and send Busy status back to the initiator.

Command queuing can be done only for initiators that support Arbitration and Reselection phases, send an Identify message after Selection, and allow disconnection. If the initiator does not support these options, the drive will allow itself to be selected and will accept the command bytes for a new command if the command queue is full. It will then go to the Status phase and send Busy status to the initiator (see Section 5.5). After a Command Complete message and going to Bus Free phase, the drives resumes execution of its current command. An initiator that received Busy status in this manner will have to resend the command later in order to have it executed.

All commands that are queued are executed in the order received, unless a hard Reset, a Power-on Reset, or a Bus Device Reset message is received. In these cases, all queued commands are cleared. Some commands are cleared when a Clear Queue or Abort message is received. Refer to the descriptions for these messages. In all cases, no status is sent to the initiator.

5.2 Command Descriptor Block (CDB)

A request by an initiator to a drive is performed by sending a Command Descriptor Block (CDB) to the drive. For several commands, the request is accompanied by a list of parameters sent during the Data Out phase. See the specific commands for detailed information.

The Command Descriptor Block always has an operation code as the first byte of the command. This is followed by a logical unit number, command parameters (if any), and a control byte.

For all commands, if there is an invalid parameter in the Command Descriptor Block, the drive shall terminate the command without altering the medium.

The format description for the Command Descriptor Block is shown in the tables that follow.

5.2.1 Operation Code

The operation code of the Command Descriptor Block has a group code field and a command code field. The three-bit group code field provides for eight groups of command codes. The five-bit command code field provides for thirty-two command codes in each group. Thus, a total of 256 possible operation codes exist. Operation codes are defined in Section 6.1.

5.2.1.1 Operation Code Format for CDB Byte 0

Bit Byte	7	6	5	4	3	2	1	0
0	Group Code			Command Code				

The group code specifies one of the following groups:

- Group 0 - Six-byte commands
- Group 1 - Ten-byte commands

These groups are described in the sections that follow.

5.2.1.2 Typical 6-Byte Command Descriptor Block

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code							
1	Logical Unit No. (0)			Logical Block Address (if req.) (MSB)				
2	Logical Block Address (if required)							
3	Logical Block Address (if required) (LSB)							
4	Transfer Length (if required)							
5	Control Byte							

5.2.1.3 Typical 10-Byte Command Descriptor Block

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code							
1	Logical Unit No. (0)			Reserved (0)				RelAdr (0)
2	Logical Block Address (if required) (MSB)							
3	Logical Block Address (if required)							
4	Logical Block Address (if required)							
5	Logical Block Address (if required) (LSB)							
6	Reserved							
7	Transfer Length (if required) (MSB)							
8	Transfer Length (if required) (LSB)							
9	Control Byte							

5.2.2 Logical Unit Number (LUN)

The logical unit number (LUN) addresses one of up to eight physical or virtual devices attached to a target. The only valid LUN for the drive is zero.

The LUN in the CDB is provided for systems that do not implement the Identify message. If an Identify message is sent to the drive, the drive uses the LUN specified in this message. In this case, the drive ignores the LUN specified within the command descriptor block. The drive rejects commands that select an invalid LUN (except Request Sense and Inquiry) by requesting and accepting the command bytes, then going to Status phase and sending Check Condition status. Note that the LUN is sent in the LUN field of a CDB (if no Identify message has been received for this selection) or by the LUN field of an Identify message.

Request Sense commands selecting an invalid LUN receives a sense data block with the Illegal Request Sense Key and an Invalid LUN Error Code. Inquiry commands return inquiry data with the peripheral device type field set to logical unit not present ($7F_H$). Request Sense and Inquiry commands do not send Check Condition status in response to an invalid LUN selection.

5.2.3 Logical Block Address

The Logical Block Address on logical units shall begin with block zero and be contiguous up to the last logical block on that logical unit.

Group 0 CDBs contain 21-bit logical block addresses. Group 1 CDBs contain 32-bit logical block addresses.

The Logical Block concept implies that the initiator and target shall have previously established the number of data bytes per logical block. This may be established through the use of the Read Capacity command or the Mode Sense command, or by prior arrangement.

The maximum Logical Block Address which is accessible by the initiator, is defined in the Read Capacity data. See Section 6.2.1.

5.2.4 Relative Address Bit

The relative address bit of the Group 1 (and Group 5) commands is set to one to indicate that the logical block address portion of the command descriptor block is a two's complement displacement. This displacement is to be added to the logical block address last accessed on the drive to form a new logical block address for the current command. This feature is only available when linking commands.

5.2.5 Transfer Length

The transfer length specifies the amount of data to be transferred, usually the number of blocks. For several commands, the transfer length indicates the requested number of bytes to be sent as defined in the command description. For these commands the transfer length field may be identified by a different name. See the following descriptions and the individual command descriptions for further information.

Commands that use one byte for transfer length allow up to 256 blocks of data to be transferred by one command. A transfer length value of 1 to 255 indicates the number of blocks that shall be transferred. A value of zero indicates 256 blocks.

Commands that use two bytes for transfer length allow up to 65,535 blocks of data to be transferred by one command. In this case, a transfer length of zero indicates that no data transfer shall take place. A value of 1 to 65,535 indicates the number of blocks that shall be transferred.

For several commands, more than two bytes are allocated for transfer length. Refer to the specific command description for further information.

The transfer length of the commands that are used to send a list of parameters to a drive is called the parameter list length. The parameter list length specifies the number of bytes sent during the Data Out phase.

The transfer length of the commands (for example, Request Sense, Inquiry, Mode Sense) used to return sense data to an initiator is called the allocation length. The allocation length specifies the number of bytes that the initiator has allocated for returned data. The drive terminates the Data In phase when allocation length bytes have been transferred or when all available data has been transferred to the initiator, whichever is less.

The Request Sense command is an exception. An allocation length of zero means four bytes are to be transferred. See Mode Sense and Mode Select commands.

5.2.6 Control Byte

The control byte is the last byte of every command descriptor block. The control byte is described in the table below.

Bit	Description
7-2	Reserved = 0
1	Flag bit: If the link bit is zero, the flag bit must be zero. If the link bit is one, and if the command terminates successfully, the drive sends the Linked Command Complete message if the flag bit is zero, or the Linked Command Complete with Flag message if the flag bit is one.
0	Link bit: This bit is set to one to indicate that the initiator wants an automatic link to the next command when the current command is successfully completed. When a command has been successfully completed, the drive returns to intermediate status and sends one of the two messages defined by the flag bit.

5.3 Command Examples

Typical operations on the SCSI bus are described and illustrated in this section.

5.3.1 Single-Command Example

A typical operation on the SCSI bus is likely to include a single Read command to a peripheral device such as the drive. (See Figure 12.) The initiator has active pointers and a set of stored pointers representing active disconnected SCSI devices. (An initiator that does not have disconnect capability does not require stored pointers.)

The initiator sets up the active pointers for the operation requested, arbitrates for the SCSI bus, and selects the drive. Once this process is completed, the drive assumes control of the operation. The drive obtains the command from the initiator (in this case, a Read command). The drive interprets the command and executes it. For this command, the drive reads the requested data from the disc media and sends this data to the initiator. After sending the read data to the initiator, the drive sends a status byte to the initiator. To end the operation, the drive sends a Command Complete message to the initiator and then goes to the Bus Free state.

5.3.2 Disconnect Example

In the single command example, the length of time necessary to obtain the data may require a time-consuming physical seek. In order to improve system throughput, the drive may disconnect from the initiator, freeing the SCSI bus to allow other requests to be sent to other SCSI devices. To do this, the initiator must be reselectable and capable of restoring the pointers upon reconnection. The drive must be capable of arbitrating for the SCSI bus and reselecting the initiator. See Figure 13.

After the drive has received the Read command (and has determined that there will be a delay), it disconnects by sending a Disconnect message and releasing BSY (goes to Bus Free state).

When the data is ready to be transferred, the drive reconnects to the initiator, the initiator restores the pointers to their most recently saved values (which, in this case, are the initial values) and the drive continues (as in the single-command example) to finish the operation. The initiator recognizes that the operation is complete when a Command Complete message is received.

Figure 12: Single-Command Example

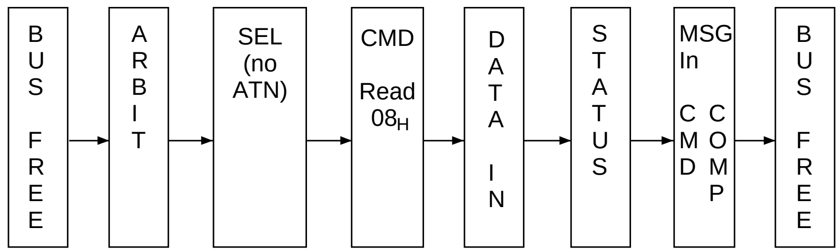
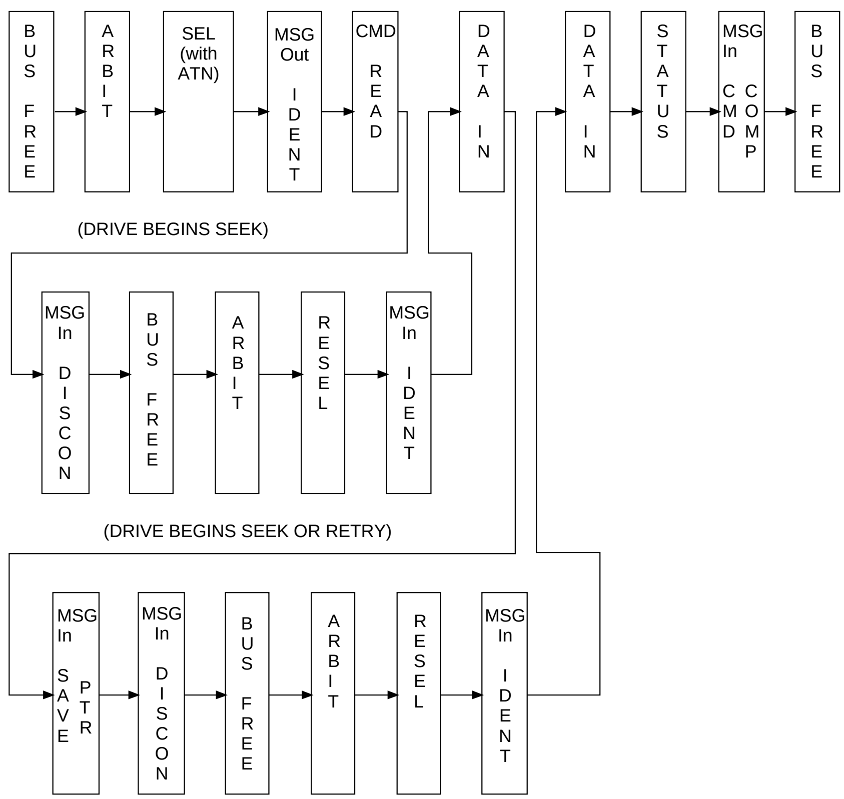


Figure 13: Disconnect Example



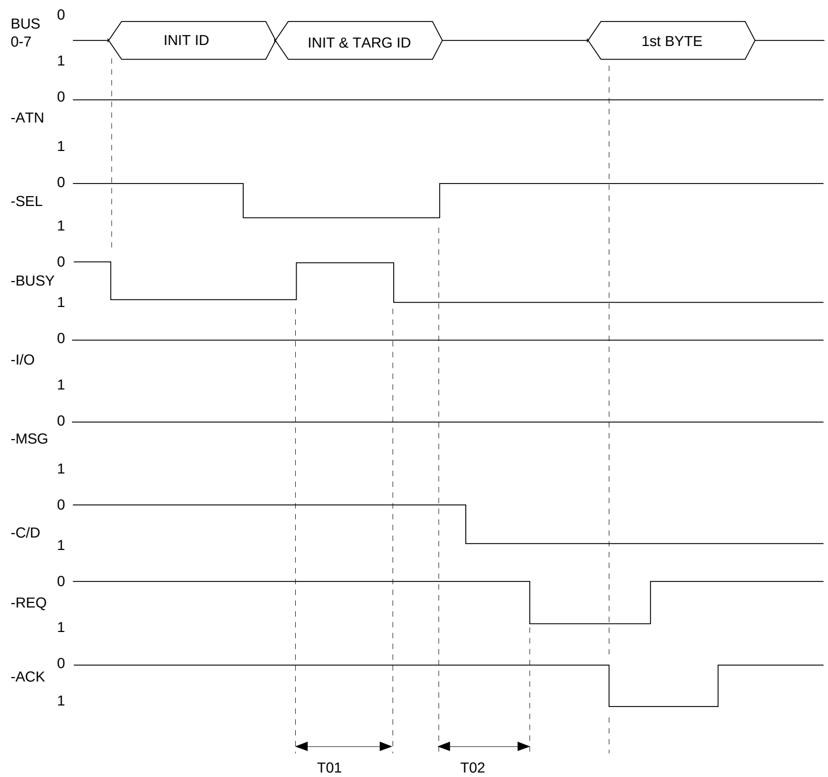
If the drive wishes to disconnect after transferring part of the data (e.g. while crossing a cylinder boundary), it may do so by sending a Save Data Pointer message and a Disconnect message to the initiator and then disconnecting. When reconnection is completed, the current data pointer is restored to its value immediately before the Save Data Pointer message.

On those occasions when an error or exception condition occurs and the drive elects to repeat the information transfer, the drive may repeat the transfer by issuing a Restore Pointers message or by disconnecting without issuing a Save Data Pointer message. When reconnection is completed, the most recently saved pointer values are restored.

5.4 Timing Examples

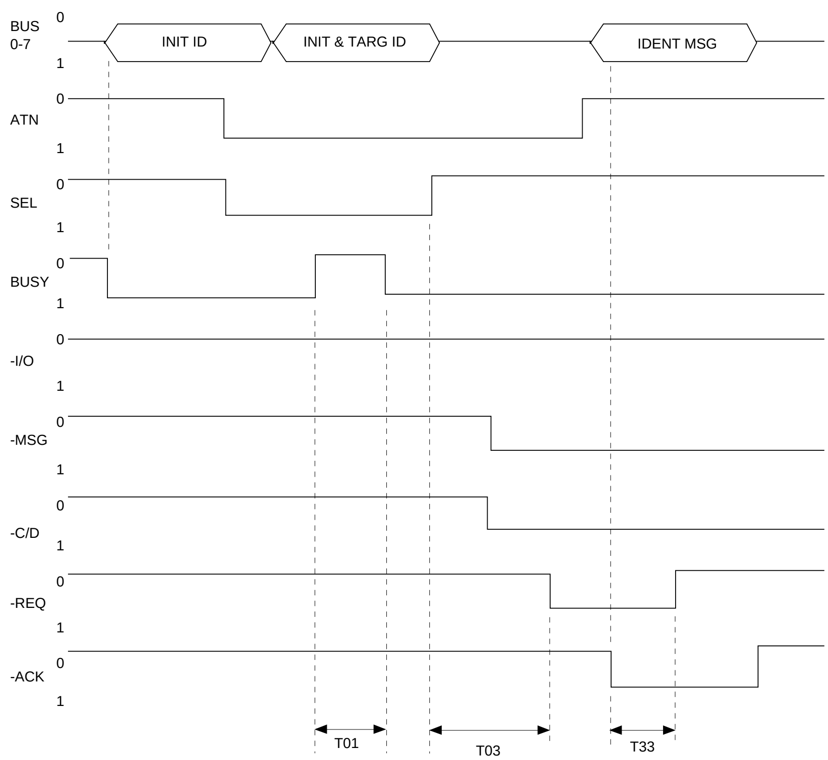
This section contains several example timing diagrams.

Figure 14: Arbitration, Selection (without ATN), and Command Phase



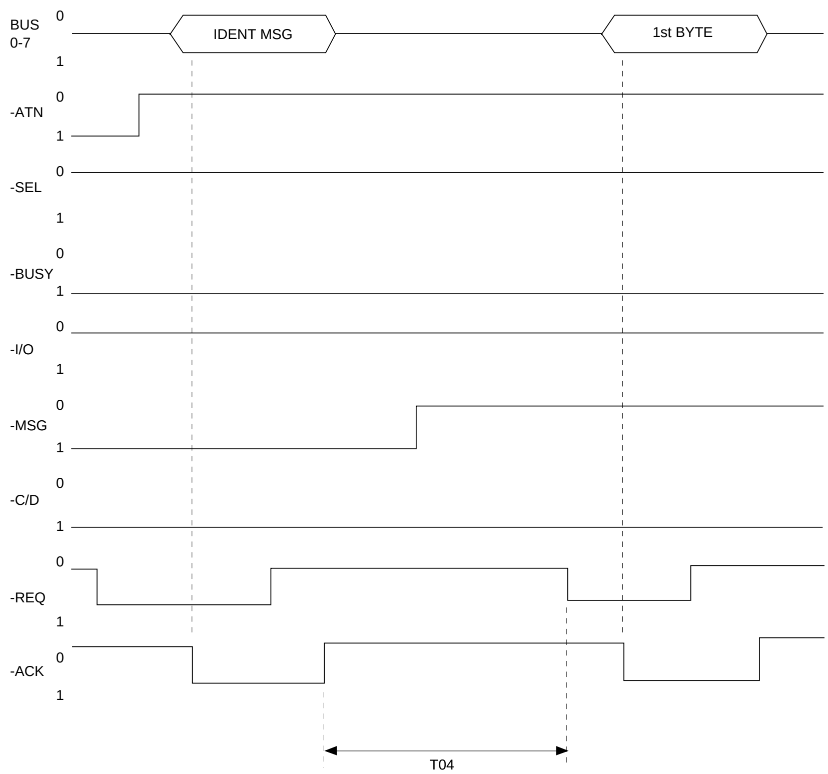
Description	Symbol	Typical	Max
Target Select Time (no Arbitration)	T00	<80 µsec	<250 msec
Target Select Time (with Arbitration)	T01	<90 µsec	<250 msec
Target Select to Command	T02	<150 µsec	—

Figure 15: Arbitration, Selection (with ATN), and Message Out



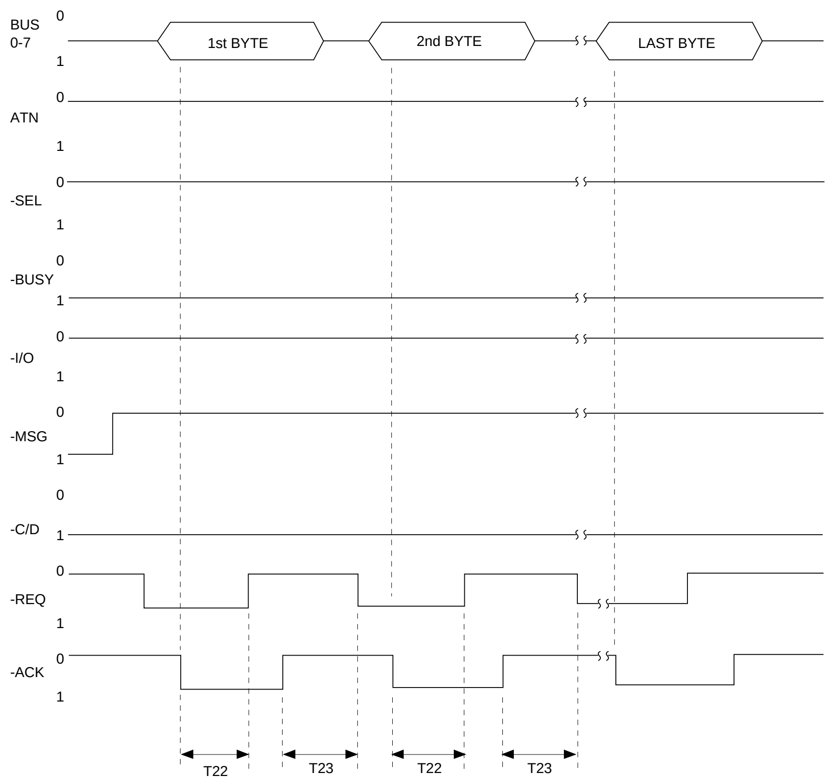
Description	Symbol	Typical	Max
Target Select Time (no Arbitration)	T00	<1.0 µsec	<250 µsec
Target Select Time (with Arbitration)	T01	<55 µsec	<250 µsec
Target Select to Message Out	T03	<125 µsec	—
Message Out Byte Transfer	T33	<0.1 µsec	0.15 µsec

