

**Quantum ProDrive Series™
Intelligent Disk Drives**

ProDrive™ 40S/80S

Product Manual

**Quantum Corporation
730-00-9302**

**Rev: A
Date: 6/88**

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UL/CSA/VDE

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SECTION 1

GENERAL DESCRIPTION AND SPECIFICATIONS

1.1 GENERAL DESCRIPTION

The Quantum *ProDrive Series*[™] is a family of ten hard disk drives using non-removable 3 1/2-inch rigid disk platters as storage media. These drives feature formatted capacities ranging from 42 to 168 megabytes and a variety of interfaces. This manual covers the *ProDrive*[™]40S and *ProDrive* 80S, which feature the industry-standard Small Computer System Interface (SCSI) host interface. The *ProDrive* 40S has 42 megabytes of formatted capacity on two disks with three movable heads; the *ProDrive* 80S has 84 megabytes of formatted capacity on three disks with six movable heads. These drives make optimum use of powerful SCSI commands to provide maximum system performance. Media defects and error recovery are efficiently managed within these products and can be fully transparent to the user. The *ProDrive Series* drives feature an innovative design using an integrated controller, minimum number of parts, and close control of product quality during manufacture. The result is low cost, high reliability products.

NOTE: Throughout this manual, *ProDrive* 40S/80S or *ProDrive* will refer to either the *ProDrive* 40S or the *ProDrive* 80S. *ProDrive* 40S and *ProDrive* 80S will be used to refer specifically to the 42 and 84 megabyte versions, respectively.

1.1.1 APPLICABLE DOCUMENTS

This document provides a general description of the *ProDrive* 40S/80S, including installation, principles of operation, interface command implementation, and maintenance. Additional information pertaining to the SCSI interface may be found in the ANSI X3.131-1986, Small Computer System Interface Specification Common Command Set, Rev 4B, (by an ANSC X3T9.2 working group).

1.2 SPECIFICATIONS

Key features of the *ProDrive* 40S/80S include:

- Formatted storage capacity of 42 or 84 megabytes
- Industry-standard (ANSI) SCSI host interface, CCS, Rev 4B
- Fully integrated SCSI controller
- Industry standard 3 1/2-inch form factor
- Data transfer rate of up to 2.0 megabytes/second asynchronous, 4.0 megabytes/second synchronous
- Full disconnect/arbitrate/reconnect capability
- 64 KB look-ahead, programmable DisCache[®]
- 19 msec average access time
- 48 bit computer generated cyclic ECC (Error Correcting Code) with 11-bit burst correction capability
- Automatic retry for read disk errors
- Transparent defect mapping
- High-performance in-line defective sector skipping and reassignment of new defective sectors without need to reformat
- Buffer memory parity and SCSI bus parity
- Patented AIRLOCK[®] automatic shipping lock and dedicated landing zone
- Read/Write with 1:1 interleave operation
- Support for 512, 1024, and 2048 byte logical block sizes
- Multiple block data transfer up to 64K blocks

1.2.1 PHYSICAL SPECIFICATIONS

Environmental Limits

Ambient Temperature -	Non-Operating:	-40°F to 140°F (-40°C to 65°C) 42°F/hr (20°C/hr) gradient
	Operating:	39°F to 122°F (4°C to 50°C) 23°F/hr (10°C/hr) gradient
Ambient Relative Humidity -	Non-Operating:	5% to 95% without condensation Maximum wet bulb = 115°F (46°C)
	Operating:	8% to 85% without condensation Maximum wet bulb = 79°F (26°C)
Altitude (relative to sea level) -	Non-Operating:	-200 (-60M) to 40,000 ft. (12 km)
	Operating:	-200 (-60M) to 10,000 ft. (3 km)

Mechanical Dimensions (Exclusive of Faceplate)

Height	=	1.625 in.	(41.3 mm)
Width	=	4.0 in.	(101.6 mm)
Depth	=	5.75 in.	(144.9 mm)
Weight	=	1.9 lb.	(0.88 kg)

Heat Dissipation

Average Power Consumption (idle):	8 Watts (27.3 BTU/Hr)
Typical Power Consumption (30% Seeking):	9 Watts (30.7 BTU/Hr)

Power consumption includes power dissipated by drive's SCSI bus terminators.

Shock and Vibration

Table 1-1 lists specified levels for shock and vibration applied to any of the three mutually perpendicular axes (the principal drive base axes). The term "operating" implies that the drive will be fully functional while being subjected to the shock or vibration level listed during operation. "Non-operating" implies that there will be no change in performance once the drive is powered up after being subjected to the listed shock or vibration in the powered-down (non-operating) condition.

TABLE 1-1 Vibration and Shock Specfication

	Operating	Non-Operating
VIBRATION:		
5-500 Hz Sine Wave (Peak to Peak)	0.50 G	2.00 G
1 Oct/Min Sine Sweep		
SHOCK:		
1/2 Sine Wave of	10 G (1 soft error/shock)	60 G
11 msec Duration (10 hits maximum)	(6 G No soft errors)	

In addition, the *ProDrive* as packaged in the shipping container will withstand drops onto a concrete surface from 48 inches on all surfaces, six edges and three corners. It will withstand vibration applied to the container of 0.5 G, 5-100 Hz (0 to Peak) and 1.5 G, 100-500 Hz (0 to Peak).

1.2.2 PERFORMANCE SPECIFICATIONS

Capacity

	ProDrive 40S	ProDrive 80S
Formatted capacity (MB) *	40	80
Number of 512 byte sectors	82,029	164,058

* One megabyte is defined as 2^{20} bytes

Data Transfer Rates	Buffer to SCSI Bus -	Up to 2.0 Mbytes/second asynchronous, 4.0 Mybtes/seconds synchronous
	Disk to Buffer -	Up to 1.25 Mbytes/second in bursts

Seek Times/Miscellaneous Times

DESCRIPTION	TYPICAL NOMINAL CONDITION	NOMINAL CONDITION	MAXIMUM WORST CASE CONDITION
Single Track Seek (msec)	6	7	7
Average Seek (msec)	19	21	23
1/3 Stroke Seek (msec)	20	23	25
Full Stroke Seek (msec)	35	40	45
Average Rotational Latency (msec)	8.3	8.3	8.3
Sequential Head Switch (msec)	3.0	3.0	3.0
Power-Up Time (sec)	13	15	18

NOTES: Quoted seek times include head settling time but do not include command overhead or latency time. Seek time is the time required for the actuator to seek and settle on track.

Seek times are measured by averaging 1000 seeks of the indicated length. Average seek time is the average of 1000 random seeks. In the rare occurrence of a seek error, any individual seek may take up to 5 seconds for recovery.

Sequential head switch time is the time required for the head to move from the end of the last sector on a track to the beginning of the next sequential sector, located on the next track, same cylinder. This time is fixed by the track skewing feature of the drive. (See Appendix B.)

Power-up time is the time from the supply voltages reach operating range to the time the drive is able to accept all commands.

Nominal conditions are defined as 25°C ambient temperature, nominal supply voltages, and no applied shock or vibration. Worst case conditions are defined as worst case extremes of temperature and supply voltages.

Media Quality

The *ProDrive* features defect management, which eliminates the need to manually identify defects. Defect management is completely transparent to the user. See Appendix C for a detailed description of the *ProDrive* defect handling procedure and ECC (Error Correcting Code) capability.

Error Rates

Random Data Errors (2):	1 error per 10^{10} bits read (maximum)
Defect Data Errors (3):	1 error per 10^{12} bits read (maximum)
Unrecoverable Data Errors (4):	1 error per 10^{14} bits read (maximum)
Seek Errors (5):	1 error per 10^6 seeks (maximum)

Error rates are defined by Quantum as follows:

- 1) A data error is one (1) sector read incorrectly. Data error rates are defined as average rates measured over at least 1000 different sectors under any of the specified operating conditions except applied shock or vibration.
- 2) Random errors are those which do not exhibit a repeating error pattern, i.e., the error does not occur twice in a row within a specified number of retry reads; the default is eight. (Retries are terminated once data is read correctly.) The sectors will not be automatically reallocated since the errors are probably not due to media defects. See Appendix C for information on defect handling.
- 3) Defect errors are those which exhibit a repeating error pattern, i.e., the error occurs twice in a row within eight retry reads, and cannot be read without error up to that point. Such errors are likely due to media defects. The sectors will be automatically reallocated if the Automatic Read Reallocation Enabled bit in page 1H and the Reallocate Uncorrectable Error Enabled bit in page 39H of the MODE SELECT command are set to 1. (The default is 0: automatic reallocation is not performed.) See Appendix C for a description of error correction options.
- 4) Unrecoverable errors are those whose final retry error pattern is uncorrectable using ECC: retry reads are terminated by either a repeating error pattern, or eight attempts without reading correctly.
- 5) A seek error is any seek in which the drive does not locate the desired cylinder, or any seek in which the drive must go through a full recalibration routine to locate the desired cylinder. A full recalibration takes approximately five seconds.