Figure 16: Identify Message Out to Command Phase



Description	Symbol	Typical
Identify Message to Command	T04	<150 μsec

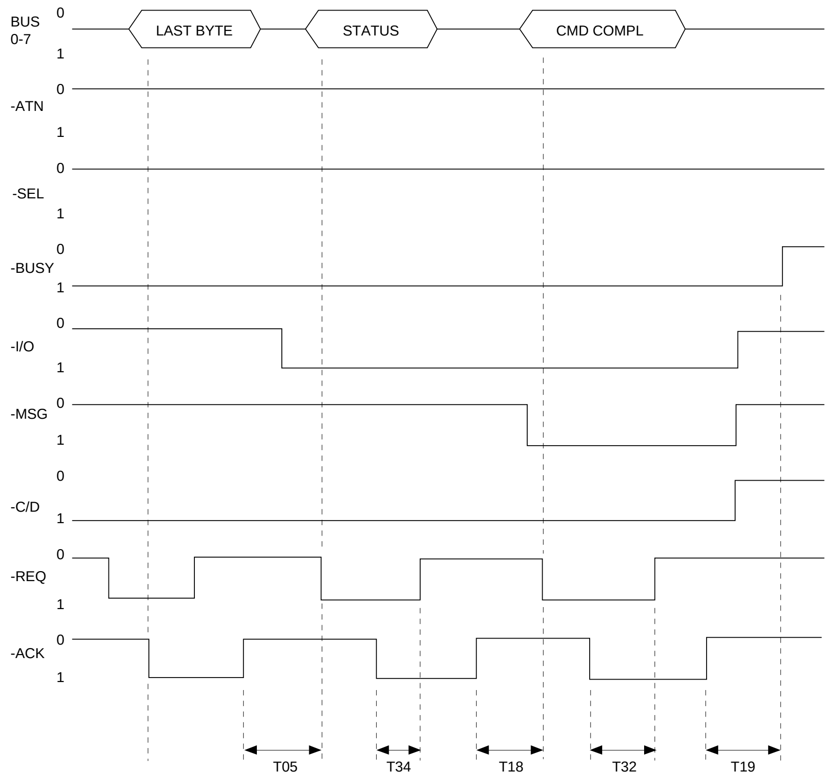
Figure 17: Command Descriptor Block Transfer



Description	Symbol	Typical	Max
Command Byte Transfer	T22	<0.08 µsec	0.15 µsec
Next Command Byte Access *	T23	<6.5 µsec	1.0 µsec

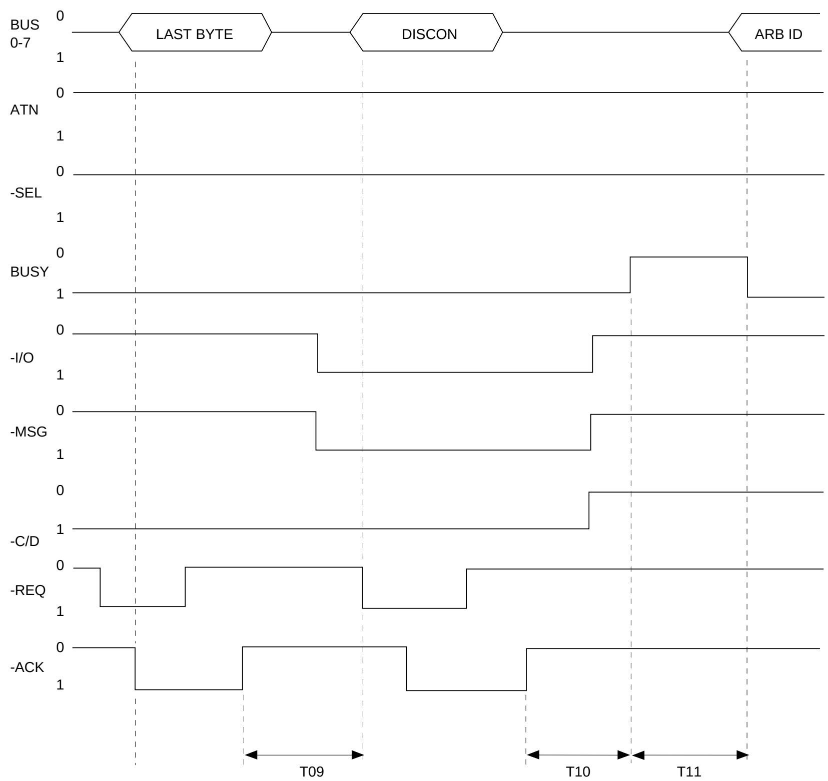
* T23 is used, except for Byte 7 of a 10-byte CDB. A 6-byte CDB requires less than 5 µsec for five T23 occurrences. A 10-byte CDB requires <110 µsec for 9 occurrences.

Figure 18: Command, Status, Command Complete Message, and Bus Phase



Description	Symbol	Typical	Max
Command to Status	T05	Command Dependent	
Status to Command Complete Message	T18	<150 µsec	—
Command Complete Message to Bus Free	T19	<100 µsec	—
Message In Byte Transfer	T32	<0.1 µsec	0.15 µsec
Status Byte Transfer	T34	<0.1 µsec	0.15 µsec

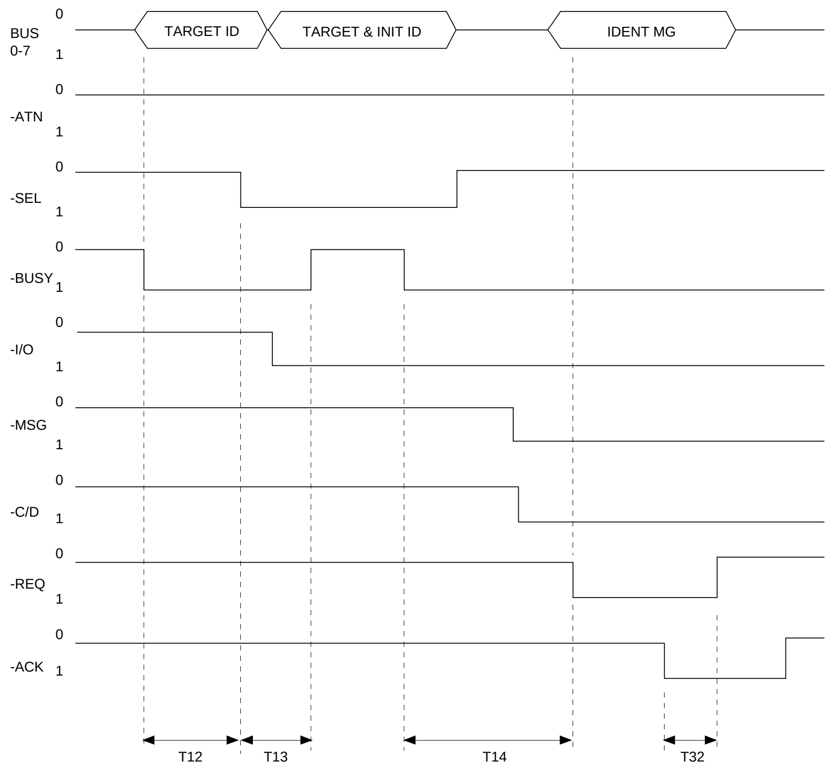
Figure 19: Last Command Byte, Disconnect Message, Bus Free, and Reselect



Description	Symbol	Typical	Max
Command to Disconnect Message	T09	Command Dependent	
Disconnect Message to Bus Free	T10	<100 µsec	—
Disconnect to Arbitration (for Reselect). Measures disconnected command overhead.	T11	Command Dependent	

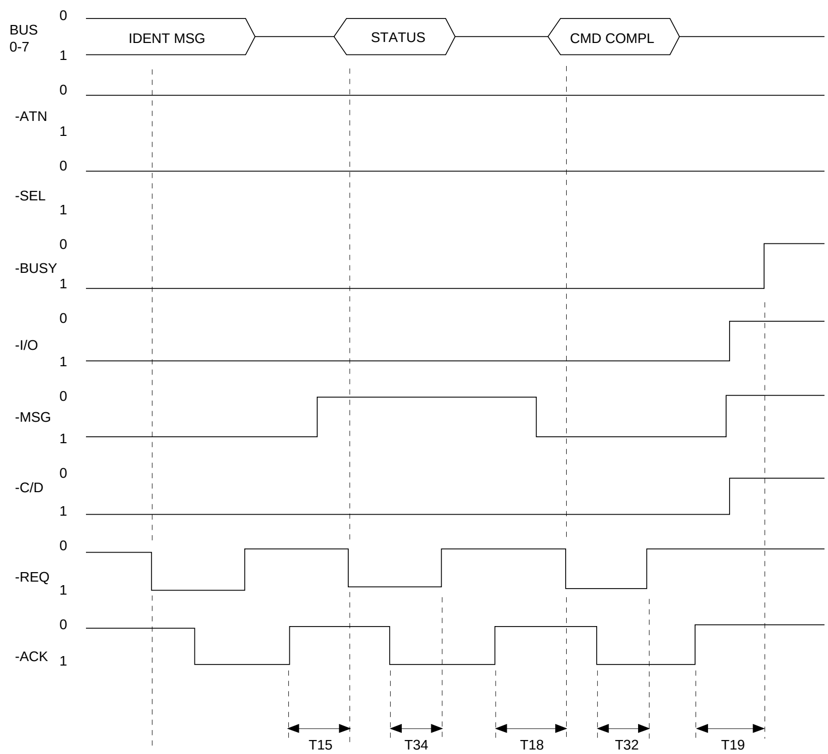
Note: To measure T11, there must be no other device contending for the SCSI bus.

Figure 20: Arbitration, Reselection, and Message In



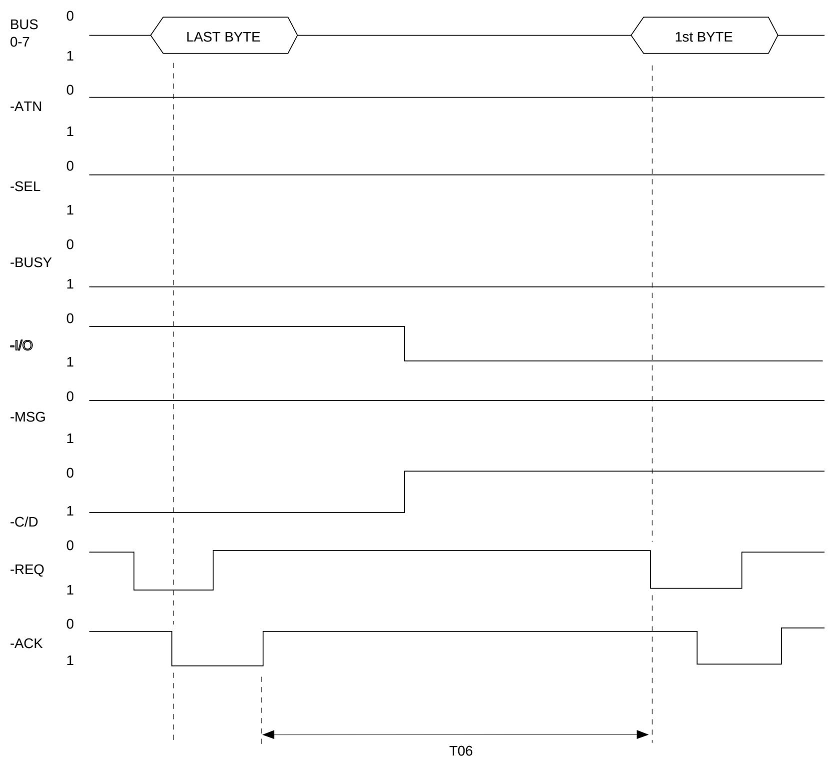
Description	Symbol	Typical	Max
Target Wins Arbitration (for Reselect)	T12	<6 µsec	—
Arbitration to Reselect	T13	<5 µsec	—
Reselect to Identify Message In	T14	<150 µsec	—
Message In Byte Transfer	T32	<0.1 µsec	0.15 µsec

Figure 21: Reselect, Status Phase, Command Complete, and Bus Free



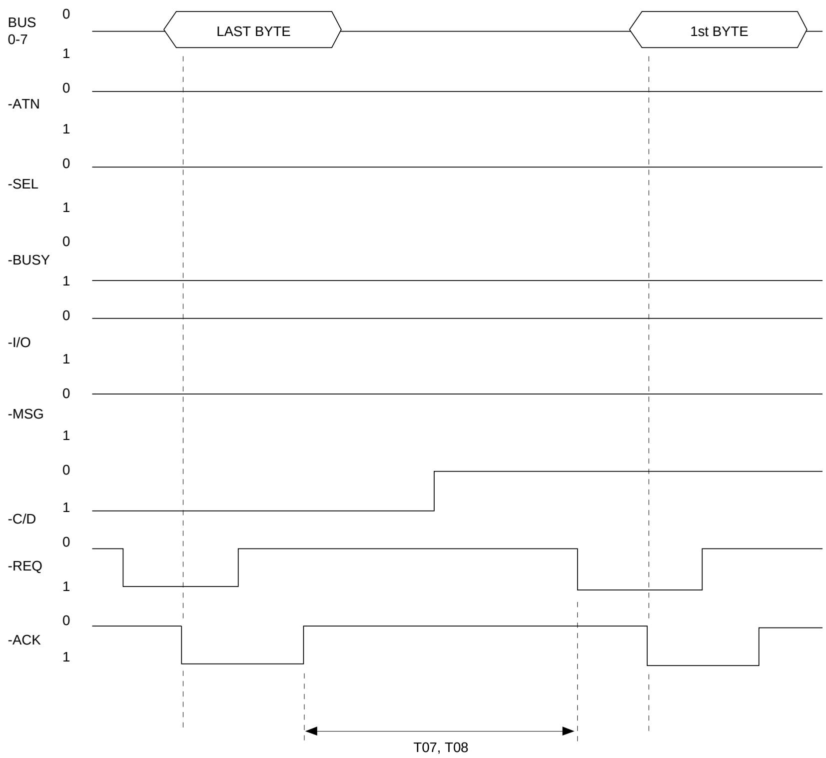
Description	Symbol	Typical	Max
Reselect Identify Message to Status	T15	<150 µsec	—
Status to Command Complete Message	T18	<150 µsec	—
Command Complete Message to Bus Free	T19	<100 µsec	—
Message In Byte Transfer	T32	<0.1 µsec	0.15 µsec
Status Byte Transfer	T34	<0.1 µsec	0.15 µsec

Figure 22: Last Command Byte to Data In Phase



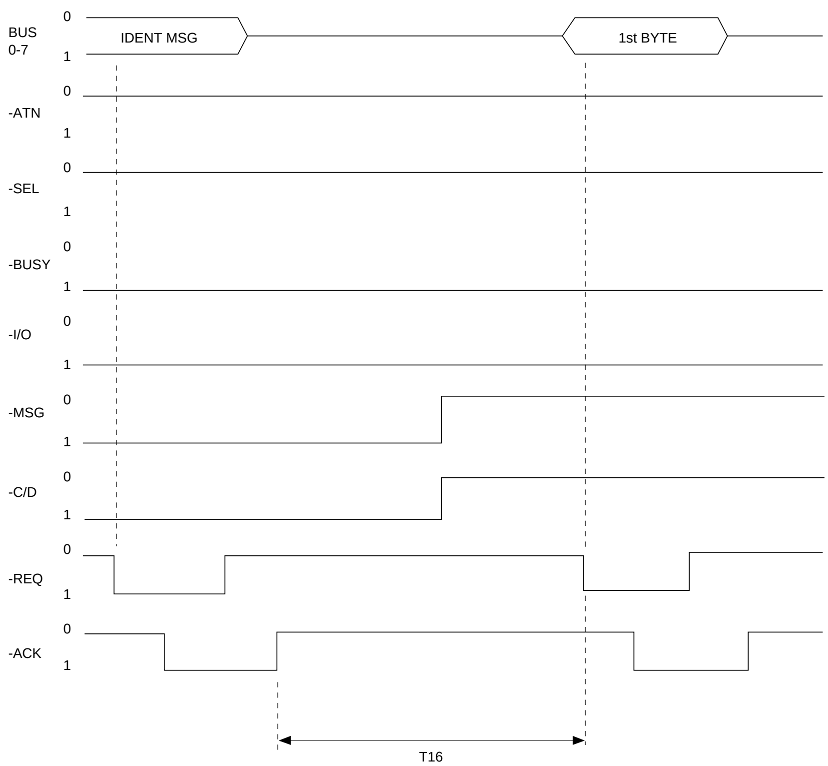
Description	Symbol	Typical	Max
Command to Data (Parameter In)	T06	Command Dependent	

Figure 23: Last Command Byte to Data Out Phase



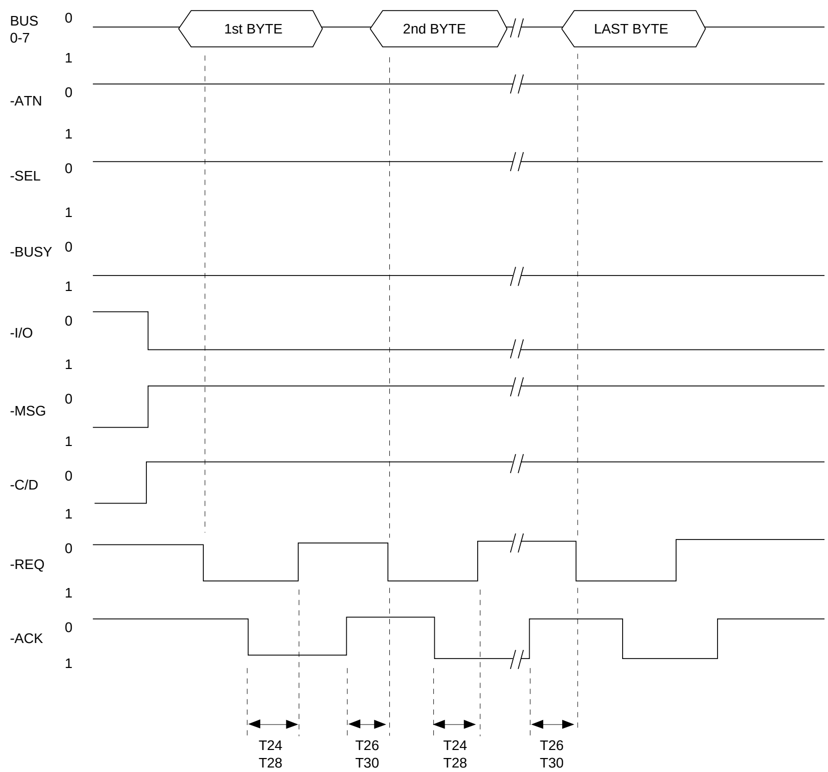
Description	Symbol	Typical	Max
Command to Data (Parameter Out)	T07	Command Dependent	
Command to Data (Write to Data Buffer)	T08	<500 µsec	1025 µsec

Figure 24: Reselect Identify Message to Data In Phase



Description	Symbol	Typical	Max
Reselect Identify Message to Data (Media)	T16	Command Dependent	

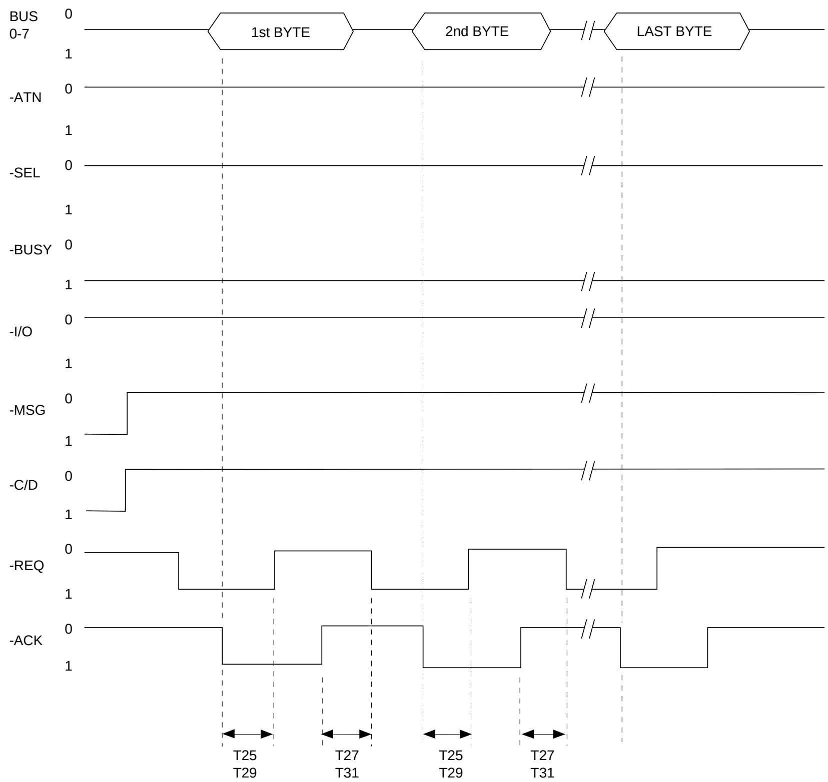
Figure 25: Data In Block Transfer



Description	Symbol	Typical	Max
Data in Byte Transfer (ASYNC)	T24	<0.1 µsec	0.2 µsec
Next Data in Byte Access (ASYNC)	T26	<0.8 µsec	1.5 µsec
Data in Byte Transfer (SYNC)	T28	< 60 nsec	100 nsec
Next Data in Byte Access (SYNC)	T30	<600 nsec	1.2 µsec

- Maximum SCSI asynchronous interface transfer rate is 1.5 Mbytes/sec. Therefore, the minimum time between two leading edges of Request is 667 nsec.
- Maximum SCSI synchronous interface transfer rate is 10.0 Mbytes/sec. Therefore, the minimum time between two leading edges of Request is 100 nsec.