1.2.3 FUNCTIONAL SPECIFICATIONS

	ProDrive 40S	ProDrive 80S
Nom Rotational Speed (RPM)	3,662 $\pm 0.3\%$	3,662 $\pm 0.3\%$
Max Recording Density (bpi)	22,055	22,055
Max Flux Density (fci)	14,700	14,700
Track Density (tpi)	1,000	1,000
Data Cylinders	834	834
Data Tracks	2,502	5,004
R/W Heads	3	6
Disks	2	3
Encoding Scheme	RLL 2,7	RLL 2,7

1.2.4 RELIABILITY SPECIFICATIONS

MTBF: 50,000 POH typical usage
PM: Not required
MTTR: 30 minutes
Start/Stop: 10,000 cycles

1.2.5 ACOUSTICS

Idle Mode: 45 dBa maximum at 1 foot in any direction

1.2.6 STANDARDS AND REGULATIONS

The *ProDrive* disk drives satisfy the following standards and regulations:

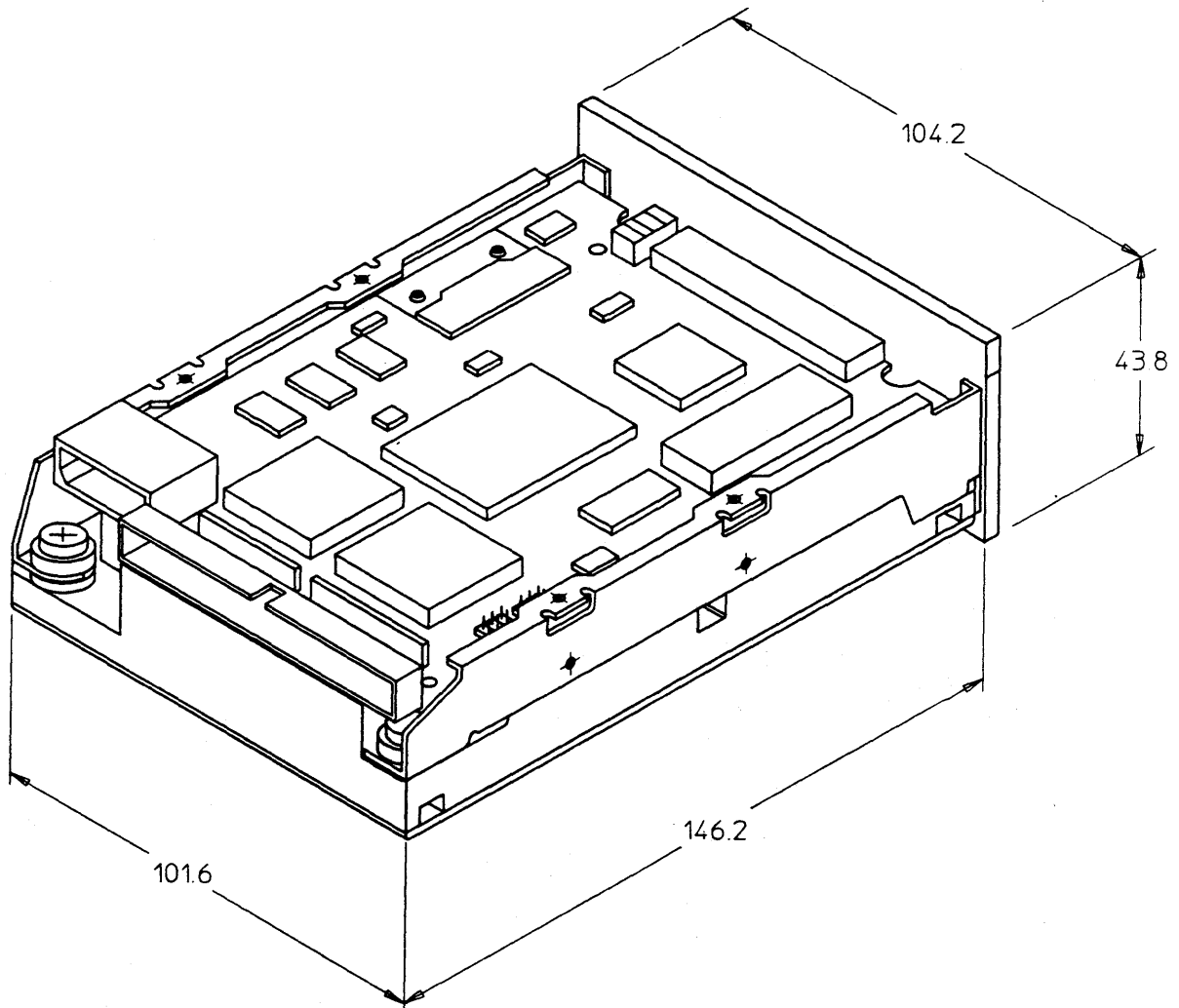
- a) U.L.: Standard 478, Standard for Safety, Electronic Data Processing Units and Systems
- b) CSA: Standard C22.2-154 Data Processing Equipment
SDA: Standard C22.2-143 Office Equipment
- c) VDE: VDE 0806, (IEC 380), Standard for Office Appliances and Machines
- d) FCC: FCC Rules for Radiated and Conducted Emissions, Part 15, Sub Part J, For Class B Equipment

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2.1 INSTALLATION

2.1.1 SPACE REQUIREMENTS

The *ProDrive* disk drives are shipped with a faceplate installed and shock mounts mounted directly to the base casting. Figure 2-1 shows the external dimensions of the drives.



All dimensions in millimeters

FIGURE 2-1 *ProDrive Mechanical Dimensions*

2.1.2 UNPACKAGING INSTRUCTIONS

- a) Open the shipping container.
- b) Lift shipping container material and remove drive.

Figure 2-2 illustrates the 8-pack packing assembly for the *ProDrive*. The list following the figure identifies each item.

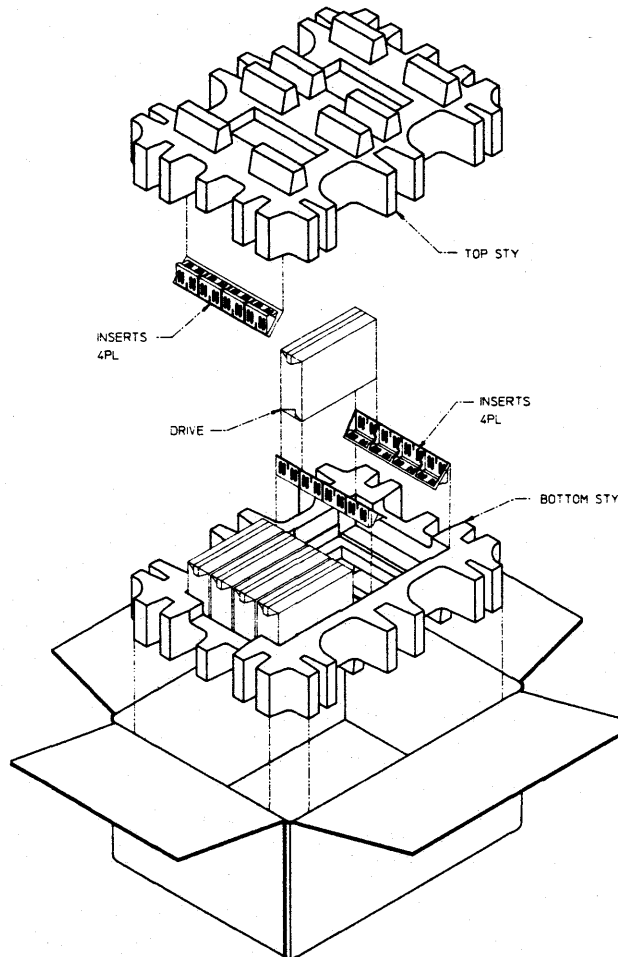


FIGURE 2-2 ProDrive Packing Assembly

Packing Assembly Item Description:

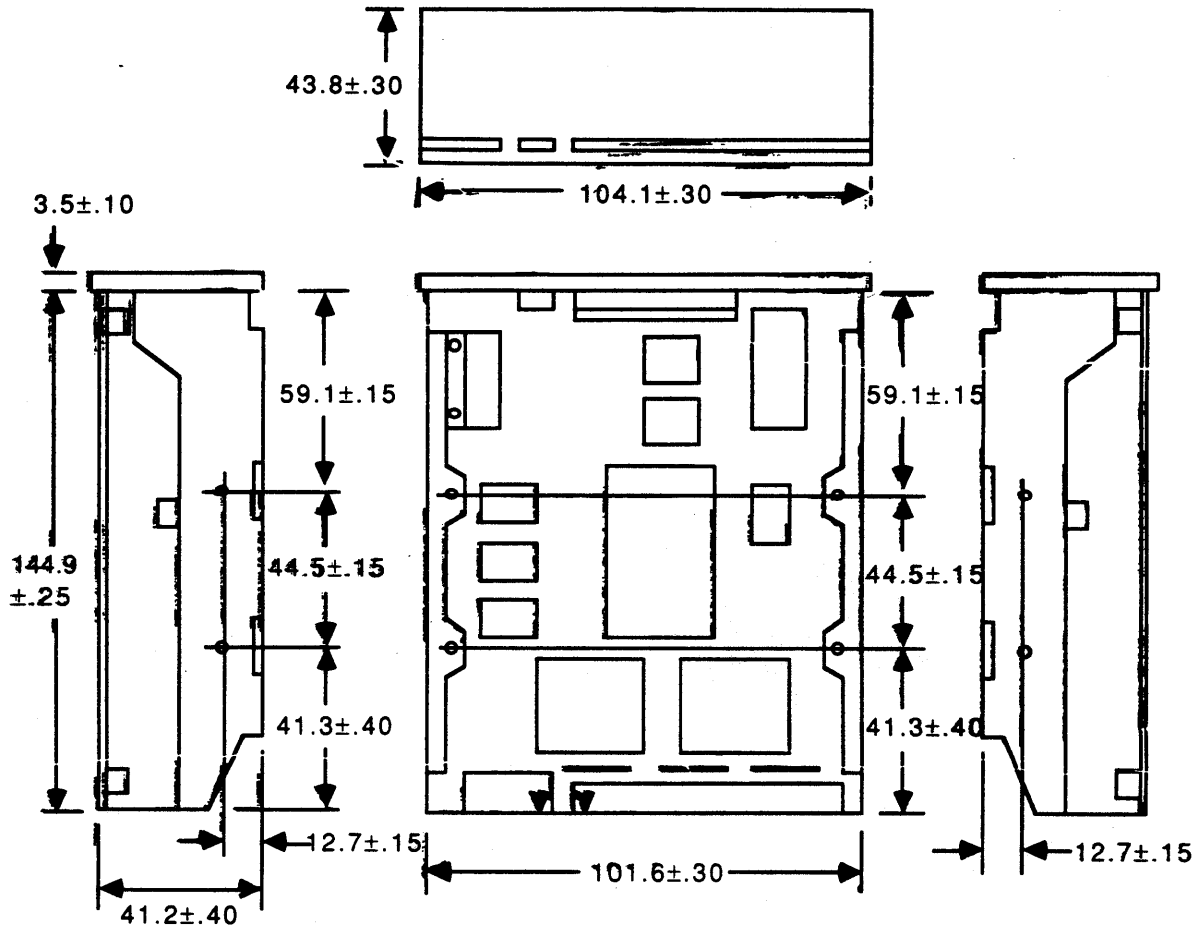
- A. Shipping Container (8-pack)
- B. Internal Padding
- C. *ProDrive* Disk Drive
- D. Package inserts

NOTES: After unpacking the disk drive(s), store the packing materials for possible future use.

The ESD bag is used to prevent electronic component damage during handling and shipment. You should ensure that your handling and shipping procedures will also preclude damage due to electrostatic discharge.

2.1.3 MOUNTING

The *ProDrive* may be mounted in any orientation. The mounting bracket with integral shock mounts is designed for this purpose. Figure 2-3 shows the location of the mounting bracket and the four mounting holes on each side of the bracket.



All dimensions in millimeters

FIGURE 2-3 *ProDrive Mounting Dimensions*

CAUTION:

The base casting is very close to the drive mounting bracket. Mounting screw lengths must be chosen so that no more than the specified length of screw thread protrudes through the mounting bracket holes. See Figure 2-4. This length will allow full use of the mounting hole threads and avoid damaging or placing unwanted stress on the base casting. To avoid stripping the mounting hole threads, the maximum torque applied to the mounting screws must not exceed 8 inch-pounds.

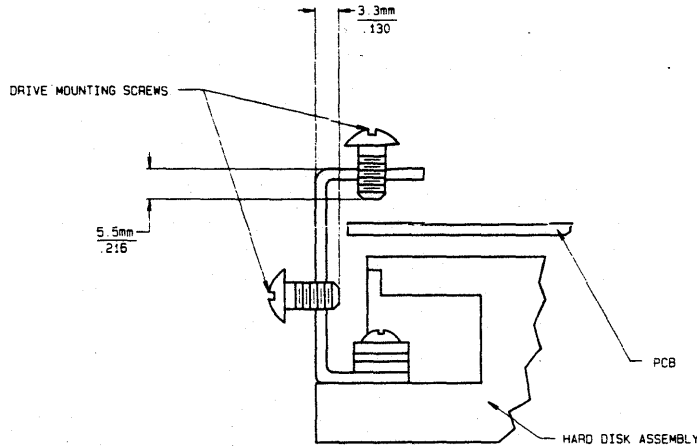


FIGURE 2-4 ProDrive Mounting Screw Clearance

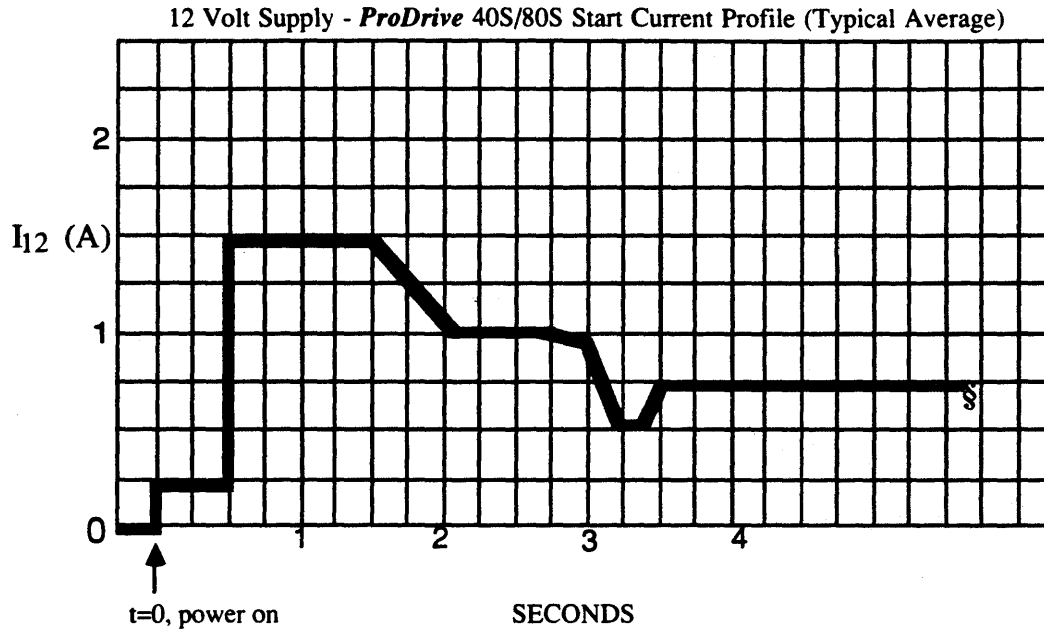
2.1.4 POWER REQUIREMENTS

DC Power

The voltages and current requirements of the DC Power supplied to the drive are listed below. No power sequencing either OFF or ON is required by the *ProDrive*. Power requirements include SCSI terminator power.

Voltage	Nominal	+12V	+5V
	Tolerance	±10%	±5%
Current	Typical (Idle)	0.50A	0.50A
	Typical (Seeking)	0.80A	0.60A
	Maximum (Power Up)	1.60A	0.65A
Ripple and Noise	Maximum	100 mV P-P	50 mV P-P

Drive Startup Current Profile



Power Sequencing

No damage or loss of data will occur if power is applied or removed during drive operation, except that data may be lost in the sector being written at the time of power loss. In particular, the drive can sustain transient voltages +10% to -100% from nominal while powering up or down, as well as the shorting out or opening up of either voltage or return line.

Power Reset Limits

- +5 Volts: 4.6 to 4.5 Volts
- +12 Volts: 10.2 to 9.6 Volts

When powering up, the drive will remain reset (inactive) until both reset limits are exceeded. When powering down, the drive will become reset when either supply voltage drops below the lower threshold; hysteresis is 50 mV minimum.

2.2 VENTILATION

The *ProDrive* operates without a cooling fan provided the ambient air temperature does not exceed 122°F (50°C). Any user-designed cabinet should provide adequate air circulation so that this maximum air temperature is not exceeded.

2.3 INTERCONNECTING CABLE CONNECTORS

2.3.1 DC POWER CONNECTOR

The DC power connector (J2) is a 4-pin DuPont Connector (SK 20055-000) mounted on the back edge of the PCB near the SCSI connector. See Figure 2-5. The recommended mating connector (P2) (AMP P/N 1-480424-0) utilizes AMP pins [P/N 350078-4 (strip) or P/N 61173-4 (loose piece)]. J2 pins are labeled on the J2 connector.

- Pin 1 +12 volts DC
- Pin 2 +12 volt return (ground)
- Pin 3 +5 volt return (ground)
- Pin 4 +5 volts DC

NOTE: Pins 2 and 3 are connected on the drive.

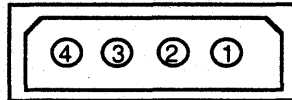


FIGURE 2-5 DC Power Connector (J2)

2.3.2 SCSI CONNECTOR

One SCSI cable connector (J1) is required for the *ProDrive*. Details of the signals required can be found in Section 4 - SCSI Interface.

Connection to J1 is through a 50-pin Universal Header connector. A connector sketch is shown in Figure 2-6. A key slot is provided to prevent incorrect installation of the mating connector. The recommended mating connector for J1 is AMP receptacle P/N 1-499508-2 (with strain relief) or P/N 1-746195-2 (without strain relief), or equivalent.

NOTE: Unkeyed mating connectors should not be used due to the possibility of plugging the connector in backwards.

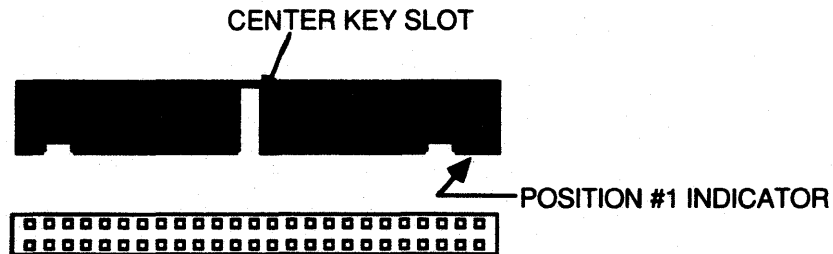


FIGURE 2-6 SCSI Connector (J1)

2.4 OPERATION

2.4.1 GENERAL PROCEDURES

Configuration of a *ProDrive* disk drive varies depending on the system in which it is to be installed. This section describes the user-selectable hardware options that should be set prior to installation. Figure 2-7 identifies the location of shorting plugs and terminators on the Printed Circuit Board which control these options. In addition to the optional hardware configurations described below, *ProDrive* operation can also be affected by many optional features controlled by individual SCSI commands. See Section 5 for information about the SCSI commands.

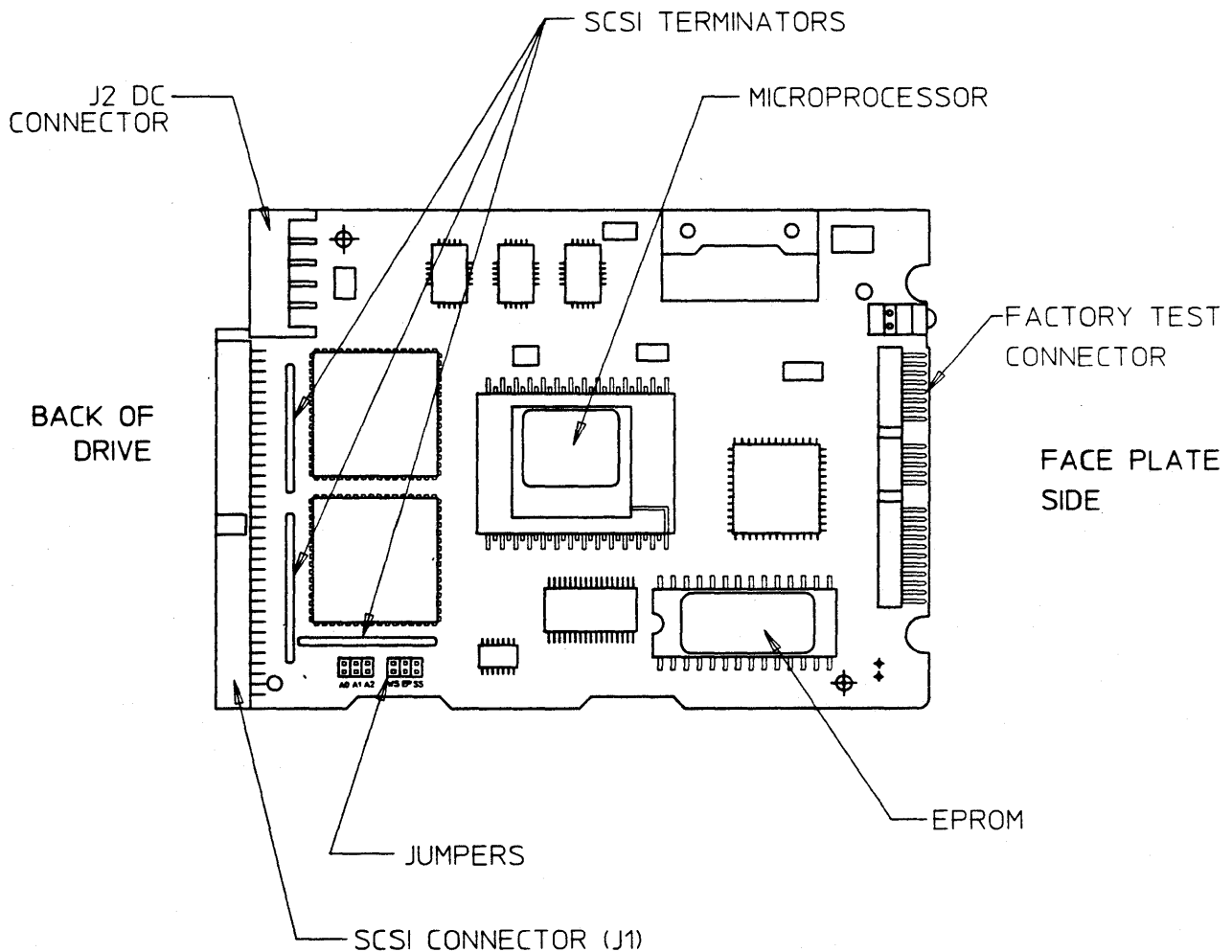


FIGURE 2-7 Shorting Plug/Terminator Locations on the PCB

2.4.2 SELF SEEK TEST OPTION

The self seek test continuously exercises the actuator of the drive. When shorting plug option SS is installed, the drive will perform random seek patterns, verifying target IDs after every seek. The pattern will repeat as long as power is applied to the drive or until an error has occurred.

The *ProDrive* is sent from the factory with shorting plug SS not installed (Self Seek Test disabled).

2.4.3 ENABLE PARITY OPTION

Shorting plug EP controls the checking of parity across the SCSI bus. When this plug is installed, parity checking of data across the SCSI bus is enabled. With EP removed, parity checking is not performed, although parity is still generated.

The *ProDrive* is sent from the factory with shorting plug EP installed (Parity enabled).

2.4.4 WAIT SPIN OPTION

The WS shorting plug controls the Wait/Spin option. When this plug is installed, the motor will not spin upon power-up or reset until the host sends the START/STOP command across the SCSI bus. This permits power sequencing so that the system power supply will not be overloaded by many devices demanding peak start current at the same time. Once the START/STOP command is received, the drive will be ready within 15 seconds. When the WS shorting plug is not installed, the motor will automatically start spinning upon power-up or reset and be ready within 15 seconds.

The *ProDrive* is sent from the factory with the WS plug not installed (Wait/Spin option disabled).

2.4.5 SCSI BUS DEVICE IDENTIFICATION

The SCSI bus can support up to eight devices including the host system. The identity number determines the priority level of each device, so careful consideration must be taken in choosing the identity number of the *ProDrive* prior to installation.

Three shorting plugs (A2, A1 and A0) shown in Figure 2-7, are used for device identification. These plugs comprise a 3-bit binary number in which A2 is the most significant bit and A0 is the least significant. Installation represents a 1, meaning that with all shorting plugs installed the device identity is 7. With no shorting plugs installed, the device identity is 0.

The *ProDrive* is sent from the factory with plugs A2 and A1 installed (device 6).

2.4.6 FACEPLATE LED OPERATION

The green LED located on the *ProDrive's* faceplate illuminates when the drive is executing a command. It lights at the beginning of a command and does not go off until the command is completed or aborted. The LED remains on even when the drive is disconnected from the initiator during a command.

2.4.7 DRIVER TERMINATORS

The *ProDrive* contains three resistor networks, in sockets, to terminate the SCSI bus. The location of these terminators is shown in Figure 2-7. Section 3.2.2 of the manual describes the function of these terminators. It is important to note that only the first device (usually the host) and the last device on the SCSI bus should contain the terminators. When a *ProDrive* is used in a position on the bus other than the first or last, all three of the terminators must be removed.

The *ProDrive* is sent from the factory with the terminators installed.

3.1 ProDrive 40S/80S DRIVE MECHANISM

The drive mechanism consists of the mechanical subassemblies which are sealed under a metal cover. These subassemblies are not adjustable nor are they field repairable. Please refer to Figure 3-1.