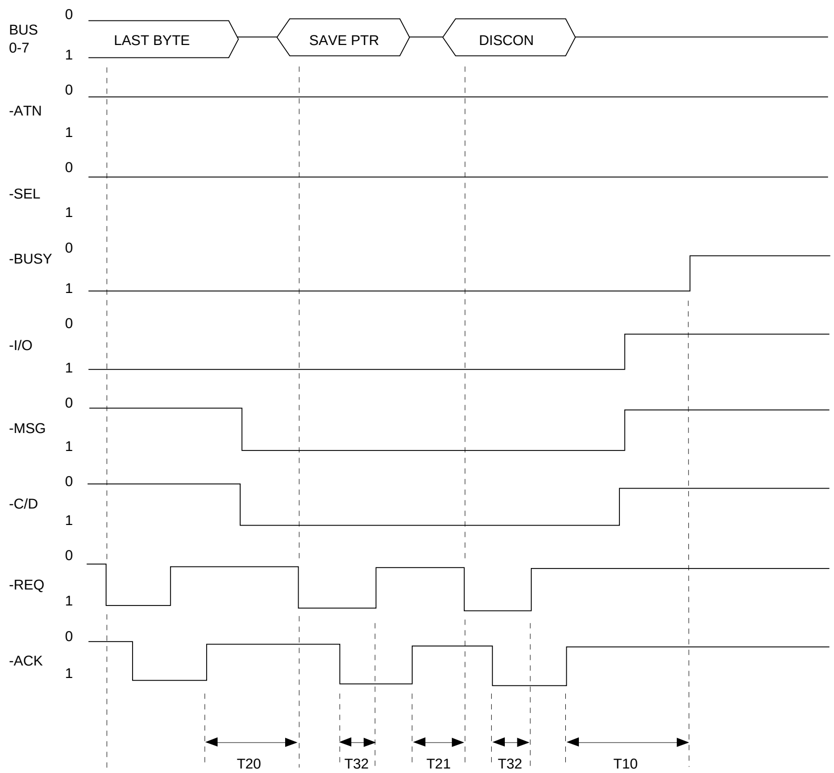
Figure 26: Data Out Block Transfer



Description	Symbol	Typical	Max
Data Out Byte Transfer (ASYNC)	T25	<0.1 µsec	0.2 µsec
Next Data Out Byte Access (ASYNC)	T27	<0.8 µsec	1.5 µsec
Data Out Byte Transfer (SYNC)	T29	< 60 nsec	100 nsec
Next Data Out Byte Access (SYNC)	T31	<600 nsec	1.2 µsec

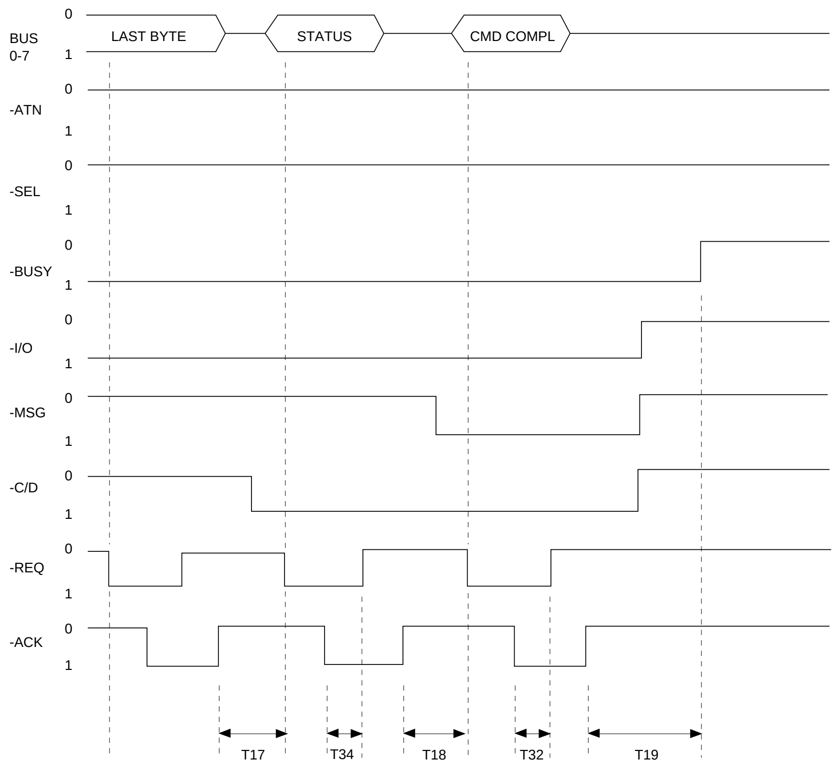
- Maximum SCSI asynchronous interface transfer rate is 1.5 Mbytes/sec. Therefore, the minimum time between two leading edges of Request is 667 nsec.
- Maximum SCSI synchronous interface transfer rate is 10.0 Mbytes/sec. Therefore, the minimum time between two leading edges of Request is 100 nsec.

Figure 27: Last Data Byte, Save Pointer Message and Disconnect Message



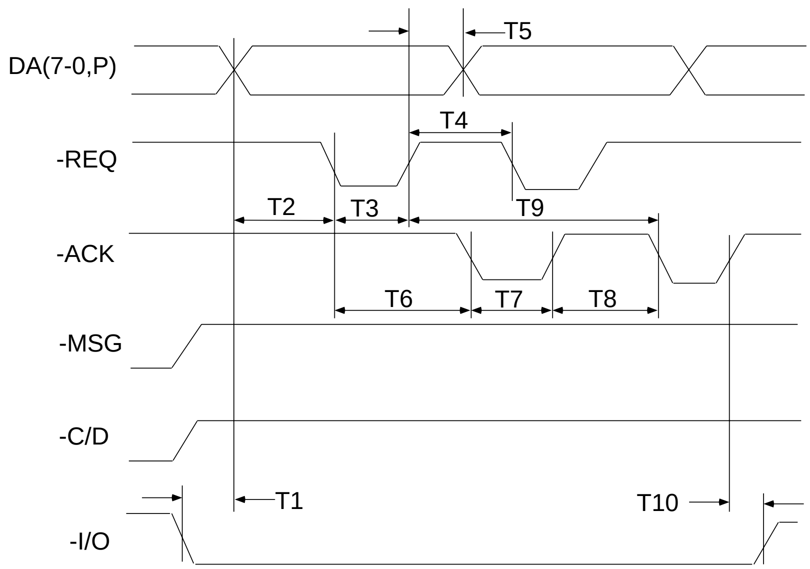
Description	Symbol	Typical	Max
Disconnect Message to Bus Free	T10	<100 µsec	—
Data to Save Data Pointer Message	T20	<175 µsec	—
Save Data Pointer Message to Disconnect Message	T21	<175 µsec	—
MSG IN Byte Transfer	T32	<0.1 µsec	0.15 µsec

Figure 28: Data In, Status Phase, Command Complete Message and Bus Free



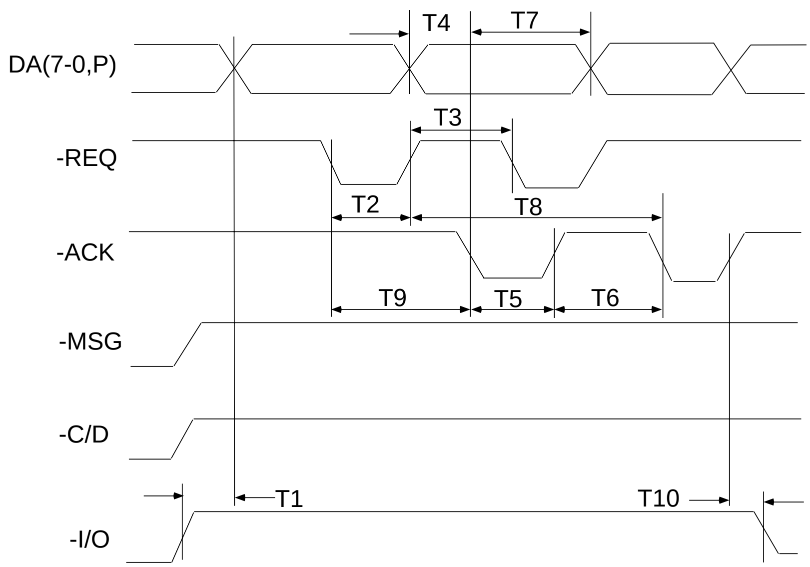
Description	Symbol	Typical	Max
Data to Status	T17	Command Dependent	
Status to Command Complete Message	T18	<150 µsec	—
Command Complete Message to Bus Free	T19	<100 µsec	—
Message In Byte Transfer	T32	<0.1 µsec	0.15 µsec
Status Byte Transfer	T34	<0.1 µsec	0.15 µsec

Figure 29: Synchronous Read Timing



Description	Symbol	Min
I/O Low to Data Bus Enable	T1	400 nsec
Data Bus Valid to -Req Low	T2	57.5 nsec
-REQ Assertion Period	T3	93.75 nsec
-REQ De-assertion Period	T4	93.75 nsec
-REQ High to Data Hold	T5	—
-REQ Low -ACK Low	T6	10 nsec
-ACK Assertion Period	T7	62.5 nsec
-ACK De-assertion Period	T8	62.5 nsec
-ACK Period	T9	187.5 nsec
Last -ACK Pulse High to Phase Change	T10	125 nsec

Figure 30: Synchronous Write Timing



Description	Symbol	Min	Max
I/O High to Data Bus Disable	T1	—	50 nsec
-REQ Assertion Period	T2	93.75 nsec	—
-REQ De-assertion Period	T3	93.75 nsec	—
Data Valid to -ACK Low	T4	—	—
-ACK Assertion Period	T5	62.5 nsec	—
-ACK De-assertion Period	T6	62.5 nsec	—
-ACK Low to Data Hold	T7	45 nsec	—
-ACK Period	T8	156.25 nsec	—
-REQ Low to -ACK Low	T9	10 nsec	—
Last -ACK Pulse High to Phase Change	T10	125 nsec	—

5.5 Status

When a command terminates successfully (i.e., the command is not terminated by an abort message, a bus device reset message, a hard reset, or a catastrophic reset condition), the drive sends the status byte to the initiator during the status phase. See Sections 5.5.1 and 5.5.2 below.

5.5.1 Status Byte

Bit Byte	7	6	5	4	3	2	1	0
0	Command Completion Status							

5.5.2 Command Completion Status Values

Status	Definition
00H	Good Status
02H	Check Condition
08_H	Busy Status
10_H	Intermediate
18_H	Reservation Conflict

Good Status: The drive has successfully completed execution of a command.

Check Condition: There is an error, exception, or abnormal condition causing sense data to be set. In response, the Request Sense command is issued to determine the nature of the condition.

Busy Status: The drive is busy, and therefore unable to accept a command from an initiator. The normal initiator recovery action retries the command later.

Intermediate: A command, other than the last command, in a series of linked commands, has successfully completed (i.e., the command did not terminate with check condition or reservation conflict status). If intermediate is not returned, the series of linked commands is terminated.

Reservation Conflict: Caused by a SCSI device attempting to access a logical unit reserved for another SCSI device.

6.0 Command Set

The drive supports Group 0, Group 1, and Group 7 commands for direct access devices.

6.1 Group 0 Command Descriptions

The implemented Group 0 commands are listed below.

Operation Code	Command Name
00_H	Test Unit Ready
01_H	Rezero Unit
03_H	Request Sense
04_H	Format Unit
07_H	Reassign Blocks
08_H	Read
$0A_H$	Write
$0B_H$	Seek
12_H	Inquiry
15_H	Mode Select
16_H	Reserve
17_H	Release
$1A_H$	Mode Sense
$1B_H$	Start/Stop Unit
$1C_H$	Receive Diagnostic Results
$1D_H$	Send Diagnostic

6.1.1 Test Unit Ready (00_H)

The Test Unit Ready command verifies that the logical unit is ready. This is not a request for a self test. If the logical unit accepts an appropriate medium access command without returning a Check Condition status, the drive returns a Good status. The only valid logical unit number is zero.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	0	0	0
1	LUN = 0			0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	Flag	Link

6.1.2 Rezero Unit Command (01_H)

The Rezero Unit command requests that the drive set its logical block address to zero and return the disc drive read/write heads to the track (or cylinder) containing Logical Block Zero. This command is implemented for a logical unit number of zero. This command is intended for systems that disable retries and the initiator performs error recovery. It is longer than a seek to logical block address zero and should be utilized if seek errors are encountered.

For systems that support disconnection, the drive disconnects when this command is received.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	1
1	LUN = 0			0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	Flag	Link

6.1.3 Request Sense Command (03_H)

The Request Sense command requests that the drive transfer sense data to the initiator in the Extended Sense Data Format, shown below. The sense data is valid for a Check Condition status returned on the previous command. This sense data is saved for the initiator until:

- The initiator requests the sense data using the Request Sense command, or
- Another command is received for the same logical unit from the initiator that issued the command resulting in the Check Condition status.

Sense data is cleared upon receipt of any subsequent command to the logical unit from the initiator receiving the Check Condition status.

If an error occurs during a Request Sense command, the drive sends a Check Condition only if the error was a fatal error. For example:

- The drive receives a nonzero reserved bit in the CDB.
- An unrecovered parity error occurs on the Data Bus.
- A malfunction prevents return of sense data.

If any nonfatal error occurs during execution of Request Sense, the drive returns sense data with Good status. Following a fatal error on a Request Sense command, sense data may be invalid.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	0	1	1
1	LUN = 0			0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	Allocation Length (in bytes)							
5	0	0	0	0	0	0	Flag	Link

The **Allocation Length** specifies the number of bytes the initiator has allocated for returned sense data. The Allocation Length should be at least 22 bytes for the initiator to receive all of the sense data. Any other value indicates the maximum number of bytes to be transferred. The drive terminates the Data In phase when Allocation Length bytes have been transferred or when all available sense data has been transferred to the initiator, which ever is less. If the Allocation Length is zero, 4 bytes of sense data are returned in Extended Sense Data Format. (Sense data is always returned in Extended Sense Data Format.)

6.1.3.1 Extended Sense Data Format

The drive can send up to 22 bytes of extended sense data, and will send 22 bytes if the allocation length of the Request Sense command is equal to or greater than 22 bytes. Otherwise, the number of bytes specified by the allocation length is sent. The Extended Sense Data Format is shown below.

Bit / Byte	7	6	5	4	3	2	1	0
0	Valid Bit ①	Error Class ②			Extended Sense Data Format ③			
1	0	0	0	0	0	0	0	0
2	0	0	0	ILI ④	Sense Key ⑤			
3 - 6	Information Bytes (3 = MSB, 6 = LSB) ⑥							
7	Additional Sense Length ⑦							
8 - 11	Reserved (must be 0)							
12	Additional Sense Code ⑧							
13	Reserved = 0							
14	FRU Code ⑨							
15	SKSV⑩	Sense Key Specific						
16 - 17	Sense Key Specific							
18 - 22	Product Unique Sense Data ❶							

① When the **Valid** bit is 1, the Information bytes are valid, When the Validity bit is 0, the Information bytes are not valid.

② The **Error Class** field is 111_{Binary}, which means that Extended Sense is being used in this command.

③ The **Extended Sense Data Format** field contains 0000_{Binary}. Byte 12 has error codes for Extended Sense.

④ An **Incorrect Length Indicator** (ILI) bit of one indicates that the requested logical block length did not match the logical block length of the data on the medium. This bit may be set with a Read Long or Write Long command.

⑤ The **Sense Key** indicates nine general error categories. These are listed in Section 6.1.3.2. The code given in Byte 12 provides additional clarification of errors.

⑥ When the Valid bit is 1, the **Information Bytes** contain the unsigned Logical Block Address of the current logical block associated with the Sense Key. For example, if the Sense Key is Media Error, the Information Bytes contain the Logical Block Address of the block in error.

⑦ The **Additional Sense Length** specifies that additional sense bytes are to follow. This is limited to a maximum of $0E_H$ additional bytes. If the Allocation Length of the Command Descriptor Block is too small to accommodate all of the additional sense bytes, the Additional Sense Length is not adjusted to reflect the truncation.

⑧ The **Additional Sense Code** provides further detail of errors and exceptions whenever the Sense Key is valid. The additional sense codes are defined in Section 6.1.3.3.

⑨ The **FRU (Field Replaceable Unit) Code** is reserved for field service use only.

⑩ The **SKSV (Sense-Key Specific Valid)** bit is set to zero, meaning the sense key specific fields are not used.

❶ When the Valid bit is one, the **Product-Unique Sense Data** bytes are valid. (When the Valid bit is zero, these bytes are not used.) These bytes contain the physical address of the information bytes.

6.1.3.2 Sense Key Descriptions

Sense Key	Description
0_H	**No Sense:** In the case of a successful command, no specific Sense Key information needs to be reported for the drive.
1_H	**Recovered Error:** Indicates the last command was completed successfully with some recovery action performed by the drive. **Note:** For some Mode settings, the last command may have terminated before completing.
2_H	**Not Ready:** Indicates the addressed logical unit cannot be accessed. Operator intervention may be required to correct this condition.
3_H	**Medium Error:** Indicates the command was terminated with a nonrecovered error condition, probably caused by a flaw in the medium or an error in the recorded data.
4_H	**Hardware Error:** Indicates the drive detected a nonrecoverable hardware failure while performing the command or during a self test. This includes SCSI interface parity error, controller failure, device failure, etc.
5_H	**Illegal Request:** Indicates an illegal parameter in the Command Descriptor Block or in the additional parameters supplied as data for some commands (Format Unit, Mode Select, etc). If the drive detects an invalid parameter in the Command Descriptor Block, it terminates the command without altering the medium. If the drive detects an invalid parameter in the additional parameters supplied as data, the drive may have already altered the medium.
6_H	**Unit Attention:** Indicates the drive may have been reset. See Section 5.1.2 for more details about the Unit Attention Condition.
B_H	**Aborted Command:** Indicates the drive aborted the command. The initiator may be able to recover by retrying.
E_H	**Miscompare:** Indicates that the source data did not match the data read from the medium.

6.1.3.3 Additional Sense Codes

Code	Description	Sense Keys
00_H	No Additional Information	No Sense
01_H	No Index/Address Mark Found Signal	Hardware Error
02_H	No Seek Complete	Hardware Error
03_H	Write Fault	Hardware or Recovered Error
04_H	Drive Not Ready	Not Ready or Recovered Error
06_H	No Track 0 Found	Hardware Error
10_H	ID CRC or ECC Error	Hardware, Medium or Recovered Error
11_H	Unrecovered Read Error	Medium or Recovered Error
12_H	No Address Mark (on Sync Byte) Found in ID Field	Medium or Recovered Error
13_H	No Address Mark (on Sync Byte) Found in Data field	Medium or Recovered Error
14_H	No Record Found	Medium or Recovered Error
15_H	Seek Positioning Error	Hardware, Medium or Recovered Error
17_H	Recovered Read Data with Target’s Read Retries (not with Ecc)	Recovered Error
18_H	Recovered Read Data with Target’s Error Correction (ECC) Applied	Recovered Error
19_H	Defect List Error	Medium Error
$1A_H$	Parameter Overrun	Illegal request
$1B_H$	Synchronous Transfer Error	Hardware Error
$1C_H$	Primary Defect List Not Found	Medium Error
$1D_H$	Compare Error	Miscompare
20_H	Invalid Command Operation Code	Illegal Request

Code	Description	Sense Keys
21_H	Illegal Logical Block Address. Address greater than the LBA returned by the Read Capacity data with PMI bit not set in CDB.	Illegal Request
24_H	Illegal Use of a Bit in CDB	Illegal Request
25_H	Invalid LUN	Illegal Request
26_H	Invalid Field in Parameter List	Illegal Request
29_H	Power-on, Reset, or Bus Device Reset	Unit Attention
$2A_H$	Mode Select Parameters Changed by another Initiator	Unit Attention
$2B_H$	Microcode Download	Unit Attention
31_H	Medium Format Corrupted	Medium Error
32_H	No Spare Defect Location Available	Medium Error
37_H	Rounded Parameter	Recovered Error
$3D_H$	Invalid Identify Message	Illegal Request
43_H	Message Reject Error	Aborted Command
44_H	Internal Controller Error	Hardware error or Not Ready
45_H	Selection/Reselection Failure	Aborted Command
47_H	SCSI Interface Bus Parity Error	Hardware Error
48_H	Initiator Detected Error	Aborted Command
49_H	Inappropriate or Illegal Message	Aborted Command
$4E_H$	Overlapped Commands Attempted	Aborted Command
80_H-$8F_H$	Correctable ECC (low nibble = length)	Recovered Error
90_H	Configuration Error	Hardware Error
$A0_H$	Self-test Error (Program ROM)	Hardware Error
$A1_H$	Self-test Error (Processor RAM)	Hardware Error
$A2_H$	Self-test Error (Buffer RAM)	Hardware Error
$A3_H$	Self-test Error (SCSI Protocol)	Hardware Error

Code	Description	Sense Keys
$A4_H$	Self-test Error (DMA)	Hardware Error
$A5_H$	Self-test Error (Disc Sequencer)	Hardware Error
$A6_H$	Self-test Error (Disc Sequencer RAM)	Hardware Error
$A7_H$	Self-test Error	Hardware Error
$A8_H$	Unable to Read/Write EEPROM	Hardware Error
$A9_H$	Read EEPROM Directory Checksum Error	Hardware Error
AA_H	Incompatible EEPROM Version #	Hardware Error
AB_H	Incompatible EEPROM Revision#	Hardware Error
AC_H	EEPROM Data Checksum Error	Hardware Error
AD_H	Unknown or Bad Parameters in EEPROM	Hardware Error
AE_H	Wrong HDA/PCBA has been Swapped	Hardware Error
AF_H	Wrong Discware	Software Error
$B0_H$	Servo Command Time Out	Hardware Error
$B1_H$	Servo Command Failure	Hardware Error
$B2_H$	Servo command Rejected	Hardware Error
$B3_H$	Servo Interface Failure	Hardware Error
$B4_H$	PLO Unlock	Hardware Error
$B5_H$	Internal Servo Error	Hardware Error
$B6_H$	Seek Recovery	Hardware Error
$C0_H$	Defect List Full	Medium Error
$C1_H$	Failure Writing G List	Hardware Error
$C2_H$	Extended EEPROM writable life cycle limit. The data integrity cannot be assured. Extended sense data byte 3 to 6 contain the accumulative write cycle counter. **Note:** If the specified EEPROM life span is exceeded, the drive may not function properly.	Hardware Error

Code	Description	Sense Keys
$C3_H$	Illegal Entry to “G” List	Medium Error
$C4_H$	Duplicate Entry to “G” List	Medium Error

6.1.4 Format Unit Command (04_H)

The Format Unit command ensures that the medium is formatted so all of the user-addressable data blocks can be accessed. In addition, the medium may be certified and control structures may be created for the management of the medium and defects.

The Format Unit command is rejected with Reservation Conflict status if the specified logical unit is reserved. Extent reservation is not supported. See Section 6.1.11.

This command is implemented for an LUN of zero, mandatory features, and a subset of the available optional features of the Common Command Set (CCS) specification and SCSI specification, as defined below. The drive allows an initiator to specify (or not specify) sectors to be reallocated during the format process.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1	0	0
1	Logical Unit No. (0)			Fmt Data ①	Cmp Lst ②	Defect List Format ③		
2	0	0	0	0	0	0	0	0
3	Interleave (MSB) ④							
4	Interleave (LSB) ④							
5	0	0	0	0	0	0	Flag	Link

① When the **Format Data (Fmt Data)** bit is one, format data is supplied during the Data Out phase. The defect list included with this data specifies the defects that will be entered into the defect map. The format of the defect list is determined by Defect List Format field. A FMTDATA bit of zero indicates that the Data Out phase will not occur (no defect data will be supplied by the initiator).

② When the **Complete List (Cmp Lst)** bit is one, the data supplied is to be the complete list of Grown defects. Any previous Grown or Certification defect data will be erased. The drive may add to this list as it formats the medium. The result is to purge any previous Grown or Certification defect list and to build a new defect list. A CmpLst bit of zero indicates the data supplied is in addition to the existing Grown defect list.

③ The **Defect List Format** field specifies additional information related to the defect list.

④ The **Interleave** field requests that logical blocks be related in a specific fashion to the physical blocks to facilitate speed matching. An interleave value of zero requests that the target use its default interleave. An interleave value of one requests that consecutive logical blocks be placed in consecutive physical order. Values of two or greater indicate that one or more (respectively) physical blocks separate consecutive logical blocks. The only acceptable interleave value is 1. (An interleave other than 0 defaults to an interleave of 1.)

The Read Look-Ahead function reads all of the data from the starting block address to buffer full, regardless of the block count specified in the Read command. All data from the starting Logical Block Address to the end of the physical track is read into the buffer regardless of the transfer length in the CDB specified. This data is available for subsequent sequential disc reads without having to access the disc medium. This increases performance without the need for an interleave during format. (See Section 6.1.6.)

The categories of flawed sectors are listed below:

- P (Primary Defect) Type: These sectors are identified at the time of shipment in a list of defects (permanent flaws) supplied by Seagate and stored on the disc in an area that is not directly accessible by the user. (This list may be referred to as an ETF List.) This defect list is not modified or changed by the drive (or initiator) after shipment.

- C (Certification Defect) Type: These sectors fail a Format Verify during the format function. The use of this defect list is controlled by Byte 1 of the defect list header described later in this section.

- D (Data Defect) Type: These sectors are identified in a list supplied to the target by the initiator during a Data Out phase of the current Format Unit command. The D List follows a four byte defect list header and is referred to as Defect Descriptor Bytes.

- G (Grown Defect) Type: These sectors contain media flaws and have been reallocated as a result of receiving a Reassign Blocks command, or certification defects (C type) reallocated during a previous Format Unit command, or Data Defects (D type) reallocated during a previous Format Unit command or defects that have been automatically reallocated by the drive. This G list is recorded on the media and may be referenced for the current (and subsequent) Format Unit commands. This G list does not include the P type defects.

6.1.4.1 Format Unit Parameter Definition

CDB Byte 1 Bits					Description
Fmt Data	Cmp Lst	Defect List Format			
		2	1	0	
0	X	X	X	X	Default Format: No Data Out phase occurs. The drive reallocates all sectors in the P list plus any sector that fails the Format Verify phase (C type flaws). Any previous G list is erased.
1	0	0	X	X	Format with G and no D: A 4-byte Defect List Header is sent by the initiator. No Defect Descriptors (D list) are sent by the initiator. All sectors are reallocated in the drives current G list.*
1	0	1	0	0	Format with G and D Bytes from Index.
1	0	1	0	1	Format with G and D physical sector.
1	1	0	X	X	Format without G or D: A 4-byte Defect List Header is sent by the initiator. No D list is sent by the initiator. The drive erases any previous G list.*
1	1	1	0	0	Format with D and without G. The initiator sends a 4-byte Defect List Header followed by a D list of defects to be reallocated. The D list is in the Bytes from Index format. Any previous G list is erased.*
1	1	1	0	1	Format with D and without G: The initiator sends a 4-byte Defect List Header followed by a D List of defects to be reallocated. The D list is in the Physical Sector format. (See Section 6.1.4.5.) Any previous G list is erased.*

* Byte one of the Defect List Header determines whether the P and C defects are reallocated. See Section 6.1.4.2.

The defect list shown below contains a four-byte header, followed by one or more defect descriptors. The Defect List Length in each table specifies the total length in bytes of the defect descriptors that follow. As shown below, the Defect List Length is equal to eight times the number of defect descriptors.

6.1.4.2 Defect List Header and Defect List

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	0	0	0
1	FOV	DPRY	DCRT	STPF	0	0	0	0
2	Defect List Length (MSB)							
3	Defect List Length (LSB)							
4 - n	Defect Descriptor Bytes							

The fields of the defect list headers are described in the table below.

6.1.4.3 Defect List Header Bit Interpretation

Function	Bit Interpretation
FOV	If one, the DPRY, DCRT and STFP bits are interpreted. If zero, the DPRY, DCRT and STFP bits are checked for zeros.
DPRY	If one, the defects described in the P list are not reallocated during formatting. This means existing reallocations of the P list will be cancelled and no new reallocations made during formatting. The P list is retained. If zero, the defects described in the P list will be reallocated during formatting. A check condition is sent in the status if the P list cannot be found.
DCRT	If one, a verify function will not be performed during formatting (thus no C list for this format will be created or reallocated). If zero, a verify function will be performed during formatting and any sector which fails the verify will be reallocated (i.e.; a C list will be created and these flaws reallocated).
STPF	If one, formatting is terminated if an error is encountered while accessing either the P or G defect list. If zero, formatting is not terminated if an error is encountered while accessing either the P or G defect list.
Defect List Length	The length of any following D list (Defect List Length) must be equal to 8 times the number of sectors to be reallocated.

6.1.4.4 Defect Descriptor: Bytes from Index

Byte	Description
0	Cylinder Number of Defect (MSB)
1	Cylinder Number of Defect
2	Cylinder Number of Defect (LSB)
3	Head Number of Defect
4	Defect Bytes from Index (MSB)
5	Defect Bytes from Index
6	Defect Bytes from Index
7	Defect Bytes from Index (LSB)

For defects to be specified in the Bytes from Index format, the Defect List Format field must be 100_{BINARY}.

Each defect descriptor for the Bytes from Index format specifies the beginning of a single-byte defect location on the medium. Each defect descriptor is comprised of the cylinder number of the defect, the head number of the defect, and the number of Bytes from Index to the defect location.

The defect descriptors must be in ascending order. In determining the ascending order, the cylinder number of the defect is the most significant part of the address and the Defect Bytes from Index is the least significant part of the address. A value for defect bytes from index of $FFFFFFFF_H$ (which means reassign the entire track) is illegal.

6.1.4.5 Defect Descriptor: Physical Sector Number

Byte	Description
0	Cylinder Number of Defect (MSB)
1	Cylinder Number of Defect
2	Cylinder Number of Defect (LSB)
3	Head Number of Defect
4	Defect Sector Number (MSB)
5	Defect Sector Number
6	Defect Sector Number
7	Defect Sector Number (LSB)

The information in this table is repeated for each defect. For defects to be specified in the physical sector format, the defect list format field must be 101_{BINARY}.

Each defect descriptor for the physical sector format specifies a sector size defect location comprised of the cylinder number of the defect, the head number of the defect, and the defect sector number.

The defect descriptors must be in ascending order. In determining the ascending order, the cylinder number of the defect is considered the most significant part of the address and the defect sector number is considered the least significant part of the address. A defect sector number of $FFFFFFFF_H$ (which means reassign the entire track) is illegal.

Note: The initiator cannot use any previously defined “C,” “G” or “D” lists if the sector size (block length) has been changed by the Mode Select command. See Section 6.1.10.

For systems that support disconnection, the drive disconnects while executing the Format Unit command.

6.1.5 Reassign Blocks Command (07_H)

The Reassign Blocks command requests that the target reassign defective logical blocks to an area on the logical unit reserved for this purpose. The logical unit number must be zero.

After sending the Reassign Blocks command, the initiator transfers a defect list containing the logical block addresses to be reassigned. The physical medium used for each logical block address is reassigned. The data contained in the logical blocks specified in the defect list is not preserved, but the data in all other logical blocks on the media is preserved. It is recommended that the initiator recover the data from the logical blocks to be reassigned before issuing this command. After completion of this command, the initiator can write the recovered data to the same logical block addresses.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1	1	1
1	Logical Unit No. (0)			0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	Flag	Link

A logical block can be repeatedly assigned to multiple physical addresses until there are no more spare locations available on the disc.

This command should be used by an initiator to immediately reallocate any block (sector) that requires the drive to recover data using ECC if the automatic reallocation feature is not enabled. See Section 6.1.10.

For systems which support disconnection, the drive will disconnect while executing this command.

The Reassign Blocks defect list contains a four-byte header followed by one or more Defect Descriptors. The length of each Defect Descriptor is four bytes.

6.1.5.1 Reassign Block Defect List

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	Defect List Length (MSB)							
3	Defect List Length (LSB)							
4 - n	Defect Descriptor Bytes							

Defect Descriptors

0	Defect Logical Block Address (MSB)
1	Defect Logical Block Address
2	Defect Logical Block Address
3	Defect Logical Block Address (LSB)

The Defect List Length specifies the total length in bytes of the Defect Descriptors that follow. The Defect List Length is equal to four times the number of Defect Descriptors.

The Defect Descriptor specifies a four-byte Defect Logical Block Address that contains the defect. The Defect Descriptors must be in ascending order.

If the logical unit has insufficient capacity to reassign all of the defective logical blocks, the command terminates with a Check Condition status and the Sense Key is set to Medium Error. The Logical Block Address of the first logical block not reassigned is returned in the information bytes of the Sense Data.

6.1.6 Read Command (08_H)

The Read command requests that the drive transfer data to the initiator.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	0	0	1	0	0	0
1	Logical Unit No. (0)			Logical Block Address (MSB)				
2	Logical Block Address							
3	Logical Block Address (LSB)							
4	Transfer Length							
5	0	0	0	0	0	0	Flag	Link

The **Logical Block Address** specifies the logical block at which the read operation will begin.

The **Transfer Length** specifies the number of contiguous logical blocks of data to be transferred. A Transfer Length of zero indicates that 256 logical blocks are to be transferred. Any other value indicates the number of logical blocks that will be transferred.

The data value most recently written in the addressed logical block will be returned.

Read data transfers with the initiator do not begin until at least one full sector of data is available in the data buffer. For multiple sector reads, the transfer of data will continue until the number of blocks specified in Byte 4 of the CDB has been read and transferred or until an unrecoverable error is detected.

Data transfer could stop if the option to stop on recovered error is selected by the Mode Select command. See Section 6.1.10.

For systems that support disconnection, the drive disconnects when a valid Read command is received unless a cache “hit” occurs. The point at which the drive will reconnect depends on the value of the Buffer Full Ratio Set in Page 2 of the Mode Select Data. (See Section 7.2.) After data transfer has been initiated with an initiator, the drive will not disconnect unless an internal error recovery procedure is required or the data transfer to an initiator will be interrupted for more than 1 millisecond.

The initiator must accept all data presented after sending this command until the drive sends Command Complete status during a Status phase.

Note: The drive may disconnect and reconnect while executing this command and the initiator may prematurely terminate this command by creating the Reset condition or by sending an Abort or Bus Device Reset message.

Sense Data is valid after this command is executed and Command Complete status is sent. If the address valid bit in the Sense Data is one, the Sense Data Logical Block Address (Information bytes) points to the last logical block accessed. If the address valid bit in the Sense Data is zero, the Sense Data Logical Block Address bytes are not valid.

The Read Look Ahead and/or caching function reads all data from the starting Logical Block Address to full buffer regardless of the transfer length in the CDB specified. This data is available for subsequent sequential disc reads without having to access the disc medium, a cache "hit."

If there is a reservation access conflict, this command terminates with a Reservation Conflict status and no data is read. See Section 6.1.11.

If any of the conditions listed in the table below occur, this command terminates with a Check Condition status. If Extended Sense is implemented, the Sense Key is set as indicated. This table does not include all of the conditions that can cause a Check Condition status.

6.1.6.1 Check Condition Status (Read Command)

Condition	Sense Key
Invalid Logical Block Address	Illegal Request (see note)
Target reset since last command from Initiator	Unit Attention
Unrecoverable read error	Medium Error
Recoverable read error	Recovered Error
Overrun or other error that might be resolved by repeating the command	Aborted Command

Note: The Extended Sense information byte is set to the Logical Block Address of the first invalid address.

6.1.7 Write Command ($0A_H$)

The Write command requests that the drive write the data transferred by the initiator to disc.

For a valid Write command, the drive requests write data before disconnecting, if disconnection is supported by the system, and before initiating any required seek function specified for this command.

For systems that support disconnection, the drive disconnects when any internal error recovery procedure is required, or the data transfer with the initiator is interrupted for more than 1 millisecond, or if the drive's internal data buffer is full. The point at which reconnection takes place after a disconnect depends on the value of the Buffer Empty Ratio in Page 2 of Mode Select Data. See Section 6.1.11.

The initiator must send requested write data to the drive until the drive sends completion status during a status phase or until the initiator Resets/Aborts the command.

Note: The drive may disconnect and reconnect while executing this command.

Sense Data is valid after this command is executed and Completion status is sent. See Section 6.1.6.

If any reservation access conflict exists, this command terminates with a Reservation Conflict status and no data will be written. See Section 6.1.11.

Bit / Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	1	0	1	0
1	LUN = 0			Logical Block Address (MSB)				
2	Logical Block Address							
3	Logical Block Address (LSB)							
4	Transfer Length							
5	0	0	0	0	0	0	Flag	Link

The **Logical Unit Number (LUN)** is always zero.

The **Logical Block Address** specifies the logical block where the write operation begins.

The **Transfer Length** specifies the number of contiguous logical blocks of data to be transferred. A transfer length of zero indicates that 256 logical blocks are to be transferred. Any other value indicates the number of logical blocks that will be transferred.

6.1.7.1 Check Condition Status (Write Command)

If any of the following conditions occur, the Write command terminates with a check condition status, and if extended sense is implemented, the sense key is set as indicated in the table below.