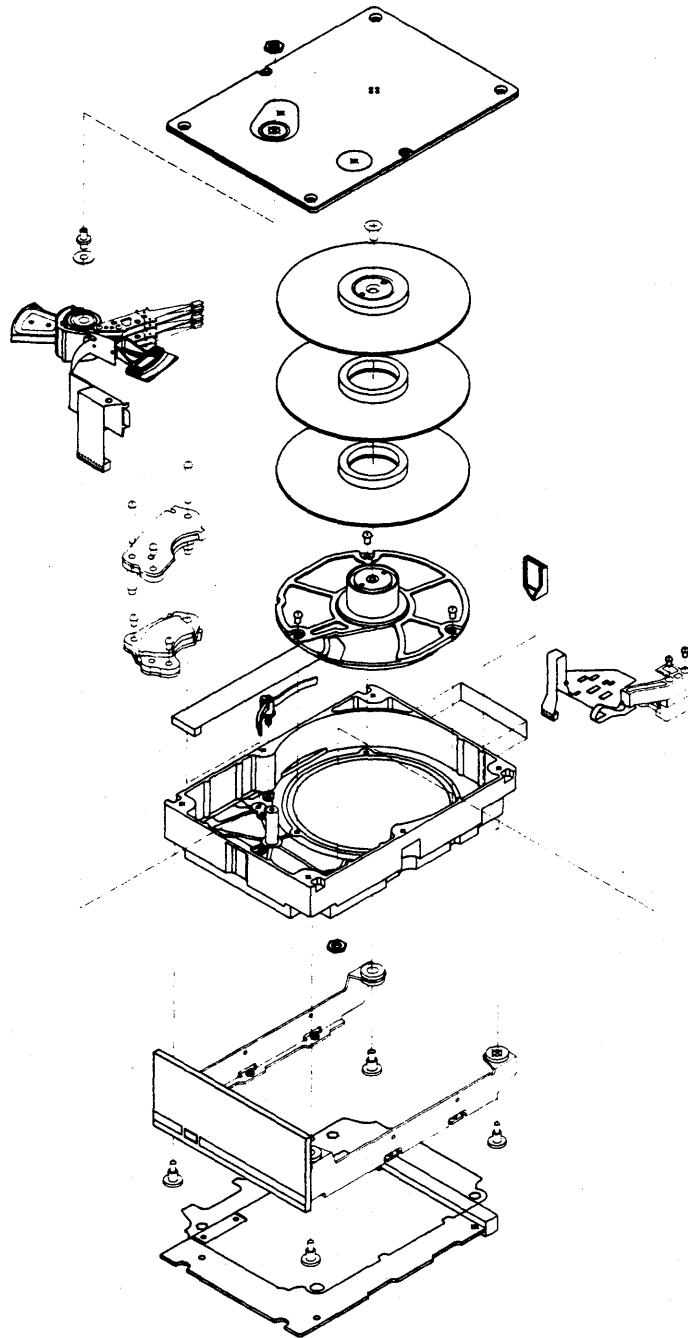


FIGURE 3-1 ProDrive Exploded View

3.1.1 BASE CASTING ASSEMBLY

The base casting is a single-piece cast aluminum alloy which provides a mounting surface for the rest of the drive mechanism. It has two machined holes for mounting the motor/spindle assembly and the positioner assembly. A gasket is mounted on the outside top edge to ensure a seal with the metal cover. Surfaces are provided for mounting the magnet plate assemblies for the rotary positioner assembly, and a read/write preamplifier. Mounting holes are provided outside the cover area, for the PCB and shock mount bracket assembly.

3.1.2 DISK STACK ASSEMBLY

The disk stack assembly is secured to the DC spindle motor which is bolted to the base casting. It consists of disks, disk spacers and a disk clamp. The DC motor assembly consists of a DC motor, spindle bearing assembly, disk mounting hub, and ferro-fluid magnetic seal. This seal prevents outside air from entering the drive through the bearing bore or along the bearing shaft. In the *ProDrive* 80S, three disks and two spacers are placed on the hub and clamped in place; the *ProDrive* 40S uses two disks and one spacer. The disks are an aluminum alloy with a thin film magnetic metal coating which is lubricated using a carbon overcoat. This overcoat prevents head and media wear when the heads are in contact with the disk surface, which only occurs outside the data area.

3.1.3 ROTARY POSITIONER ASSEMBLY (ACTUATOR)

The positioner used on the *ProDrive* is a Quantum proprietary design. It consists of the upper and lower magnet plates, a rotary single phase coil, a headstack mounting hub, and a bearing shaft. The magnets are composed of two alternating poles bonded to the magnet plates which in turn, are bolted to the base casting. The rotor and hub are molded together. The shaft is pressed into the base casting. Crash stops mounted to the magnet plate assembly prevent the heads from being driven into the spindle or off the disk surface.

3.1.4 HEADSTACK ASSEMBLY

The headstack assembly consists of the read/write heads, head arms, spacers, flex circuit, an optical scale, and the rotary positioner assembly. It is designed such that the mass center of the entire stack is at the center of the mounting hub. This is accomplished without the need for external counterbalances through a design in which the head arms, optical scale, and rotary positioner coil assembly balance each other. The heads are mini-composite slider type heads. They are mounted to Whitney-style spring steel flexures which are screwed to the head arms. The head conductors are flex cables routed through one flex circuit. A read preamplifier/write driver is mounted to this flex circuit.

3.1.5 OPTICAL ENCODER

The optical encoder assembly consists of a housing, an infrared light-emitting diode (LED), a mirror, an optical reticle, a multi-cell photo diode matrix, and a flex circuit.

The infrared LED and the mirror are mounted in the upper portion of the housing. This allows the optical scale mounted with the headstack to move between the mirror-reflected light from the infrared LED and the lower portion of the housing which contains the reticle and photo cells. The reticle masks the photo cells so that each cell only receives light through a specific portion of the movable scale. Both the clearance and angular position of the reticle and scale are precision adjustments made when the drive is manufactured.

3.1.6 AUTOMATIC ACTUATOR LOCK

The *ProDrive* uses a dedicated landing zone to ensure data integrity and prevent damage during shipment. It also uses AIRLOCK®, Quantum's patented means of locking the headstack in the landing zone. The AIRLOCK consists of an airvane mounted close to the edge of the disk stack with an arm that intersects the actuator to hold the headstack in the landing zone whenever the disk is not rotating. As DC power is applied to the motor and the disk stack starts rotating, an airflow is generated around the disk. As airflow increases with disk rotation, the airvane and its arm rotate, enabling the headstack to move freely out of the landing zone. When DC power is removed from the motor, an electronic return mechanism automatically pulls the actuator into the landing zone so the AIRLOCK can hold it in place.

3.1.7 AIR FILTRATION

The *ProDrive* Series drives are Winchester type drives and, as such, the heads fly very close to the media surface. The nominal flying height is 8 microinches - more than 2500 times smaller than the period at the end of this sentence.

It is absolutely essential that the air circulating within the drive be kept free of particles. To this end, the drive is assembled in a Class 100 purified air environment, then sealed with a metal cover. During the life of the drive, the rotating disks act as an air pump to force the air through an internal filter. Figure 3-2 shows the air flow in the enclosed area of the drive.

The lowest pressure area within the drive is at the top in the center of the spindle. A 0.3 micron breather filter is bonded in this area of the cover. This filter allows outside air into the sealed area of the drive to equalize internal and external pressures. The highest pressure area within the drive is located at the outer edge of the disk. Another 0.3 micron filter called the circulation filter is mounted to the base casting at this location. Air is pumped continuously into the side of the filter facing the rotating direction of the disks, is filtered, and exits from the side of the filter facing away from the rotating direction of the disks. Since this area of the drive is at a lower pressure than at the edge of the disks, air will circulate through the filter. This setup ensures a continuous flow of filtered air as soon as the disks start to rotate. Due to the stringent cleanliness required, the cover and seals should not be tampered with.

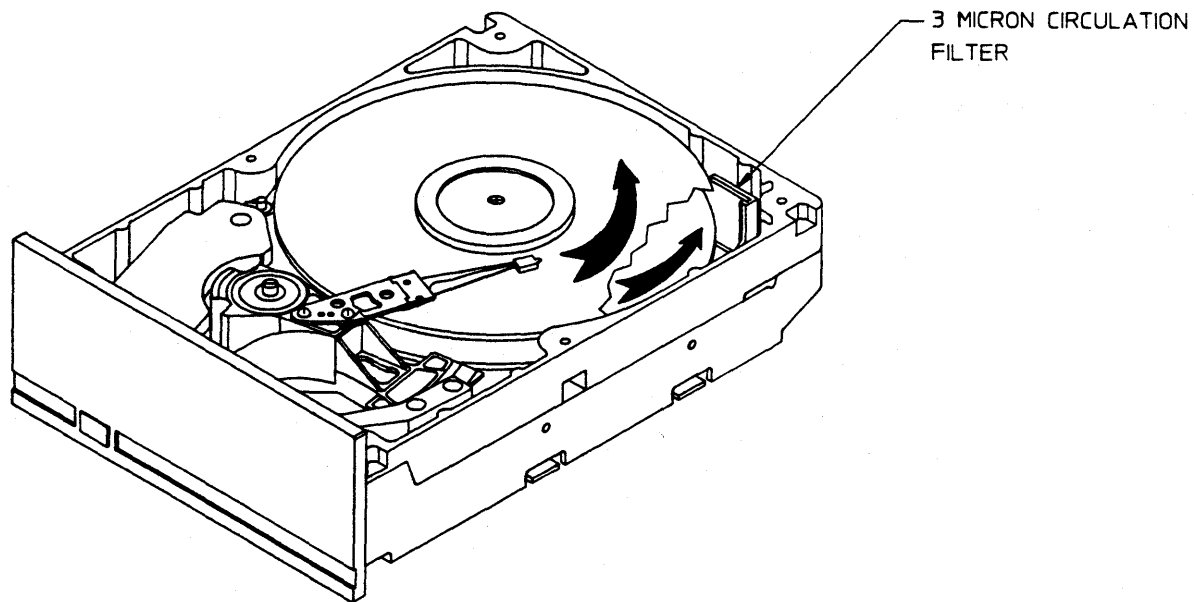


FIGURE 3-2 Air Filtration

3.2 ProDrive 40S/80S DRIVE ELECTRONICS

3.2.1 GENERAL DESCRIPTION

All drive electronics, including SCSI controller functions, are contained on one Printed Circuit Board Assembly (PCBA). This is accomplished through advanced circuit design and the use of miniature surface-mounted devices and proprietary VLSI components. The only electrical components not contained on the PCBA are the preamplifier chip for the read/write circuitry, and the electronic circuitry for the optical encoder photocells and infrared LED; these are located under the drive cover. The preamplifier is mounted as close to the read/write heads as possible to improve the signal-to-noise ratio. The following paragraphs provide operation details for major functional circuits within the drive.

3.2.2 HEAD POSITIONING SYSTEM

At power-on and at other predetermined times, wedge data on the inside and outside tracks is read by the read channel for each disk surface. This analog data is converted to a digital value by an on-chip A/D converter on the microcontroller. The controller uses these values to calculate the slope of the expected track position error line from outside to inside of each surface. These values are stored along with the current HDA internal temperature and a time mark. New values are read and the slope is recalculated whenever the temperature and/or time exceeds a predetermined value. When seeking, signals P1 and P2 from the optical encoder are used to determine track crossings. Once the actuator has positioned the head close to the desired track, the position error for that track is applied, and the head settles to the center of the proper track. Signals P1 and P2 are monitored and compared with a reference position to hold the head on track. Differences between the reference position and the position indicated by P1 and P2 will result in an output from the pulse width modulator. This signal is converted to an analog form and applied to the actuator driver, causing the actuator to move the head back onto the desired track centerline.

Figure 3-3 provides a block diagram of the head positioning electronics.

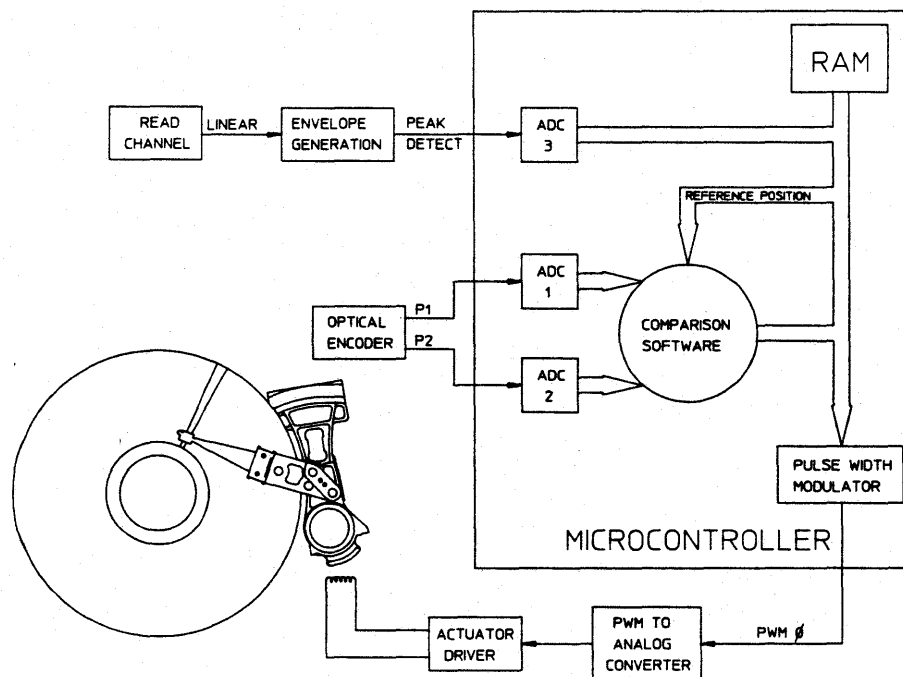


FIGURE 3-3 Head Positioning Electronics

3.2.3 READ/WRITE SYSTEM

The read channel path on the *ProDrive* begins at the heads as the magnetic flux transitions recorded on the disk pass under the heads causing a low amplitude output differential voltage. These signals pass from the head onto a flex circuit where a preamplifier/write driver IC is mounted to amplify the signal. Preamplification is done on the flex circuit at the point closest to the head to improve the signal to noise performance.

The flex circuit leaves the enclosed drive through a gap between the base casting and the cover, and connects with a mating header on the PCB. This gap is sealed by the cover gasket. Here the read signal is amplified further, filtered, and differentiated by the read data processor IC which outputs the signal READ DATA. This signal is fed to the data synchronizer/ENDEC IC which decodes the data into an NRZ data stream (NRZ), and a byte clock (BCLK). The IC also provides the signal address mark detected (AMD) if the data pattern read is the address mark pattern. These signals are fed to the data sequencer/DMA controller IC called SOLO. Once SOLO has identified the incoming data as belonging to the target sector(s) the data sequencer portion converts the NRZ serial bit stream into an 8 bit word. The DMA portion of SOLO then feeds this word to the cache/buffer RAM. The interface IC then outputs the data to the host with DMA control from SOLO.

Writing data is the reverse of reading in that data is presented at the interface IC and passed to SOLO as an 8-bit word. Data presented at a rate faster than can be written are temporarily stored in the cache/buffer RAM. In this way, data can be passed to the drive at a rate independent of the rate at which data can be written to the disk.

The data synchronizer/ENDEC IC provides SOLO with the signal address mark detect (AMD) and data to identify the target sector. Once SOLO detects the correct sector, it converts the data from an 8-bit word into a serial bit stream and passes this data and a clock to the data synchronizer/ENDEC IC. The data is then encoded into an RLL 2,7 bit stream and passed to the preamplifier/write driver IC via the write data line. The preamplifier/write driver IC receives the signal write gate from SOLO and writes the data to the disk.

Figure 3-4 provides a block diagram of the read/write electronics.