Condition	Sense Key
Invalid Logical Block Address	Illegal Request (see note)
Target reset since last command from this initiator	Unit Attention
Overrun or other error that might be resolved by repeating the command	Aborted Command

Note: The extended sense Information Bytes will be set to the Logical Block Address of the first invalid address. In this case, no data will be written on the logical unit.

6.1.8 Seek Command ($0B_H$)

The Seek command requests that the drive seek to the specified logical block address. This command is not often used because all commands involving data transfer to and from the media contain implied seeks. For systems that support disconnection, the drive disconnects when a valid Seek command is received.

Bit / Byte	7	6	5	4	3	2	1	0
0	0	0	0	0	1	0	1	1
1	Logical Unit No. (0)			Logical Block Address (MSB)				
2	Logical Block Address							
3	Logical Block Address (LSB)							
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	Flag	Link

For the maximum **Logical Block Address** that may be specified for a Seek command. See Section 6.2.1.

6.1.9 Inquiry Command (12_H)

The Inquiry command requests that information regarding parameters of the drive be sent to the initiator.

Inquiry data may be returned even though the drive is not ready for other commands. A Check Condition status is reported only when the requested inquiry data cannot be returned, for example, before receiving a Start Unit command required to start the spindle motor.

If an Inquiry command is received from an initiator with a pending Unit Attention condition (before the drive reports Check Condition status), the Inquiry command is performed and the Unit Attention condition is not cleared.

The Inquiry data contains a five-byte header, followed by the vendor unique parameters. The Inquiry command is implemented with the following drive-specific parameters. The data fields have the most significant byte returned first with no leading spaces.

The initiator should allocate 36_H bytes of inquiry data. The Inquiry command format is shown below. The inquiry data returned to the initiator is summarized in the tables below.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	1	0	0	1	0
1	Logical Unit No. (0)			0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	Allocation Length (in bytes)							
5	0	0	0	0	0	0	Flag	Link

The **Allocation Length** specifies the number of bytes the initiator has allocated for returned Inquiry data. An Allocation Length of zero indicates that no Inquiry data is to be transferred. This condition is not considered an error. Any other value indicates the maximum number of bytes to be transferred. The Data In phase is terminated by the drive when Allocation Length bytes have been transferred or when all available Inquiry data has been transferred to the initiator, whichever is less. The Initiator should have an allocation length of 36_H minimum in order to receive all of the Inquiry Data.

6.1.9.1 Inquiry Data Summary

Bit / Byte	7	6	5	4	3	2	1	0
0	Device Type							
1	RMB	Device Type Qualifier						
2	ISO Version		ECMA Version			ANSI Version		
3	0	0	0	0	Response Format			
4	Additional Length (31_H)							
5	Reserved (00_H)							
6	Reserved (00_H)							
7	Rel Adr	Wbus 32	Wbus 16	Sync	Linked	RSVD	Cmd Que	Sft Re
8 - 14	Vendor Identification: ASCII “SEAGATE”							
15	Blank Space: ASCII (20_H)							
16 - 22	Product Identification: ASCII “ST3283N”							
23 - 31	Blank Space: ASCII (20_H)							
32 - 35	Disc/PROM Rev. Level: ASCII							
36 - 39	Servo Revision Level: ASCII							
40 - 53	Unit Serial Number: ASCII							

6.1.9.2 Inquiry Data Summary Field Definitions

Field	Definition
Device Type	00_H indicates a Direct Access Device $7F_H$ indicates the Requested LUN is not present.
RMB	00_H indicates the media is not removable
Device Type Qualifier	00_H (default) indicates this field is not supported. User-programmable. See Mode Page 0, Byte 3.

Field	Definition
ISO Version	00_H indicates that the drive does not claim compliance with any ISO version.
ECMA Version	00_H indicates that the drive does not claim compliance with any ECMA version.
ANSI Version	01_H indicates compliance to the first release of the ANSI SCSI Standard (ANSI X3.131-1986)
Response Data Format	01_H indicates the format of the additional inquiry data (bytes 5 - 35).
Additional Length	31_H specifies the length of additional inquiry data. If the allocation length in the CDB is too small to transfer all of the Inquiry data, this additional length is not adjusted to reflect the truncation.
Relative Addressing Bit (RelAdr)	One means the device supports the relative addressing mode.
Wide Bus, 32-bit (Wbus32)	Zero means the device does not support 32-bit data transfers.
Wide Bus, 16-bit (Wbus16)	Zero means the drive does not support 16-bit transfers. (These drives only support 8-bit transfers.)
Synchronous Transfer Bit (Sync)	One means the device supports synchronous data transfer.
Linked Command Bit (Linked)	One means the device supports linked commands.
Command Queueing Bit (CmdQue)	Zero means the device does not support tagged command queueing.
Soft Reset (Sft Re)	Zero means the device responds to Reset with a hard reset.

6.1.10 Mode Select Command (15_H)

The Mode Select command provides a means for the initiator to specify medium, logical unit, or peripheral device parameters to the drive. The Logical Unit number must be zero.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	0	1	0	1	0	1
1	Logical Unit No. (0)			PF = 1	0	0	0	SP
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	Parameter List Length (in bytes)							
5	0	0	0	0	0	0	Flag	Link

The **Page Format (PF)** bit is always set to one. Therefore, the data sent by the initiator after the mode select Header and Block Descriptors (if any) complies with the Page Format.

When the **Save Mode Parameters (SP)** bit is one, the drive saves the savable pages. Pages 3 and 4 are saved only after a Format command, so they cannot be saved immediately by the Mode Select command. The drive must update the current mode values with parameters included with this command, save the current values of the savable parameters, and report Good status only after the save operation is completed. The saved parameters are not changed if an error is detected during the Mode Select command. When the SP bit is set to zero, the Saved parameter values will not be changed.

The **Parameter List Length** specifies the length in bytes of the mode select parameter list that are transferred during the data out phase. A parameter list length of zero means that no data is to be transferred. Any list length of zero, or other than those shown in Section 6.1.10.4, is considered an error by the drive.

The Mode Select parameter list contains a four-byte header, followed by a zero or one-block descriptor, followed by the pages of Mode Select Parameters.

6.1.10.1 Mode Select Parameter List

Each block descriptor specifies the media characteristics for all or part of a logical unit. Each block descriptor contains the density code, the number of blocks, and the block length.

The rest of the Mode Select parameters are organized into pages that group the parameters by function. The parameter definitions are the same as those described in the Mode Sense command.

Bit Byte	7	6	5	4	3	2	1	0
0	Reserved (0)							
1	Medium Type (0)							
2	Reserved (0)							
3	Block Descriptor Length (0 or 8)							
	Block Descriptor							
0	Density Code (0)							
1	Number of Blocks MSB							
2	Number of Blocks							
3	Number of Blocks LSB							
4	Reserved (0)							
5	Block Length MSB							
6	Block Length							
7	Block Length LSB							
	Parameter Information							
8 - n	Mode Select Pages							

If the **Medium Type** field is 00_H (default), a direct access device is specified.

The **Block Descriptor Length** specifies the length, in bytes, of the block descriptor. It is equal to the number of bytes in the block descriptor (either 0 or 8) and does not include the page headers and mode parameters. A block descriptor length of zero means that no block descriptor is included in the parameter list. This condition is not considered an error.

If the **Density Code** is 00_H, the default density of the medium is specified.

The **Number Of Blocks** field specifies the number of logical blocks on the media that correspond to the density code and block length in the block descriptor.

The **Block Length** specifies the length in bytes of each logical block described by the block descriptor. The block length set to the desired sector size (512) before a format.

6.1.10.2 Page Descriptor Header

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

Each page of mode parameters begins with a two-byte page descriptor header. The page code identifies which page of mode parameters is being transferred. The page length indicates the number of additional bytes of mode parameters contained in this page. The number of additional bytes sent must always match the page length value.

The drive only verifies mode select data that is defined as changeable by the drive. The supported page codes are listed in Section 6.1.10.3.

6.1.10.3 Page Code Descriptions

For a description of all the pages listed below, see Section 7.

Page Code	Description
01_H	Error Recovery Page
02_H	Disconnect/Reconnect Page
03_H	Format Device Page
04_H	Rigid Disc Geometry Page
08_H	Caching Page (SCSI-3)
$0C_H$	Notch and Partition Page
$0D_H$	Power Condition Page
38_H	Cache Control Page
$3C_H$	Soft ID Page
00_H	Operating Page

The initiator issues a Mode Sense command requesting that the drive return all pages with changeable values before issuing any Mode Select commands. (See the PCF field description for Mode Sense command, Section 6.1.13.) This allows the initiator to correctly determine which pages are supported, the proper length for those pages, and which parameters in those pages may be changed for that logical unit number.

The table below summarizes the number of bytes and changeability status of the Mode Select parameter list. The detailed information can be obtained by issuing the Mode Sense command requesting changeable values as previously discussed.

6.1.10.4 Parameter List Length

Using the table below, you can derive parameter list length. Note that in the case of Operating page parameters, the first two bytes are accepted and the third byte is assumed unchanged.

Header or Page	Number of Bytes	Changeable by Initiator
Mode Select Header	4	No
Block Descriptor	8 (or 0)	Some
Error Recovery Page	6	Some
Disconnect/Reconnect Page	10	Some
Format Device Page	22	Some
Rigid Disc Geometry Page	18	Some
Caching Page (SCSI-3)	19	Some
Notch and Partition Page	22	Some
Power Condition Page	14	Some
Cache Control Page	14	No
Soft ID Page	1	Some
Operating Page	3 (or 2)	Some

6.1.11 Reserve Command (16_H)

The Reserve command is used to reserve logical units. If the Third-Party Reservation option is implemented, the logical unit may be reserved for another specified SCSI device. The Reserve and Release commands provide the basic mechanism for contention resolution in multiple-initiator systems.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	0	1	0	1	1	0
1	LUN = 0			3rdPty	3rd Party Device ID			Extent
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	Flag	Link

6.1.11.1 Logical Unit Reservation

If the Extent bit is zero, the Reserve command requests that the entire drive be reserved for exclusive use by the initiator, until:

- The reservation is superseded by another valid Reserve command from the initiator that made the reservation
- Released by a Release command from the same initiator
- Released by a Bus Device Reset message from any initiator
- Released by a hard reset.

A logical unit reservation is not granted if the drive is reserved by another initiator. An initiator can reserve a logical unit that has already been reserved.

After honoring the reservation, if any other initiator attempts to perform a Release command, the command is ignored. A Request Sense and Inquiry Command can be executed by any initiator. Any other command is rejected with Reservation Conflict status.

6.1.11.2 Extent Reservation

The drive does not support Extent reservations. The extent bit must always be zero. If the Extent bit is a one, Check Condition status is generated and the sense key is Illegal Request.

6.1.11.3 Third-Party Reservation Option

The Third-Party Reservation option for the Reserve command allows an initiator to reserve a logical unit for another SCSI device. This option is intended for use in multiple initiator systems that use the Copy command.

Third-Party Bit: If zero, then the Third-Party Reservation option is not requested. If one, the Reserve command reserves the drive for the SCSI device specified in the third party device ID field.

The drive preserves the reservation until it is superseded by another valid Reserve command from the initiator of the reservation or until it is released by the same initiator, by a Bus Device Reset message from any initiator, or a hard reset. The drive ignores any attempt to release the reservation made by any other initiator.

6.1.11.4 Superseding Reservations

An initiator holding a current reservation can modify that reservation by issuing another Reserve command to the same logical unit. The superseding Reserve command releases the previous reservation state when the new reservation request is granted. The previous reservation is not modified if the new reservation request cannot be granted.

Note: This option is intended for use in multiple initiator systems that use the Copy command.

Note: Superseding reservations are principally intended to allow the SCSI device ID to be changed on a reservation using Third-Party Reservation option. This capability is sometimes necessary when using the Copy command.

6.1.12 Release Command (17_H)

The Release command is used to release previously reserved logical units. It is not an error for an initiator to attempt to release a reservation that is not currently active. In this case, the target returns Good status without altering any other reservation.

The command is implemented for an Entire Unit Release and Third-Party Release supported with the parameters listed in the table below.

In the CDB the LUN must be zero, and the Extent bit must be zero.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	0	1	0	1	1	1
1	Logical Unit No. (0)			3rd Pty	3rd Party Device ID*			Extent
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	Flag	Link

* If bit 4 is zero, bits 3, 2, and 1 are zeros. If bit 4 is one, bits 3, 2, and 1 identify the SCSI device ID for which the drive is to be reserved.

6.1.12.1 Logical Unit Release

If the Extent bit is zero, the Release command will cause the drive to terminate all reservations from the initiator to the drive.

6.1.12.2 Extent Release

Extent reservations are not supported. This bit must always be zero.

6.1.12.3 Third-Party Release

The Third-Party Release option is supported. The Third-Party Release option for the Release command allows an initiator to release a logical unit that was previously reserved using the Third-Party Reservation option. (See Section 6.1.11.3.) This option is intended for use in multiple initiator systems that use the Copy command.

If the Third-Party (3rdPty) bit is zero, the Third-Party Release option is not requested. If the 3rdPty bit is one, the drive will release the specified logical unit, but only if the reservation was made using the Third-Party Reservation option by the initiator that is requesting the release, and for the same SCSI device specified in the Third-Party ID field.

6.1.13 Mode Sense Command ($1A_H$)

The Mode Sense command provides a means for a drive to report its medium, logical unit, or peripheral device parameters to the initiator. It is a command complementary to the Mode Select command for support of medium that may contain multiple block lengths or densities.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	0	1	1	0	1	0
1	LUN = 0			0	0	0	0	0
2	PCF		Page Code					
3	0	0	0	0	0	0	0	0
4	Allocation Length (in bytes)							
5	0	0	0	0	0	0	Flag	Link

The **Logical Unit Number (LUN)** must be zero.

The **Allocation Length** specifies the number of bytes that the initiator has allocated for returned Mode Sense data. An allocation length of zero means that no Mode Sense data is to be transferred. This condition is not considered an error. Any other value represents the maximum number of bytes to be transferred. The Data In phase is terminated by the drive when allocation length bytes have been transferred, or when all available Mode Sense data has been transferred to the initiator, whichever is less.

The **PCF (Page Control Field)** determines the content of Mode Parameter bytes. The drive returns the same Page Length for each supported page regardless of the value of PCF. The PCF field is described below.

PCF Bit 7	PCF Bit 6	Effect
0	0	Return current values. The current values are the values currently being used by the drive to control its operation. After a power on reset, hard reset, or Bus Device reset message, the current values will be equal to the saved values if saved values can be retrieved or the default values if Saved values cannot be retrieved. The current value of a parameter is updated whenever a Mode Select command which changes that parameter ends with good status being returned.
0	1	Return changeable values. The changeable values of any page is a mask that indicates which parameters may or may not be changed via a Mode Select command. Each returned parameter byte will contain ones where a field or bit may be changed and zeros where a field or bit may not be changed.
1	0	Return default values. The default values are the values to which the drive sets the Current values after a reset condition, unless valid Saved values are available.
1	1	Return saved values. The saved values are the values the drive stores in nonvolatile memory. The saved values of any changeable parameter can be set via a Mode Select command. For non-changeable parameters, the default value is used. The block descriptor contains current values regardless of the value of the PCF. Unsupported fields or bits within a page are returned as zeros for all PCF values.

6.1.13.1 Mode Sense CDB Setup

The Mode Sense CDB data always includes a four-byte header, followed by one eight-byte block descriptor, followed by the requested page or pages of Mode Sense parameters.

Mode Page Code (byte 2, bits 5-0)	Allocation Length	Mode Sense Data Returned
01_H	14_H	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 2 bytes of Error Recovery Page Header 6 bytes of Error Recovery Page Parameters
02_H	18_H	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 2 bytes of Disconnect/Reconnect Page Header 10 bytes of Disconnect/Reconnect Page Parameters
03_H	24_H	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 2 bytes of Format Device Page Header 22 bytes of Format Device Page Parameters
04_H	20_H	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 2 bytes of Rigid Disc Geometry Page Header 18 bytes of Rigid Disc Geometry Page Parameters
08_H	20H	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 2 bytes of Caching Page Header 18 bytes of Caching Page Parameters
$0C_H$	24_H	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 2 bytes of Notch and Partition Page Header 22 bytes of Notch and Partition Page Parameters

Mode Page Code (byte 2, bits 5-0)	**Allocation Length**	**Mode Sense Data Returned**
$0D_H$	18_H	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 2 bytes of Power Condition Page Header 10 bytes of Power Condition Page Parameters
38_H	$1C_H$	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 2 bytes of Cache Control Header 14 bytes of Cache Control Page Parameters
$3C_H$	0FH	4 bytes of Modes Sense Header 8 bytes of Block Descriptor Data 2 bytes of Soft ID Page Header 1 bytes of Soft ID Page Parameters
00_H	11_H (or 10_H)	4 bytes of Mode Sense Header 8 bytes Block Descriptor Data 2 bytes of Operating Page Header 3 (or 2) bytes of Operating Page Parameters
$3F_H$	$9C_H$ (or $9B_H$)	4 bytes of Mode Sense Header 8 bytes of Block Descriptor Data 144 (or 143) bytes of Header and Parameter data for page codes: 00_H, 01_H, 02_H, 03_H, 04_H, 08_H, $0C_H$, $0D_H$, 38_H, $3C_H$

6.1.13.2 Mode Sense Data

Multiple pages of mode parameters may be transferred in one Mode Sense Data In phase (using Page Code $3F_H$).

Bit Byte	7	6	5	4	3	2	1	0
0	Sense Data Length ① Length (from Mode Sense CDB) - 1							
1	Medium Type = 0 ②							
2	WP=0 ③	Reserved = 0						
3	Block Descriptor Length (8_H) ④							

Block Descriptor Data

0	Density Code = 0 ⑤
1	Number of Blocks MSB ⑥
2	Number of Blocks ⑥
3	Number of Blocks LSB ⑥
4	Reserved (0)
5	Block Length MSB ⑦
6	Block Length ⑦
7	Block Length LSB ⑦

Parameter Information

0 - n	Mode Sense Page Headers and their Parameters

① The **Sense Data Length** specifies the length in bytes of the following Mode Sense data that is available to be transferred during the Data In phase. The Sense Data Length does not include itself.

② The **Medium Type** field must contain zero, the default media.

③ When the **Write Protect (WP)** bit is always zero, which means the media is write-enabled.

④ The **Block Descriptor Length** is always 8_H; It specifies the number of bytes in the Block Descriptor. This value does not include the page headers and mode parameters, if any.

One **Block Descriptor** is sent by the drive. Each Block Descriptor specifies the medium characteristics for the logical unit. The Block Descriptor contains a Density Code, a Number of Blocks, and a Block Length.

⑤ Only 00_H (default) is supported in the **Density Code** field.

⑥ The **Number of Blocks** field specifies the number of logical blocks of the media that meets the Density Code and Block Length in the Block Descriptor. The drive always returns the total number of blocks available.

⑦ The **Block Length** is always 512. It specifies the length, in bytes, of each logical block described by the Block Descriptor.

6.1.13.3 Mode Sense Page Descriptor Header

Each page of mode parameters begins with a two-byte Page Descriptor Header. Multiple pages of mode parameters may be transferred in one Mode Sense Data In phase (using Page Code $3F_H$).

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

Page Code	Page Descriptor
01_H	Error Recovery Page
02_H	Disconnect/Reconnect Page
03_H	Format Device Page
04_H	Rigid Disc Geometry Page
08_H	Caching Page (SCSI-3)
$0C_H$	Notch and Partition Page
$0D_H$	Power Condition Page
38_H	Cache Control Page
$3C_H$	Soft ID Page
00_H	Operating Page

When the **Parameters Savable (PS)** bit is one, the page contains savable parameters. When the PS bit is zero, none of the parameters within the page are savable. Since the parameters within pages 3 and 4 are always saved during Format commands (but not during Mode Select commands with the SP bit set to 1), these pages return a 1 for the PS bit.

The **Page Code** identifies which page of mode parameters is being transferred.

The **Page Length** indicates the number of additional bytes of mode parameters being sent by the drive.

6.1.14 Start/Stop Unit Command ($1B_H$)

The Start/Stop Unit command requests that the drive spin or spin down the spindle motor and enable itself for further operations.

- If the Start bit is one, the drive spins up and then reads the remainder of the operational software into the program RAM.
- If the Start bit is a zero, the drive spins down.
- An Immed bit of zero indicates that status will be returned after the operation is completed. If the Immed bit is one, status will be returned as soon as the operation is initiated.

For systems that support disconnection and if the Immed bit is zero, the drive disconnects when a Start Unit command is initiated, and reconnects when the unit is up to speed and ready.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	1	1	0	1	1
1	Logical Unit No. (0)			0	0	0	0	Immed
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	Start
5	0	0	0	0	0	0	FLAG	LINK

6.1.15 Receive Diagnostic Results Command ($1C_H$)

The Receive Diagnostic Results command requests analysis data to be sent to the initiator after completion of a Send Diagnostic command.

The drive is capable of sending 8 diagnostic data bytes. All FRU and error codes are unique to this drive are not intended for field use.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	0	1	1	1	0	0
1	Logical Unit No. (0)			0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	Allocation Length in Bytes (MSB)							
4	Allocation Length in Bytes (LSB)							
5	0	0	0	0	0	0	FLAG	LINK

The **Allocation Length** specifies the number of bytes the initiator has allocated for returned diagnostic result data. An allocation length of zero indicates that no diagnostic data is to be transferred. Any other value indicates the maximum number of bytes to be transferred. The allocation length should be at least 8 bytes to accommodate all of the diagnostic data.

The Data In phase is terminated when the allocation length bytes have been transferred or when all available diagnostic data have been transferred to the initiator, whichever is less.

Code	Byte	Description
00_H	0	Additional Length (MSB)
06_H	1	Additional Length (LSB)
01_H	2	FRU Code (most probable)
00_H	3	FRU Code
00_H	4	FRU Code
00_H	5	FRU Code (Least Probable)
00_H	6	Error Code (MSB)
Vendor Unique	7	Error Code (LSB)

Additional Length: This two-byte value indicates the number of additional bytes included in the diagnostic data list. For example, if no product unique bytes were available, this value would be 0006_H. A value of 0000_H means that there are no additional bytes.

FRU Code: A Field Replaceable Unit code is a byte that identifies an assembly that may have failed. The codes will be listed with the most probable assembly listed first and the least probable last. A code of 00_H indicates there is no FRU information and a code of 01_H indicates the entire unit should be replaced. Other values are product-unique.

Error: This 2-byte value provides information designating which part of a diagnostic operation has failed. The Byte 7 error code is vendor-unique. See Section 6.1.15.1.

6.1.15.1 Diagnostics Error Codes

Error Code	Description
01_H	Format Diagnostic Error
02_H	Microprocessor RAM Diagnostic Error
04_H	No Drive Ready
08_H	No Sector or Index Detected
09_H	Fatal Hardware Error during Drive Diagnostics
$0C_H$	No Drive Command Complete
10_H	Unable to Set Drive Sector Size
14_H	Unable to Clear Drive Attention
18_H	Unable to Start Spindle Motor
20_H	Unable to Recall Drive
30_H	Unable to Send Write Current Data to Drive
34_H	Unable to Issue Drive Seek Command
40_H	Unable to Read User Table from Drive
41_H	Ran Out of Sectors during Drive Diagnostics
42H	Unable to Read Reallocation Table
43_H	Unable to Read ETF Log
60_H	Thermal Calibration Failure
70_H	Microprocessor Internal Timer Error
80_H	Buffer Controller Diagnostic Error
81_H	Buffer RAM Diagnostic Error
$C1_H$	Data Miscompare during Drive Diagnostics

6.1.16 Send Diagnostic Command ($1D_H$)

This command requests the drive to perform diagnostic tests on itself.

Bit / Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	0	1	1	1	0	1
1	Logical Unit No. (0)			0	0	Self Test	DOfL	Unit OfL
2	0	0	0	0	0	0	0	0
3	Parameter List Length in Bytes (MSB)							
4	Parameter List Length in Bytes (LSB)							
5	0	0	0	0	0	0	FLAG	LINK

The Parameter List Length specifies the length in bytes of the parameter list that will be transferred during the Data Out phase. A Parameter List Length of zero indicates that no data is to be written. The only parameter list length the drive accepts is zero.

A logical **Unit Off Line (UnitOfL)** bit of zero disables write operations on user medium or operations that affect user-visible medium positioning. The bit is not interpreted by the drive.

The SCSI **Device Off Line (DOfL)** bit of 1 enables diagnostic operations that may adversely affect operations to other Logical Units on the same target. This bit is not interpreted by the drive.

The Logical Unit Off Line and SCSI Device Off Line bits are generally set by operating system software, while the parameter list is prepared by diagnostic application software. Thus, by preventing operations that are not enabled by these bits, the drive assists the operating system in protecting its resources.

A **Self Test** bit of one directs the drive to complete its default self test. If the self test is requested, the Parameter List Length will be set to zero and no data will be transferred. If the self test successfully passes, the command will be terminated with a Good Condition status; otherwise, the command will be terminated with a Check Condition status and, if extended sense is implemented, the Sense Key will be set to Hardware Error. The self test bit must be set to 1.

For systems that support disconnection, the drive will disconnect while executing this command.

6.2 Group 1 Commands

The Group 1 commands implemented are listed in the table below.

Command	Opcode
Read Capacity	25_H
Read Extended	28_H
Write Extended	$2A_H$
Seek Extended	$2B_H$
Write and Verify	$2E_H$
Verify	$2F_H$
Read Defect Data	37_H
Write Data Buffer	$3B_H$
Read Data Buffer	$3C_H$
Read Long	$3E_H$
Write Long	$3F_H$

6.2.1 Read Capacity Command (25_H)

The Read Capacity command provides a means for the initiator to request information regarding the capacity of the drive.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	1	0	0	1	0	1
1	Logical Unit No. (0)			0	0	0	0	0
2	Logical Block Address (MSB)							
3	Logical Block Address							
4	Logical Block Address							
5	Logical Block Address (LSB)							
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	PMI
9	0	0	0	0	0	0	FLAG	LINK

A Partial Medium Indicator (PMI) bit of zero indicates the information returned in the Read Capacity data will be the Logical Block Address and Block Length (in bytes) of the last logical block of the logical unit. The Logical Block Address in the Command Descriptor Block will be set to zero for this option.

A PMI bit of one indicates the information returned will be the Logical Block Address and Block Length (in bytes) of the last Logical Block Address, after which a substantial delay (defined as approximately 1 millisecond) in data transfer will be encountered. This Logical Block Address must be greater than or equal to the Logical Block Address specified in the Command Descriptor Block. This reported Logical Block Address will be a cylinder boundary.

The 8 bytes of data returned by the Read Capacity command are listed below.

Byte	Description
0	Logical Block Address (MSB)
1	Logical Block Address
2	Logical Block Address
3	Logical Block Address (LSB)
4	Block Length (MSB)
5	Block Length
6	Block Length
7	Block Length (LSB)

6.2.2 Read Extended Command (28_H)

The Read Extended command requests that the target transfer data to the initiator.

Bit / Byte	7	6	5	4	3	2	1	0
0	0	0	1	0	1	0	0	0
1	Logical Unit No. (0)			0	0	0	0	Rel Adr
2	Logical Block Address (MSB)							
3	Logical Block Address							
4	Logical Block Address							
5	Logical Block Address (LSB)							
6	0	0	0	0	0	0	0	0
7	Transfer Length (MSB)							
8	Transfer Length (LSB)							
9	0	0	0	0	0	0	FLAG	LINK

The Logical Block Address specifies the logical block at which the read operation begins.

The Transfer Length specifies the number of contiguous logical blocks of data that will be transferred. A Transfer Length of zero indicates that no logical blocks will be transferred. This condition is not considered an error. Any other value indicates the number of logical blocks that will be transferred.

The data value most recently written in the addressed logical block will be returned.

In the CDB, the LUN must be zero.

This command operates the same as the Read command (see Section 6.1.6), except that, in the CDB for this command, a four-byte Logical Block Address and a two-byte Transfer Length may be specified.

This command terminates with a Reservation Conflict status if there is a reservation access conflict. No data is read. See Section 6.1.11.

If any of the following conditions occur, this command will return a Check Condition status. Sections 6.1.6.1 and 6.1.7.1 lists all the conditions that can cause a Check Condition status.

6.2.2.1 Sense Keys

Condition	**Sense Key**
Invalid Logical Block Address	Illegal Request (see note)
Target reset since last command from this initiator	Unit Attention
Unrecovered read error	Medium Error
Recoverable read error	Recovered Error
Overrun error or other error that might be resolved by repeating the command	Aborted Command

Note: The extended sense information bytes will be set to the Logical Block Address of the first invalid address.

6.2.3 Write Extended Command ($2A_H$)

The Write Extended command requests that the drive write to the medium the data transferred by the initiator.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	1	0	1	0	1	0
1	Logical Unit No. (0)			0	0	0	0	REL ADR
2	Logical Block Address (MSB)							
3	Logical Block Address							
4	Logical Block Address							
5	Logical Block Address (LSB)							
6	0	0	0	0	0	0	0	0
7	Transfer Length (MSB)							
8	Transfer Length (LSB)							
9	0	0	0	0	0	0	FLAG	LINK

The Logical Block Address specifies the logical block at which the write operation will begin.

The Transfer Length specifies the number of contiguous logical blocks of data that will be transferred. A Transfer Length of zero indicates no logical blocks will be transferred. This condition is not considered an error and no data will be written. Any other value indicates the number of logical blocks that will be transferred.

In the CDB, the LUN must be zero.

This command operates the same as the Write command, except that, in the CDB for this command, a four-byte Logical Block Address and a two-byte Transfer Length may be specified. (See Section 6.1.7.)

This command terminates with a Reservation Conflict status if there is a reservation access conflict. No data is written. (See Section 6.1.11.)

If any of the following conditions occur, this command will be terminated with a Check Condition status and the sense key will be set as indicated in the following table. Sections 6.1.6.1 and 6.1.7.1 lists all the conditions that can cause a Check Condition status.

Condition	Sense Key
Invalid Logical Block Address	Illegal Request (see note)
Target reset since last command from this initiator	Unit Attention
Overrun error or other error that might be resolved by repeating the command	Aborted Command

Note: The extended sense information bytes are set to the logical block address of the first invalid address. In this case, no data is written on the logical unit.

6.2.4 Seek Extended Command ($2B_H$)

The Seek Extended command requests that the drive seek to the specified logical block address.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	1	0	1	0	1	1
1	Logical Unit No. (0)			0	0	0	0	REL ADR
2	Logical Block Address (MSB)							
3	Logical Block Address							
4	Logical Block Address							
5	Logical Block Address (LSB)							
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	FLAG	LINK

In the CDB, the LUN must be zero. This command operates the same as the Seek command except that a four-byte Logical Block Address is specified. (See Section 6.1.8.)

6.2.5 Write and Verify Command ($2E_H$)

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. The data is only transferred once from the initiator to the drive.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	1	0	1	1	1	0
1	Logical Unit No. (0)			0	0	0	BYT CHK	REL ADR
2	Logical Block Address (MSB)							
3	Logical Block Address							
4	Logical Block Address							
5	Logical Block Address (LSB)							
6	0	0	0	0	0	0	0	0
7	Transfer Length (MSB)							
8	Transfer Length (LSB)							
9	0	0	0	0	0	0	FLAG	LINK

A **Byte Check (BYT CHK)** bit of zero causes a medium verification to be performed with no data comparison. A Byt Chk bit of 1 is not supported and the drive will return Check Condition status with the Sense Key set to Illegal Request.

The **Logical Block Address** field specifies the logical block at which the write operation will begin.

The **Transfer Length** field specifies the number of contiguous logical blocks to be transferred. A Transfer Length of zero indicates that no logical blocks are transferred. This condition is not considered an error and no data is written.

The drive will disconnect while this command is being executed if the initiator supports disconnect/reconnect.

6.2.6 Verify Command ($2F_H$)

The Verify command requests that the drive verify the data written on the medium. The drive disconnects while this command is being executed if the initiator supports disconnect/reconnect.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	1	0	1	1	1	1
1	Logical Unit No. (0)			0	0	0	BYT CHK	REL ADR
2	Logical Block Address (MSB)							
3	Logical Block Address							
4	Logical Block Address							
5	Logical Block Address (LSB)							
6	0	0	0	0	0	0	0	0
7	Verification Length (MSB)							
8	Verification Length (LSB)							
9	0	0	0	0	0	0	FLAG	LINK

A **Byte Check (BYT CHK)** bit of zero means that the medium alone is verified (CRC, ECC, etc). A BytChk bit of one is not supported, causing a Check Condition status and the Sense Key is set to Illegal Request.

The **Logical Block Address** specifies the logical block where the verify operation begins.

The **Verification Length** specifies the number of contiguous logical blocks of data to be verified. A verification length of zero is not an error; it means that no logical blocks are to be verified although an implied seek is still performed.

6.2.7 Read Defect Data Command (37_H)

This command is intended to be used only with the Format Unit command (Section 6.1.4). The initiator does not affect this list, it only resends the list as defect data in a Format Unit command.

Bit Byte	7	6	5	4	3	2	1	0
0	0	0	1	1	0	1	1	1
1	Logical Unit No. (0)			0	0	0	0	0
2	0	0	0	P	G	Defect List Format		
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	Allocation Length (MSB)							
8	Allocation Length (LSB)							
9	0	0	0	0	0	0	FLAG	LINK

The **Defect List Format** field indicates the defect data format preferred by the initiator. The meaning is the same as the Defect List Format field in the Format command description. The bits should be either:

- 1 0 0 to signify a defect list in the Bytes from Index format, or,
- 1 0 1 to signify a defect list in the Physical Sector format.

Otherwise, the drive responds with the defect list in the default format (physical sector) and creates the Check Condition status with Recovered Error Sense Key at the end of the Read Defect Data data transfer. The Read Defect Data command requests that the target transfer the medium defect data to the initiator.

Defect List Type		**Results**
Bit P	**Bit G**	
0	0	Return Defect List header only. The Defect List length reflects the length of the both the P and G list and no Defect Descriptor Bytes are to be sent to the initiator.
0	1	Return the grown G list only. This list reflects the grown or G list.
1	0	Return Seagate's P list only. This is the list created during the manufacturing process. It contains defect that may or may not have been reallocated, depending on the last Format command received. (The last Format command does not always request that P list flaws be reallocated during the format function.)
1	1	Return both the P and G lists. The returned list contains all of the drive's defect lists regardless of whether these lists have been reallocated by the drive.

The **Allocation Length** specifies the number of bytes the initiator has allocated for the returned defect data. An Allocation Length of zero indicates that no Read Defect Data will be transferred. Any other value indicates the maximum number of bytes to be transferred. The Data In phase ends when the Allocation Length bytes have been transferred or when all available defect data has been transferred to the initiator, whichever is less. In the CDB, the LUN must be zero.

The **Defect List Length** specifies the total length in bytes of all the defect descriptors available from the drive. If the Allocation Length of the CDB is too small to transfer all of the defect descriptors, the Defect List Length is not adjusted to reflect the truncation. The defect descriptors do not have to be in ascending order.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Reserved (0)							
1	Reserved (0)			P	G	Defect List Format		
2, 3	Defect List Length in Bytes							
4 - n	Defect Descriptor Entries							

The first 4 bytes returned are the Defect List Header. The Defect List Type (see the table on the opposite page) and Defect List Format fields indicate the defect format actually returned by the drive. The definitions are the same as for Byte 2 of the Read Defect Data Command Descriptor Block.

6.2.8 Write Data Buffer Command ($3B_H$)

The Write Data Buffer command is used in conjunction with the Read Buffer command as a diagnostic function for testing the drive's data buffer memory and the SCSI bus integrity. This command will not alter any drive medium. A mode is provided for downloading and saving executable microcode.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	1	1	1	0	1	1
1	Logical Unit No. (0)			0	0	DB2	DB1	DB0
2	Buffer ID (0)							
3	Buffer Offset (MSB)							
4	Buffer Offset							
5	Buffer Offset (LSB)							
6	Transfer Length (MSB)							
7	Transfer Length							
8	Transfer Length (LSB)							
9	0	0	0	0	0	0	FLAG	LINK

The function of this command, and fields within the CDB, depend on the contents of the Mode bits, as shown in the table that follows.

Mode			Description
DB2	DB1	DB0	
0	0	0	Write Combined Head and Data
0	0	1	Reserved
0	1	0	Write Data
0	1	1	Reserved
1	0	0	Reserved
1	0	1	Download Microcode and Save
1	1	0	Reserved
1	1	1	Reserved

6.2.8.1 Write Combined Header and Data

In this mode, the data to be transferred is preceded by the four-byte Write Data Buffer header. All four bytes are reserved.

- The Buffer ID field is zero.
- The Transfer Length field specifies the maximum number of bytes to be transferred during the Data Out phase.

The byte Transfer Length includes a four-byte header, so the data length to be stored in the drive's buffer is the Transfer Length minus four. The Buffer Offset is added to the starting address of the data buffer to determine the destination of the first data byte. The bytes that follow are placed in sequential addresses. The transfer continues until the Transfer Length is exhausted. If the Buffer Offset added to the Transfer Length exceeds the buffer size reported by the Read Data Buffer command, or if the Buffer ID code is not zero, the Check Condition status is created with the Sense Key of Illegal Request. In this case, no data is transferred from the initiator.

6.2.8.2 Reserved

These modes are reserved and may not be used. If any reserved mode is received, the Check Condition status is created with a Sense Key of Illegal Request. In this case, no data is transferred from the initiator.

6.2.8.3 Data Mode

In the Data Mode, the Data Out phase contains only buffer data (no header). The Buffer ID must be zero. The Buffer Offset is added to the starting address of the data buffer to determine the destination of the first data byte. The bytes that follow are placed in sequential addresses.

The transfer continues until the Transfer Length is exhausted. If the Buffer Offset added to the Transfer Length exceeds the buffer size reported by the Read Data Buffer command, or if the Buffer ID code is not zero, the Check Condition status is created with a Sense Key of Illegal Request. In this case, no data is transferred from the initiator.

Note: In the Write (Read) Combined Header and Data and the Data Mode, the buffer is treated as a single segment regardless of the number of segments specified in Mode Page 08_H. (See Section 7.5.) The single segment only applies to the Read Data Buffer and Write Data Buffer commands. Subsequent reads or writes still have the same number of segments, as specified in Mode Page 08_H. The Write Data Buffer command causes all cached data to be invalidated and lost.

6.2.8.4 Download Microcode and Save Mode

This mode is used to download executable software to the control memory of the drive, and then save the downloaded software in the system configuration data stored on the medium. This new software version is to be used by the drive for all future operations, including power cycles, and resets until it is supplanted by another Write Data Buffer command which uses a Download Microcode and Save operation

The Link, Flag, and Buffer ID fields must be zero. The Buffer Offset is used as an offset into the control memory. When the data is transferred from the data buffer to the control memory, the first data byte is transferred to the address that is the sum of the start of the control memory plus the Buffer Offset. The Transfer Length indicates the number of bytes to be transferred during the Data Out phase. If the Buffer Offset added to the Transfer Length exceeds the control memory size, or if the Buffer ID, Link, or Flag fields are not zero, a Check Condition status is created with a Sense Key of Illegal Request. In this case, no data is transferred from the initiator.

When the microcode has been successfully downloaded, the drive generates a Unit Attention condition for all initiators except the one that issued the current Write Data Buffer command. The Unit Attention condition is set to “Microcode has been Downloaded.”

6.2.8.5 Write Data Buffer Header

Bit / Byte	7	6	5	4	3	2	1	0
0	0							
1	0							
2	0							
3	0							

6.2.9 Read Data Buffer Command ($3C_H$)

The Read Data Buffer command is used in conjunction with the Write Data Buffer command as a diagnostic function for testing the drive's data buffer memory and the SCSI bus integrity. The medium is not accessed during the execution of this command.