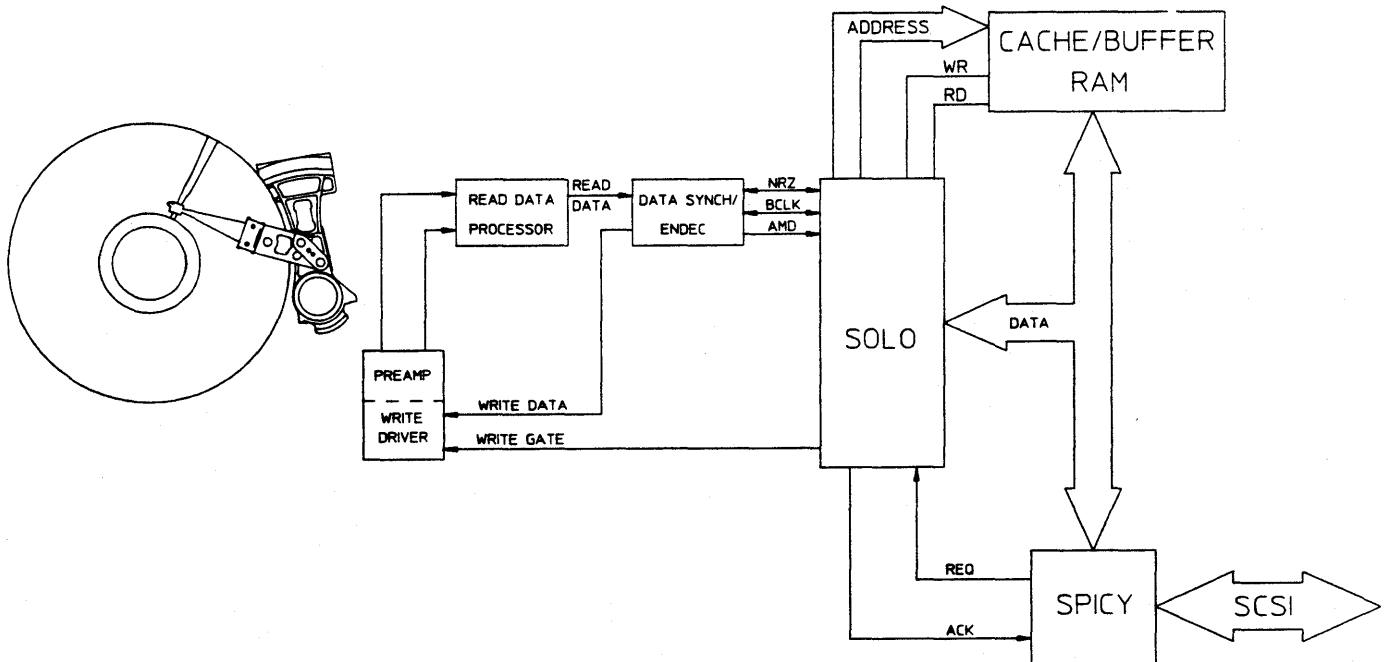


Figure 3-4 Read/Write Block Diagram

3.2.4 Interface Control

The Small Computer System Interface (SCSI) logic is implemented using an SCSI controller chip called SPICY. This chip interfaces to the host system through the 50-pin SCSI connector (J1); and to drive electronics including the microprocessor's control lines and address/data bus, and the DMA controller/data sequencer (SOLO).

The controller chip is configured to operate under control of the microprocessor, which can send and receive information through the multiplexed address/data bus. An address is strobed into the SCSI controller chip on the falling edge of ALE (Address Latch Enable). Data is then strobed from or onto the bus by -RD (read status from the controller chip) or -WR (write to the controller chip) if the address selects the chip.

The microprocessor can also command SPICY to perform data transfer operations between the SCSI bus and the buffer RAM in synchronous or asynchronous mode. SPICY reads or writes data from/to the buffer RAM over nine lines (eight data lines and one parity line). The transfer is controlled by the DMA controller/data sequencer IC (SOLO) which handles addressing of the buffer RAM for SPICY. Data can be transferred between the buffer RAM and SPICY at up to 8.0 MBytes/second in SOLO page mode operations. This high DMA transfer rate allows SPICY to communicate over the SCSI bus at a synchronous data rate of 4.0 MBytes/second, while SOLO simultaneously controls disk-to-RAM transfers and RAM refresh operations.

4.1 INTRODUCTION

The *ProDrive* 40S and *ProDrive* 80S disk drives are "intelligent" disk drives in that they feature an integrated Small Computer System Interface (SCSI) controller. This section defines the functional requirements for interfacing with the *ProDrive* 40S/80S via the SCSI bus, including the command set, bus timing, and other parameters. The paragraphs below are intended to provide a brief description of this interface. Refer to Section 5 for more detailed information on the *ProDrive* 40S/80S programming requirements.

4.2 ANSI CONFORMANCE

4.2.1 Conformance Level and Alternatives

The *ProDrive* 40S and 80S conform to ANSI X3T9.2/82-2 Revision 17B at conformance level 2 with the following alternatives supported: single-ended drivers, terminator power, parity, hard reset, and reservation queuing. In addition, the synchronous data transfer option is implemented with a minimum transfer period of 250 nanoseconds and a maximum REQ/ACK offset of 8.

4.2.2 Hardware Implementation Choices

In many cases, the ANSI specification allows more than one option. When more than one option is allowed, and only one option was implemented, the decision as to which option to implement was based on the following:

- All SCSI bus drivers are OR-tied type drivers and do not actively drive any signals to the false state.
- During arbitration, if the *ProDrive* loses arbitration due to a higher priority SCSI ID bit being driven on the SCSI data bus, it will release its signals without waiting for SEL to become true.
- During arbitration phase, DB(P) will be undriven.

4.3 SCSI INTERFACE CHARACTERISTICS

4.3.1 GENERAL DESCRIPTION

The SCSI bus can support up to eight SCSI devices in any combination of initiators and targets. The *ProDrive* always assume a fixed role as a target.

Certain SCSI bus functions are assigned to the initiator or the target:

- The initiator may arbitrate for the SCSI bus and select a particular target.
- The target may request the transfer of COMMAND, DATA, STATUS, or other information on the DATA BUS, and in some cases it may arbitrate for the SCSI bus and reselect an initiator for the purpose of continuing an operation.

Communication with the *ProDrive* takes place on the SCSI DATA BUS in asynchronous or synchronous mode, using a defined REQ/ACK handshake protocol.

4.3.2 SCSI ELECTRICAL CHARACTERISTICS

All signals are low true and use open collector drivers terminated with 220 ohms to +5 volts (nominal) and 330 ohms to ground at each end of the cable. Resistor networks in sockets are provided on the *ProDrive* to terminate the lines.

NOTE: If multiple devices will be connected to the SCSI bus, terminators should be removed in all but the two devices at the cable ends. See Section 2.4 of this manual for the location of terminators on the drive.

Each signal driven by the *ProDrive* has the following output characteristics:

- True (Signal Assertion) = 0.0 to 0.5 Vdc at 48 mA (max)
- False (Signal Non-Assertion) = 2.5 to 5.25 Vdc

Each signal from the host to the *ProDrive* must have the following characteristics (measured at the drive):

- True (Signal Assertion) = 0.0 to 0.8 Vdc
- False (Signal Non-Assertion) = 2.5 to 5.25 Vdc

A 50-pin connector is provided at position J1 for connecting to the standard SCSI bus. The standard SCSI single-ended non-shielded connection is used. All signals are asserted at the low level. All odd pins are grounded. (An exception is Pin 25 which is not connected.) A maximum cable length of 20 ft. (6 meters) is allowed. Figure 4-1 shows the SCSI connection pins.

SCSI Pins		
Ground	Signal	
1	2	- Data Bit 0 (DB0)
3	4	- Data Bit 1
5	6	- Data Bit 2
7	8	- Data Bit 3
9	10	- Data Bit 4
11	12	- Data Bit 5
13	14	- Data Bit 6
15	16	- Data Bit 7 (DB7)
17	18	- Data Bit P (DBP)
19	20	Ground
21	22	Ground
23	24	Ground
25		Open
	26	Terminator Power
27	28	Ground
29	30	Ground
31	32	- ATN
33	34	Ground
35	36	- BSY
37	38	- ACK
39	40	- RST
41	42	- MSG
43	44	- SEL
45	46	- C/D
47	48	- REQ
49	50	- IO

FIGURE 4-1 SCSI Bus Pin Assignments

4.3.2.1 Terminator Power

ProDrive supplies terminator power through a schottky diode and a 1-Amp fuse with the following characteristics:

V_{TERM} = 4.25 VDC to 5.25 VDC
800 milliamps minimum source drive capability when supplying both sets of terminators
1.0 milliamp maximum sink capability, except for the purposes of providing power to an internal terminator
1.0 Amp current limiting (fuse)

4.3.3 **BUS SIGNALS**

There are a total of 18 SCSI bus signals. Nine are control signals and nine are used for data. (The parity signal option is included as a data signal.) Definitions of these signals are given below:

Control Signals:

BSY (BUSY) - An "OR-tied" signal that indicates that 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 a target that indicates whether CONTROL or DATA information is on the DATA BUS. True indicates CONTROL.

I/O (INPUT/OUTPUT) - A signal driven by a target that controls the direction of data movement on the DATA BUS with respect to an initiator. True indicates input to the initiator. This signal is also used to distinguish between SELECTION and RESELECTION phases.

MSG (MESSAGE) - A signal driven by a target during the MESSAGE phase.

REQ (REQUEST) - A signal driven by a target to indicate a request for a 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.

Data Signals:

DB(7-0,P) (DATA BUS) - Eight data-bit signals, plus a parity-bit signal that 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 value is true and zero when the signal value is false.

DB(P) is set to either zero or one so that data parity is odd. The use of parity is a system option, but parity generation and checking must be consistent for all SCSI devices on the bus: either all SCSI devices on the bus must generate and check parity, or all SCSI devices on the bus must not check parity. Parity is not valid during the ARBITRATION phase.

4.3.3.1 Signal Values

Signals may assume true or false values. If any driver is asserted, the signal is true. Whenever the term negated is used in this manual, it means that the signal is actively driven false.

4.3.3.2 OR-Tied Signals

The BSY and RST signals are OR-tied only. During 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) shall not be 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.

4.3.3.3 Signal Sources

Table 4-1 indicates which type of SCSI device may source each signal. No attempt is made to show if the source is driving asserted, driving negated, or is passive. 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.