Bit / Byte	7	6	5	4	3	2	1	0
0	0	0	1	1	1	1	0	0
1	Logical Unit No. (0)			0	0	DB2	DB1	DB0
2	Buffer ID (0)							
3	Buffer Offset (MSB)							
4	Buffer Offset							
5	Buffer Offset (LSB)							
6	Transfer Length (MSB)							
7	Transfer Length							
8	Transfer Length (LSB)							
9	0	0	0	0	0	0	FLAG	LINK

The function of this command, and fields within the CDB, depend on the contents of the Mode bits, as shown in the table that follows.

Mode			Description
DB2	DB1	DB0	
0	0	0	Read combined header and data
0	0	1	Reserved
0	1	0	Read Data
0	1	1	Reserved
1	X	X	Reserved

6.2.9.1 Read Combined Header and Data

In this mode, the data to be transferred is preceded by the four-byte Read Data Buffer header. All four bytes are reserved.

- The Buffer ID field is zero.
- The Buffer Offset is added to the starting address of the data buffer to determine the source of the first data byte.
- The Transfer Length field specifies the maximum number of bytes to be transferred during the Data In phase.

The Byte Transfer Length includes a four-byte header, so the data length to be read from the drive's buffer is the Transfer Length minus four. A Transfer Length of zero indicates that no data transfer will take place. This condition does not create the Check Condition status. If the Transfer Length added to the buffer offset is greater than the Available Length reported by the Read Data Buffer header, the drive transfers data until the data buffer end is reached.

Bit Byte	7	6	5	4	3	2	1	0
0	0							
1	Available Length (MSB)							
2	Available Length							
3	Available Length (LSB)							

6.2.9.2 Reserved

These modes are reserved and may not be used. If any reserved mode is received, a Check Condition status is created with a Sense Key of Illegal Request. In this case, no data will be transferred from the initiator.

6.2.9.3 Data Mode

In the Data Mode, the Data In phase contains only buffer data that is read from the drive's data buffer (no header). The Buffer ID must be zero. The Buffer Offset is added to the starting address of the data buffer to determine the source of the first data byte. The bytes that follow are read from sequential addresses.

The transfer continues until the Transfer Length is exhausted. If the Buffer Offset added to the Transfer Length exceeds the buffer size reported in the header by the Read Data Buffer command, the drive transfers data until the end of the buffer is reached. If the Buffer ID code is not zero, a Check Condition status is created with a Sense Key of Illegal Request. In this case, no data is transferred from the initiator.

6.2.10 Read Long Command ($3E_H$)

The Read Long command requests that the drive transfer data to the initiator. The data consists of the contents of the logical block specified in the Logical Block Address followed by the six-byte error correction code (ECC) that the drive calculates and stores on the medium with the logical block data.

Bit / Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	0	1	1	1	1	1	0
1	Logical Unit No. (0)			0	0	0	0	0
2	Logical Block Address (MSB)							
3	Logical Block Address							
4	Logical Block Address							
5	Logical Block Address (LSB)							
6	0	0	0	0	0	0	0	0
7	Transfer Length (in bytes, MSB)							
8	Transfer Length (in bytes, LSB)							
9	0	0	0	0	0	0	FLAG	LINK

The Transfer Length specifies the number of bytes that will be transferred during the Data In phase. The drive transfers the lesser of the Transfer Length and the logical block size plus six.

6.2.11 Write Long Command ($3F_H$)

The Write Long command requests that the drive transfer data from the initiator that consists of one logical block of data and six bytes of error correction code (ECC).

Bit / Byte	7	6	5	4	3	2	1	0
0	0	0	1	1	1	1	1	1
1	Logical Unit No. (0)			0	0	0	0	0
2	Logical Block Address (MSB)							
3	Logical Block Address							
4	Logical Block Address							
5	Logical Block Address (LSB)							
6	0	0	0	0	0	0	0	0
7	Transfer Length (in bytes, MSB)							
8	Transfer Length (in bytes, LSB)							
9	0	0	0	0	0	0	FLAG	LINK

The logical block data is written in the logical block specified by the Logical Block Address. The ECC bytes are written in the ECC field for the specified logical block address that the drive usually calculates and stores on the medium. No ECC verification is performed during the write operation. The Transfer Length specifies the number of bytes to be transferred during the Data In phase. If the Transfer Length does not equal the sum of the logical block size plus six, the command is terminated with a Check Condition and the sense key is set to Illegal Request.

6.3 Group 2-4 Commands

Group 2, 3, and 4 commands are 10-byte commands. These commands are reserved and are not implemented. These commands return a Check Condition status with an Illegal Request sense key.

6.4 Group 5 and 6 Commands

Group 5 and 6 commands are 12-byte commands. Group 6 commands are reserved for Seagate use. These commands return a Check Condition status with an Illegal Request sense key.

Note: Do not use Group 3, 4 and 6 commands. If you do, stored data may be destroyed.

6.5 Group 7 Commands

The Group 7 commands are listed below.

Operation Code	Command Name
$E5_H$	Read Long
$E6_H$	Write Long
$E8_H$	Read Long
EA_H	Write Long

6.5.1 Read Long Command ($E5_H$)

This command is identical to the Read Long command described in Section 6.2.10, except the Operation Code specified in byte zero of the Command Descriptor Block is $E5_H$. This version is provided for compatibility with systems designed before the Group 1 version of the command was defined.

6.5.2 Write Long Command ($E6_H$)

This command is identical to the Write Long command described in Section 6.2.11, except the Operation Code specified in byte zero of the Command Descriptor Block is $E6_H$. This version is provided for compatibility with systems designed before the Group 1 version of the command was defined.

6.5.3 Read Long Command ($E8_H$)

This command is identical to the Read Long command described in Section 6.2.10, except the Operation Code specified in byte zero of the Command Descriptor Block is $E8_H$. This version is provided for compatibility with systems designed before the Group 1 version of the command was defined.

6.5.4 Write Long Command (EA_H)

This command is identical to the Write Long command described in Section 6.2.11, except the Operation Code specified in byte zero of the Command Descriptor Block is EA_H. This version is provided for compatibility with systems designed before the Group 1 version of the command was defined.

7.0 Mode Pages

The pages used by the Mode Sense and Mode Select commands are described in this section.

For all pages, when the changeable value is zero, this bit function is not directly changeable by an initiator. A changeable value of one indicates the bit function is directly changeable by an initiator.

For all pages, the Page Savable (PS) bit is used in Mode Sense commands. PS is set to one to show the page is savable on the medium. This location is reserved in Mode Select commands and must be zero. All reserved fields are not changeable.

7.1 Error Recovery Page

The Error Recovery page is shown below. This table summarizes the function, the default value, and changeability value for each byte/bit.

Bit Byte	7	6	5	4	3	2	1	0
0	PS ①	Page Code (01_H)						
	1	0	0	0	0	0	0	0
1	Page Length in Bytes (06_H)							
2 (Default)	AWRE 0	ARRE 0	TB 0	RC 0	EER 0	PER 0	DTE 0	DCR 0
Changeable ②	1	1	1	1	1	1	1	1
3 (Default)	Retry Count ($1B_H$) ③							
Changeable	FF_H							
4 (Default)	Correction Span in Bits ($0B_H$) ④							
Changeable	00_H							
5 (Default)	Head Offset Count (00_H) ⑤							
Changeable	00_H							
6 (Default)	Data Strobe Offset Count (00_H) ⑥							
Changeable	00_H							
7 (Default)	Recovery Time Limit (FF_H) ⑦							
Changeable	00_H							

① When the **PS (Parameter Savable**) bit is one, the parameter data for this page is savable. When the PS bit is zero, the parameter data for this page is not savable. The default is one. (See the Mode Select command, Section 6.1.10.)

② When the **Automatic Write Reallocation Enabled (AWRE)** bit is one, the drive automatically reallocates bad blocks detected during write operations. When the AWRE bit is zero, automatic reallocation is not be performed but Check Condition status will be created with Sense Key of Medium Error instead. This function does not apply to the Format Unit command.

When the **Automatic Read Reallocation Enabled (ARRE)** bit is one, the drive automatically reallocates bad blocks detected during read operations. When the ARRE bit is zero, the drive does not automatically reallocate bad blocks. Instead, a Check Condition status is created with a Medium Error sense key.

When the **Transfer Block (TB)** bit is one, the failing data block is transferred to the initiator. When the TB bit is zero, the failing data block is not transferred.

When the **Read Continuous (RC)** bit is one, the drive will send all data without doing any corrections. This function supersedes other bits in this byte. When the RC bit is zero, the correction is performed according to the other bits in this byte.

An **Enable Early Recovery (EER)** bit of one indicates that the target uses the most expedient form of error recovery first. This bit only applies to data error recovery and it does not affect positioning retries and the message system error recovery procedures. An EER bit of zero indicates that the target uses an error recovery procedure that minimizes the risk of mis-detection or mis-correction.

When the **Post Error (PER)** bit is one, the drive reports the Check Condition status and the appropriate sense key for any recovered errors encountered. When the PER bit is zero, any errors recovered within the limits established by the other error recovery flags are not reported. Any unrecoverable errors are reported.

The **Disable Transfer on Error (DTE)** bit is valid only when the PER bit is set to one. When the DTE bit is one, the drive terminates data transfer even for recoverable errors. When the DTE bit is zero, the drive continues transferring data if recoverable errors are encountered; recoverable errors are reported, if the PER bit is one, after all the data has been transferred. The TB bit determines whether the block in error is to be transferred.

The **Disable Correction (DCR)** bit, when set to one, indicates ECC correction is not applied to the data even if correction is possible.

③ The **Retry Count** is the maximum number of times the drive attempts its read recovery algorithms. The Retry Count is changeable between 0 and 27, inclusive. A Retry Count of zero means that no retries are performed. If the EER bit is set, the number of retries specified by the Retry Count, up to a maximum of nine retries, is performed before ECC is applied.

④ The **Correction Span** is the size of the largest read data error, in bits, on which ECC correction is to be attempted. Longer errors are reported as unrecoverable.

⑤ The **Head Offset Count** is zero, by default, and not changeable. This feature is not programmable by the initiator. Head offsets are performed as part of the drive's retry algorithms.

⑥ The **Data Strobe Offset Count** is a default of zero and not changeable to signify that this feature is not programmable by the initiator.

⑦ The **Recovery Time Limit** always has an FF_H value, which means that the recovery time is unlimited.

7.2 Disconnect/Reconnect Page

The Disconnect/Reconnect page is shown below. This table summarizes the function, the default value, and changeability value for each byte/bit.

Bit **Byte**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	PS (1)	Page Code (02_H)						
1	Page Length in Bytes ($0A_H$)							
2 (Default)	Buffer Full Ratio ($C0_H$) ①							
Changeable	FF_H							
3 (Default)	Buffer Empty Ratio (40_H) ②							
Changeable	FF_H							
4 (Default)	Bus Inactivity Limit MSB (00_H) ③							
Changeable	00_H							
5 (Default)	Bus Inactivity Limit LSB ($0A_H$) (1 msec) ③							
Changeable	00_H							
6 - 7 (Default)	Disconnect Time Limit (0000_H) ④							
Changeable	0000_H							
8 - 9 (Default)	Connect Time Limit (0000_H) ⑤							
Changeable	0000_H							
10 - 11	Reserved (0000_H)							

① The **Buffer Full Ratio** indicates, on Read commands, how full the drive’s buffer is before reconnecting. The drive rounds up to the nearest whole logical block. This value is changeable by an initiator. This parameter is the numerator of a fractional multiplier that has 256 as its denominator.

② The **Buffer Empty Ratio** indicates, on Write commands, how empty the drive's buffer is before reconnecting to fetch more data. The drive rounds up to the nearest whole logical block. This value is changeable by an initiator. This parameter is the numerator of a fractional multiplier that has 256 as its denominator.

③ The **Bus Inactivity Limit** field (Bytes 4 and 5) indicates the time, in 100-µsec increments, that the drive can assert the Busy signal without handshakes until it disconnects. The drive may round down to its nearest capable value. The default value of OA_H allows the drive to maintain the Busy signal for 1 msec without handshakes. This value is not changeable by the initiator.

④ The **Disconnect Time Limit** field (Bytes 6 and 7) indicates the minimum time, in 100-µsec increments, the drive will remain disconnected until it attempts to reconnect. A value of zero indicates the drive is allowed to reconnect immediately. This is always zero and the changeable code is always zero.

⑤ The **Connect Time Limit** field (Bytes 8 and 9) indicates the maximum time, in 100 µsec increments, that the target should remain connected until it attempts to disconnect. The target may round to its nearest capable value. A value of zero means that the drive can remain connected indefinitely until it tries to disconnect.

7.3 Format Device Page

The Format Device page is shown below. This table summarizes the function, the default value, and changeability value for each byte/bit.This page can only be sent immediately before sending a Format Unit command to the drive.

The current parameters for this page are updated immediately, but any changes between these current parameters and the existing media format are not in effect until after the Format Unit command is completed.

Bit Byte	7	6	5	4	3	2	1	0
0	PS (1)	Page Code (03$_H$)						
1	Page Length in Bytes (16$_H$)							
2,3 Default	Tracks per Zone (0005$_H$) ①							
Changeable	FFFF$_H$							
4,5 Default	Alternate Sectors per Zone (0001$_H$) ②							
Changeable	FFFF$_H$							
6,7 Default	Alternate Tracks per Zone (0000$_H$) ③							
Changeable	0000$_H$							
8,9 Default	Alternate Tracks per Volume (000A$_H$) ④							
Changeable	FFFF$_H$							
10,11 Default	Sectors per Track (00XX$_H$) ⑤							
Changeable	0000$_H$							
12,13 Default	Data Bytes per Physical Sector (0200$_H$) ⑥							
Changeable	0000$_H$							
14,15 Default	Interleave (0001$_H$) ⑦							
Changeable	0000$_H$							
16,17 Default	Track Skew Factor (0001$_H$) ⑧							
Changeable	FFFF$_H$							
18,19 Default	Cylinder Skew Factor (0009$_H$) ⑨							
Changeable	FFFF$_H$							
20 Default ⑩	SSEC 1	HSEC 0	RMB 0	SURF 0	Reserved			
Changeable	0	0	0	0	0	0	0	0
21,22,23	00 Default, 00 Changeable to indicate Not Implemented by the drive.							

In the CDB, XX indicates variation in Sectors per Track due to the zone location.

This page of parameters may be sent only immediately before sending a Format Unit command to the drive. The Current parameters for this page will be updated immediately, but any changes between these current parameters and the existing media format will not be in effect until after the Format Unit command is completed.

① The **Tracks per Zone** field indicates the number of tracks the drive will allocate to each defect management zone. Spare sectors or tracks will be placed at the end of each defect management zone. Valid values for Tracks per Zone are 1 (Zone = Track), or number of heads in the drive, 5 (Zone = Cylinder).

② The **Alternate Sectors per Zone** field indicates the number of spare sectors to be reserved at the end of each defect management zone. The drive defaults to one spare sector per zone (Zone = Track). Allowable values for Alternate Sectors per Zone if Zone = Track is 1. If Zone = Cylinder, spare sectors may be changed by the initiator to any value between 1 and 3.

③ The **Alternate Tracks per Zon**e field indicates the number of spare tracks to be reserved at the end of each defect management zone. A value of zero indicates that no spare tracks are to be reserved in each zone for defect management by the drive. This field is not changeable.

④ The **Alternate Tracks per Volume** field indicates the number of spare tracks to be reserved at the end of the logical unit. The drive will use these locations for replacing sectors. A value of zero indicates that no spare tracks are to be reserved at the end of the unit for defect management. The drive defaults to two times the number of read/write heads in the drive. The initiator may change this value to any number between 0 and 256. This number must be a multiple of 5, which is the number of read/write heads.

⑤ The **Sectors per Track** field indicates the number of physical sectors the drive will allocate per track. A value of zero indicates that the number of sectors per track may be variable, or that the drive is to determine the best value. The drive will report the average number of physical sectors per track since the number of sectors per track varies between the outer and inner tracks. This field will not be verified on a Mode Select command.

⑥ The **Bytes per Physical Sector** field indicates the number of data bytes allocated per physical sector. This value will equal the block length reported in the block descriptor. The bytes per physical sector is not directly changeable by the initiator and will not be verified on a Mode Select command. The block size is changed by setting the bits in the block descriptor.

⑦ The **Interleave** field is the interleave value sent to the drive during the last Format Unit command. This field is valid only for Mode Sense commands. The drive ignores this field during Mode Select commands. The interleave is always 1:1.

⑧ The **Track Skew Factor** field indicates the number of physical sectors on the media between the last logical block of one track and the first logical block of the next sequential track of the same cylinder. A value of zero indicates no skew. The default value is 01_H for 512-byte sectors, with Tracks per Zone and Alternate Sectors per Zone set to one. This value is not changeable by the initiator.

⑨ The **Cylinder Skew Factor** field indicates the number of physical sectors between the last logical block of one cylinder and the first logical block of the next cylinder. A value of zero indicates no skew. The default value is not changeable by the initiator.

⑩ The Drive Type field bits are defined as follows:

The **Soft Sectoring (SSEC)** bit is set to one. Although this bit is reported as non-changeable, it can be set according to the systems requirements and have no affect upon drive performance.

The **Hard Sectoring (HSEC)** bit is set to Zero. Although this bit is reported as non-changeable, it can be set according to the systems requirements and have no affect upon drive performance.

The **Removable Media (RMB)** bit is always set to zero, indicating that the drive does not support removable media. This same bit is also returned in the Inquiry parameters.

The **Surface Map (SURF)** bit is set to zero, indicating that the drive allocates successive logical blocks to all sectors within a cylinder before allocating logical blocks to the next cylinder.

7.4 Rigid Disc Geometry Page

The Rigid Disc Geometry page is shown below. This table summarizes the function, the default value, and changeability value for each byte/bit.

The page can be sent using a Mode Select command only immediately before sending a Format Unit command to the drive and must equal the values reported by the Mode Sense command.

<table>
<tr><th>Bit
Byte</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>0</td><td>PS</td><td colspan="7">Page Code (04_H)</td></tr>
<tr><td>1</td><td colspan="8">Page Length in Bytes (12_H)</td></tr>
<tr><td>2, 3, 4</td><td colspan="8">Number of Cylinders ($00069B_H$) ①</td></tr>
<tr><td>5</td><td colspan="8">Number of Heads (5) ②</td></tr>
<tr><td>6, 7, 8</td><td colspan="8">Starting Cylinder - Write Precomp = 0 ③</td></tr>
<tr><td>9, 10, 11</td><td colspan="8">Starting Cylinder - Reduced Write Current = 0 ③</td></tr>
<tr><td>12, 13</td><td colspan="8">Drive Step Rate = 0 ③</td></tr>
<tr><td>14, 15, 16</td><td colspan="8">Loading Zone Cylinder = 0 ③</td></tr>
<tr><td rowspan="2">17 Default</td><td colspan="6" rowspan="2">Reserved</td><td colspan="2">RPL ④</td></tr>
<tr><td>0</td><td>0</td></tr>
<tr><td>Changeable</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>18 Default</td><td colspan="8">Rotational Position Lock Offset (00_H)</td></tr>
<tr><td>Changeable</td><td colspan="8">FF_H</td></tr>
<tr><td>19</td><td colspan="8">Reserved</td></tr>
</table>

① The **Number of Cylinders** field specifies the number of user-accessible cylinders, with two spare cylinders or set aside for defects. The maximum number of usable cylinders is 1689. The drive uses the additional cylinders for storing parameters and defect lists, or for diagnostic purposes.

② The **Number of Heads** field specifies the number of read/write heads on the drive. The Number of Heads is always 5.

③ The **Starting Cylinder**, **Drive Step Rate**, and **Loading Zone Cylinder** bytes are not used by the drive.

④ When the **Rotational Position Locking (RPL)** bits are 00_{BINARY}, rotational position locking is changeable. The external reference is not checked and no reference signal is transmitted. This is the default value. All drives arbitrate at power-up to see which will be the master. Once the master is determined, all other drives will synchronize their spindles to the master. When a drive has just powered-up and is calibrating the heads, it checks the Reference signal line for a reference pulse. If no pulse is detected, the drive takes over as the master and begins sending the reference pulse.

When the RPL bits are 01_{BINARY}, the drive operates as a synchronized-spindle slave.

When the RPL bits are 10_{BINARY} or 11_{BINARY}, the drive operates as a synchronized-spindle master.

7.5 Caching Page

The Caching Page is shown below. This table summarizes the function, default value and changeability value for each byte/bit.

Bit Byte	7	6	5	4	3	2	1	0
0	PS	RSVD	Page Code (08_H)					
1	Page Length in Bytes (12_H)							
2	IC	ABPF	CAP	DISC	SIZE	WCE	MF	RCD
(Default)	1	0	0	1	0	0	0	0
Changeable ①	1	0	1	0	0	0	0	1
3	Demand Read Retention Priority ②				Write Retention Priority ③			
(Default)	0	0	0	0	0	0	0	0
Changeable	0	0	0	0	0	0	0	0
4 - 5 (Default)	Disable Prefetch Transfer Length ($FFFF_H$) ④							
Changeable	0000_H							
6 - 7 (Default)	Minimum Prefetch (0000_H) ⑤							
Changeable	0000_H							
8 - 9 (Default)	Maximum Prefetch (0100_H) ⑥							
Changeable	0000_H							
10-11 (Default)	Maximum Prefetch Ceiling (0100_H) ⑦							
Changeable	0000_H							
12	FSW	RSVD	DRA	Reserved				
(Default)	1	0	0	0	0	0	0	0
Changeable ⑧	1	0	1	0	0	0	0	0

13	Number of Cache Segments							
(Default)	0	0	0	0	0	0	0	1
Changeable ⑨	1	1	1	1	1	1	1	1
14 - 15	Cache Segment Size							
Changeable ⑩	0000_H							
16	Reserved (00_H)							
17 - 19 ❶	Non-Cache Segment Size							
Changeable	000000_H							

① When the **Initiator Control (IC)** bit is one, the drive uses the Number of Cache Segments field to control the caching algorithm. This is the default value and is non-changeable.

The **Abort Prefetch (ABPF)** bit, when set to zero, indicates that the drive controls completion of prefetch. See DISC below. This is the default value and is non-changeable

The **Caching Analysis Permitted (CAP)** bit, when set to zero, indicates that caching analysis be disabled to reduce overhead time or to prevent non-pertinent operations from impacting tuning values. This is the default value and is non-changeable.

The **Discontinuity (DISC)** bit, when set to one, indicates that the drive may Prefetch across time discontinuities. This is the default value and is non-changeable.

The **Size Enable (SIZE)** bit equals zero, the Initiator requests that the Number of Cache Segments is to be used to control caching segmentation. This is the default value and is non-changeable.

The **Write Cache Enable (WCE)** bit, if zero, tells the drive to return Good status for a Write command after successfully writing all the data to the media. If one, tells the drive to return good status for a Write command after successfully receiving the data and before successfully writing it to the media.

The **Multiplication Factor (MF)** bit, if zero, tells the drive to interpret the Minimum Prefetch and Maximum Prefetch fields in terms of the number of logical blocks for each of the respective types of Prefetch. This is the default value and is non-changeable.

The **Read Cache Disable (RCD)** bit of zero specifies that the drive may return data requested by a Read command by accessing either the cache or the media. If RCD is one, the cache will not be used.

② The **Demand Read Retention Priority** field is not used. No special retention priority may be assigned by the initiator.

③ The **Write Retention Priority** field is not used. No special retention priority may be assigned by the initiator.

④ The **Disable Prefetch Transfer Length** fields selectively disables anticipatory Prefetch on long transfer lengths. A value of FF_H indicates that the drive is advised that it should attempt an anticipatory prefetch for all Read commands. This is the default value and is non-changeable.

⑤ The **Minimum Pre-fetch** field is an advisory parameter. It is interpreted as specifying a number of blocks. The number of blocks is the number the host tells the drive to prefetch regardless of the delays it might cause in executing subsequent commands. By setting this field to zero, the host is advising the drive that prefetching should be terminated whenever another command is ready to be executed. The host can advise the drive to ignore this consideration by setting the Minimum Prefetch equal to Maximum Prefetch.

⑥ The **Maximum Pre-fetch** field specifies a number of blocks. The number of blocks is the number that the host advises the drive to prefetch if there are no delays in executing subsequent commands. This field tells the drive the maximum amount of data to prefetch into the cache for any single Read command.

⑦ The **Maximum Pre-fetch Ceiling** field is a control parameter and should be equal to the Maximum Pre-fetch. The Maximum Pre-fetch Ceiling and Maximum Pre-fetch fields are indistinguishable if the MF bit is zero.

⑧ The **Force Sequential Write (FSW)** bit, when set to one, indicates that multiple block writes are to be transferred over the SCSI bus and written to the media in an ascending, sequential, logical block order. This is the default value and is non-changeable.

The **Disable Read-Ahead (DRA)** bit, when set to one, requests that the target not read into the buffer any logical blocks beyond the addressed logical blocks. When the DRA bit equals zero, the target may continue to read logical blocks into the buffer beyond the addressed logical blocks. This is the default value.

Note: By definition, if RCD is one, no read ahead is performed regardless of the value of the DRA.

⑨ The **Number of Cache Segments** advises the target how many segments the host requests that the cache be divided into. Valid values are 1, 2, 4, 8, 16 and 32.

⑩ The **Cache Segment Size** field indicates the segment size in bytes. This standard assumes that the Cache Segment Size field is valid only when the SIZE bit is one. This field is ignored on Mode Select commands.

❶ The **Non-Cache Segment Size** is zero to indicate that the entire buffer is available for caching.

7.6 Notch Page

The Notch page is shown below. This table summarizes the function, the default value, and changeability value for each byte/bit.

This 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 to as a notch.

Each notch spans a set of consecutive logical blocks on the logical unit. Notches do not overlap. No logical block is excluded from a notch.

Bit Byte	7	6	5	4	3	2	1	0
0	PS (1)	RSVD	Page Code ($0C_H$)					
1	Page Length in Bytes (16_H)							
2	ND	LPN	Reserved					
Default	1	0	0	0	0	0	0	0
Changeable ①	0	0	0	0	0	0	0	0
3	Reserved							
4 - 5 ②	Maximum Number of Notches (0013_H)							
6 - 7	Active Notch							
Changeable ③	$001F_H$							
8 - 11	Starting Boundary							
Changeable ④	00000000_H							
12 - 15	Ending Boundary							
Changeable ⑤	00000000_H							
16 - 23	Pages Notched							
	0000000000000008_H							
Changeable ⑥	0000000000000000_H							

① When the **Notched Drive (ND)** bit is one, the device is notched. For each supported active notch value, this page defines the starting and ending boundaries of the notch. This is the default value and is non-changeable.

When the **Logical or Physical Notch (LPN)** bit is one, the notch boundaries are based on logical blocks of the logical unit. The cylinder is considered most significant, the head is least significant. This is the default value and is non-changeable.

② The **Maximum Number of Notches** field indicates the maximum number of notches supported by the logical unit.

③ The **Active Notch** field indicates the notch that this and all subsequent Mode Select and Mode Sense commands refer to, until the active notch is changed by a later Mode Select command. The value of the Active Notch field must be greater than or equal to zero and less than or equal to the Maximum Number of Notches. An active notch value of zero indicates that this and subsequent Mode Select and Mode Sense commands refer to the parameters that apply across all notches.

④ The **Starting Boundary** field indicates the beginning of the active notch, if the active notch is not zero, or the starting boundary of the logical unit, if the active notch is zero. This field is not changeable. This field is ignored by the Mode Select command.

When the LPN bit is zero, the three most significant bytes represent the cylinder number and the least significant byte represents the head number.

⑤ The **Ending Boundary** field indicates the end of the active notch, if the active notch is not zero, or the end of the logical unit, if the active notch is zero. This field is not changeable. This field is ignored by the Mode Select command.

When the LPN bit is zero, the three most significant bytes represent the cylinder number and the least significant byte represents the head number.

⑥ The **Pages Notched** field is a bit map of the mode page codes. This field indicates which pages may contain different parameters for each notch. When a bit is one, the corresponding mode page may contain different parameters for each notch. When a bit is zero, the corresponding mode page contains the same parameters for all the notches. The most significant bit of this field corresponds to Page Code $3F_H$ and the least significant bit corresponds to Page Code 00_H. This field is unchangeable.

7.7 Power Condition Page

The Power Condition page is shown below. This table summarizes the function, the default value, and changeability value for each byte/bit.

Bit Byte	7	6	5	4	3	2	1	0
0	PS (1)	RSVD	Page Code ($0D_H$)					
1	Page Length in Bytes ($0A_H$)							
2	Reserved							
3	Reserved						Idle	Stand by
Default	0	0	0	0	0	0	0	0
Changeable ①	0	0	0	0	0	0	1	1
4 - 7 (default)	Idle Condition Timer (00000064_H)							
Changeable ②	$FFFFFFFF_H$							
8 - 11 (default)	Standby Condition Timer (00000000_H)							
Changeable ③	00000000_H							

This page allows the initiator to control the delay before the drive can change its power requirements. Sometimes, when a command is received, the drive must change to a power mode from which it can execute the command. The initiator is not notified when the drive changes power modes.

① When the **Idle** bit is set to one, the drive must use the Idle Condition timer to measure the delay before entering Idle. When the Idle bit is set to zero, the drive cannot enter Idle.

When the **Standby** bit is set to one, the drive must use the Standby Condition timer to measure the delay before entering Standby. When the Standby bit is set to zero, the drive cannot enter Standby. This mode is not implemented.

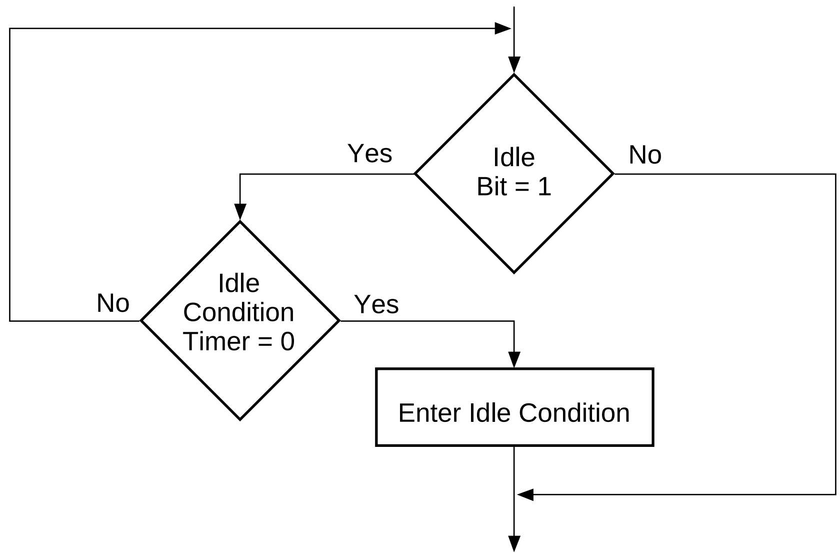
② The **Idle Condition Timer** field contains the delay time before the drive can enter Idle. The delay time is in 100-msec increments.

③ The **Standby Condition Timer** field contains the delay time before the drive can enter Standby. The delay time is in 100-msec increments.

The following table provides examples of how the values in the Power Condition page affects the drive. In the table, X means don’t care.

Bit Setting		**Timer**		**Results**
Standby Bit	**Idle Bit**	**Standby Mode**	**Idle Mode**	
1	0	0	X	The drive enters Standby upon completion of any command.
0	1	X	0	The drive enters Idle upon completion of any command.
1	1	0	X	The drive enters Standby when the Idle Condition Timer field contains zero.

Figure 31: Power Modes Flowchart



7.8 Cache Control Page

The Cache Control page is shown below. Bytes 2 through 15 are ignored by the Mode Select command. Page 38_H is a reflection of corresponding bytes in Page 08_H.

Bit / Byte	7	6	5	4	3	2	1	0
0	PS	Page Code (38_H)						
1	Page Length in Bytes ($0E_H$)							
2	RSVD	WIE	RSVD	CE	Cache Table Size ①			
3	Prefetch Threshold ②							
4	Maximum Prefetch ③							
5	Maximum Prefetch Multiplier ③							
6	Minimum Prefetch ④							
7	Minimum Prefetch Multiplier ④							
8 - 15	Reserved ⑤							

① The **Cache Enable (CE)** bit is the inverse of the RCD byte in Mode Page 08_H.

The **Write Index Enable (WIE)** controls the creation of Cache data on Write commands. If Bit 6 is zero, the next command treats the cache area as empty.

The **Cache Table Size** is a reflection of Mode Page 08_H, Byte 13, Bits 3 through 0.

② The **Pre-fetch Threshold** is not implemented. The drive reads until the buffer is full upon receipt of a Read command.

③ The **Maximum Pre-fetch Multiplier** is a reflection of Mode Page 08_H, Byte 9.

④ The **Minimum Pre-fetch Multiplier** is a reflection of Mode Page 08_H, Byte 7.

⑤ All reserved bytes have a value of zero and are not changeable.

7.9 Soft ID Page (EEPROM)

The Soft ID page is shown below. This table summarizes the function, the default value, and changeability value for each byte/bit.

This page is saved in an EEPROM that has a life span of 10,000 writes.

Bit Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	PS 1	Page Code ($3C_H$)						
1	Page Length 01_H							
2 default	Soft ID 0	Soft Parity 0	Param enable 0	Soft remote 0	Remote S/S 0	ID 2 0	ID 1 0	ID 0 0
changeable	1	1	1	1	1	1	1	1

The **ID0**, **ID1**, and **ID2** bits are the SCSI ID bits. These bits are only valid when the Soft ID bit is 1.

When the **Soft Remote** bit is one, the drive ignores the electrical remote jumper switch setting.

When the **Remote S/S** bit is one, the drive remotely spins up during startup. When the Remote S/S bit is 0, the drive spins up according to how the delay spin up is set. This bit is only valid if the Soft Remote bit is one.

The **Param Enable** bit indicates that the drive enables parity checking. This bit is only valid if the Soft Parity bit is 1.

When the **Soft ID** bit is one, the drive ignores the SCSI ID jumpers and uses ID0, ID1 and ID2 to determine the SCSI ID. When the Soft ID bit is zero, the drive ignores ID0, ID1 and ID2 and uses the SCSI ID jumpers to determine the SCSI ID. The drive must not use the same ID the host is using.

7.10 Operating Page

The Operating page is shown in the table below. This table summarizes the function, the default value, and changeability value for each byte/bit.

This vendor-unique page is saved to the medium along with other non-EEPROM pages. The Usage bit is not saved if the new parameters are identical to the current contents in the EEPROM. To preserve the EEPROM writable life cycle limit, the EEPROM memory is not updated.

The drive accepts Page 00_H with a length of two bytes, with Byte 4, the Spin-up Delay field, assumed to be unchanged.

Bit / Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	PS	Page Code (00_H)						
	1	0	0	0	0	0	0	0
1	Page Length in Bytes (02_H or 03_H)							
2 Default	Usage	Reserved		ATOFF	Reserved			
	1	0	0	0	0	0	0	0
Changeable ①	1	0	0	1	1	1	1	1
3 Default	Rsrvd 0	Device Type Qualifier (00_H)						
Changeable ②	0	$7F_H$						
4 Default	Spin-Up Delay (00_H)							
Changeable ③	FF_H							

① When the **Usage bit** is one, warnings are enabled. When the write life span of the EEPROM is exceeded, a warning message is generated. (See additional sense error code C2.) When the Usage bit is zero, no warning message is generated. If requested, the EEPROM data and the write counter is updated even after the write life span is exceeded, but data integrity cannot be assured. The write life span of the EEPROM is specified by the manufacturer.

When the **Disable Unit Attention (ATOFF)** bit is one, the drive does not issue UNIT ATTN during power up.

② The **Device Type Qualifier** is the host-programmable field in the EEPROM non-volatile memory. The field can have a value from 00_H to $7F_H$. This field can be read back by the host in Inquiry data, Byte 1. See Section 6.1.9.1.

③ The **Spin Up Delay** field controls the drive when it is not in the remote mode. When the value is 00_H, the drive spins up without delay. When the value is FF_H, the drive delays spin-up to a duration, in seconds, equal to the drive's SCSI bus ID number times 5. When the value is between 01_H and FE_H, the drive delays spin-up for the corresponding decimal duration, in seconds.

Appendix: Error Recovery

The error recovery procedures varies according to parameter values and the states of “flags” stored in error recovery parameter storage locations in the drive control memory. The drive control firmware error recovery routines reference these parameters when an error recovery procedure is performed. These error recovery parameters are changeable by Mode Select commands from the initiator. See Sections 6.1.10 and 7.1.

In general, when a read error occurs, the drive attempts to recover using retries and application of ECC. If the error still exists, the drive reports Check Condition in the status returned to the initiator. The initiator may then issue the Request Sense command. The drive replies with a Data In phase with extended sense data containing information about the error. If the error is recovered, it is reported only if the PER bit is set. See the section on the Request Sense command in Section 6.1.3 for a list of sense key, error key codes.

A.1 Seek Errors (09_H or 15_H)

If a seek error occurs, up to three retries are attempted by positioning the heads to track zero and re-issuing the seek. If all retries fail, error code 09_H or 15_H is reported in the extended sense data.

A.2 Data Field Write Fault (03_H)

If a write fault is detected while writing the data field, the operation will be immediately suspended. If the internal write fault can be cleared, the drive will automatically perform a rewrite of the sector (up to 3 attempts will be made to clear the write fault and rewrite the sector).

If the Write Fault condition cannot be cleared, the Write Fault error (03_H) will be reported in the extended sense data.

A.3 Sync Byte Error (12_H)

If the sync byte cannot be recovered during a read, up to 27 retries will be attempted using the offset combinations shown below.

No Servo Offset	Retry 9 times
Servo Offset Plus	Retry 9 times
Servo Offset Minus	Retry 9 times

A.4 Data Field ECC Error (11_H or 18_H)

If the EER bit is one, ECC correction is applied as soon as possible. If the EER bit is zero, data field ECC is not applied unless all retry attempts are exhausted, and ECC is specified by DCR bit and Retry Count. If the ECC error persists and is within the correction span being used (11 bits) the data is corrected and sent to the initiator if that capability is enabled by DTE bit. Data correction by ECC does not occur unless two ECC syndrome matches occur. For unrecoverable ECC errors, an error code of 11_H is reported. (See Section 7.1.)

A.5 Alternate Sector Processing

Any media defect detected during formatting or listed internally in the factory recorded defect table will already have been assigned an alternate sector in an area not directly accessible by the initiator. If conditions are appropriate, the initiator may want to call for a complete reformatting of the drive. The options available when that is done are discussed in Section 6.1.4.

If Automatic Read Reallocation (ARRE) is disabled, the initiator should request that media errors (that occur after formatting) be reassigned using a Reassign Blocks command.

If Automatic Read Reallocation (ARRE) is enabled, read errors that require more than 3 retries to recover or read errors that require ECC correction to recover will be automatically reallocated by the drive. The initiator should not use the Reassign Blocks command to reallocate these flaws. The initiator should still use the Reassign Blocks command to reallocate unrecoverable sectors.

If Automatic Write Reallocate (AWRE) is disabled, the drive will report a No Record Found status if a header cannot be recovered. The initiator should request that bad sector(s) be reallocated using the Reassign Blocks command and then rewrite the record.

If Automatic Write Reallocation (AWRE) is enabled, the drive will automatically reallocate the sector and rewrite the data field if a header cannot be recovered. The initiator should not use the Reassign Blocks command or rewrite the sectors if AWRE is a 1 and it receives a Record Not Found status.