TABLE 4-1 SIGNAL SOURCES

Bus Phase	Signal		C/D I/O		
	BSY	SEL	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

Notes for Table 4-1:

- All:** The signal is driven by all SCSI devices that are actively arbitrating.
- SCSI ID:** A unique data bit (the SCSI ID) is driven by any SCSI device that is actively arbitrating; the other seven data bits are released (not driven) by this SCSI device. The parity bit (DP(P)) may be undriven or driven to the true state, but must never be driven to the false state during the arbitration 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 is driven only by the active initiator.
- None:** The signal must be released, i.e., not be 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 SCSI device that wins arbitration.
- Target:** If the signal is driven, it is driven only by the active target.

4.3.4 SCSI BUS TIMING

Unless otherwise indicated, the delay-time measurements are at the drive's own SCSI bus connection. Thus, these measurements, except cable skew delay, can be made without considering delays in the cable.

ARBITRATION DELAY (2.4 microseconds) - The minimum time an SCSI device must wait from asserting **BSY** for arbitration until the **DATA BUS** can be examined to see if arbitration has been won. There is no maximum time.

ASSERTION PERIOD (90 nanoseconds) - The minimum time *ProDrive* will assert **REQ** during synchronous data transfers. Also, the minimum time an initiator will assert **ACK** during synchronous transfers.

BUS CLEAR DELAY (800 nanoseconds) - The maximum time for an SCSI device to stop driving all bus signals after:

- 1) The **BUS FREE** phase is detected (**BSY** and **SEL** both false for a *bus settle delay*)
- 2) **SEL** is received from another SCSI device during the **ARBITRATION** phase
- 3) The transition of **RST** to true.

NOTE: For the first condition above, the maximum time for an SCSI device to clear the bus is 1200 nanoseconds from both **BSY** and **SEL** first becoming false. If an SCSI device requires more than a *bus settle delay* to detect **BUS FREE** phase, it must clear the bus within a *bus clear delay* minus the excess time.

BUS FREE DELAY (800 nanoseconds) - The minimum time that an SCSI device must wait from its detection of the **BUS FREE** phase (**BSY** and **SEL** both false for a *bus settle delay*) until its assertion of **BSY** when going to the **ARBITRATION** delay.

BUS SET DELAY (1.8 microseconds) - The maximum time before an SCSI device must assert **BSY** and its SCSI ID bit on the **DATA BUS** after it detects **BUS FREE** phase (**BSY** and **SEL** both false for a *bus settle delay*) for the purpose of entering the **ARBITRATION** phase.

BUS SETTLE DELAY (400 nanoseconds) - The time to wait for the bus to settle after changing certain control signals as called out in the protocol definitions.

CABLE SKEW DELAY (10 nanoseconds) - The maximum difference in propagation time allowed between any two SCSI bus signals when measured between any two SCSI devices.

DATA RELEASE DELAY (400 nanoseconds) - The maximum time before an initiator must release the **DATA BUS** signals following the transition of the **I/O** signal from false to true.

DESKEW DELAY (45 nanoseconds) - The minimum time required for deskew of certain signals.

HOLD TIME (45 nanoseconds) - During synchronous data transfers, 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.

NEGATION PERIOD (90 nanoseconds) - During synchronous data transfers, the minimum time the *ProDrive* will negate **REQ**, and the minimum time an initiator will negate **ACK**.

RESET HOLD TIME (25 microseconds) - The minimum time for which **RST** is asserted. There is no maximum time.

SELECTION ABORT TIME (200 microseconds) - The maximum time a target (or initiator) may take from its most recent detection of being selected (or reselected) until asserting a **BSY** response. This timeout is required to ensure 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.

SELECTION TIMEOUT DELAY (250 milliseconds) - The minimum time that an initiator (or target) should wait for a **BSY** response during the **SELECTION** (or **RESELECTION**) phase before starting the timeout procedure.

Figure 4-2 provides an SCSI bus timing diagram.

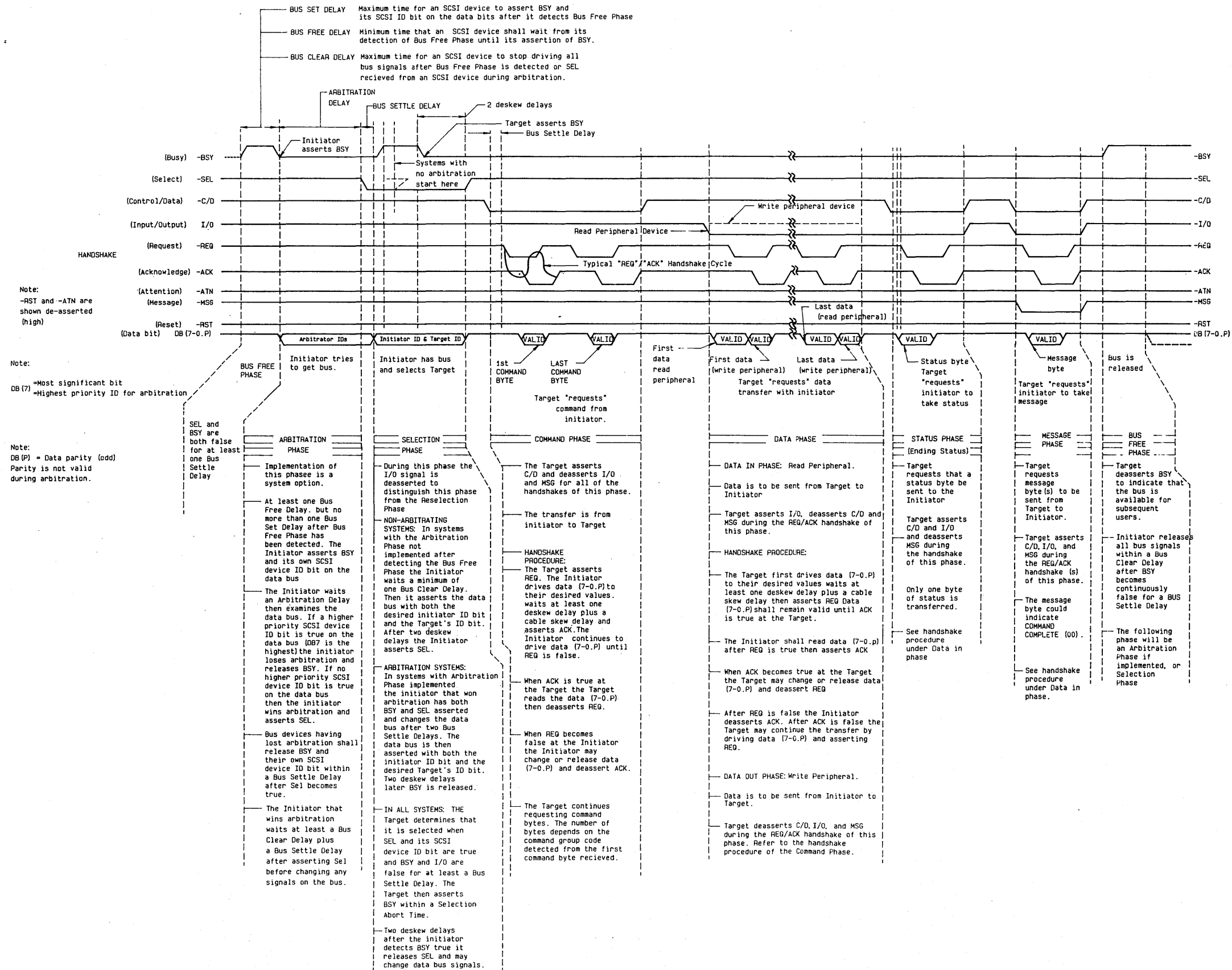


FIGURE 4-2 SCSI Bus Timing Diagram

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5.1 GENERAL DESCRIPTION

This section explains the functional operation of the SCSI commands implemented on the *ProDrive* 40S and 80S disk drives. Details on *DisCache*, track format, and defect management can be found at the end of this manual in Appendices A, B, and C, respectively.

5.2 SCSI BUS PHASES

The SCSI architecture includes eight distinct phases:

BUS FREE phase		
ARBITRATION phase		
SELECTION phase		
RESELECTION phase		
COMMAND phase	\	These phases are collectively termed the information transfer phases.
DATA phase	\	
STATUS phase	/	
MESSAGE phase	/	

The SCSI bus can never be in more than one phase at any given time. Unless otherwise noted in the following descriptions, signals that are not mentioned are not asserted.

5.2.1 BUS FREE PHASE

The BUS FREE phase is used to indicate that no SCSI device is actively using the SCSI bus and that it is available for subsequent users. SCSI devices must detect the BUS FREE phase after SEL and BSY are both false for at least a *bus settle delay*. All SCSI bus signals must be released by SCSI devices within a *bus clear delay* after BSY and SEL become continuously false for a *bus settle delay*. If a 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*.

5.2.2 ARBITRATION PHASE

The ARBITRATION phase allows one SCSI device to gain control of the SCSI bus so it can assume the role of an initiator or target.

NOTE: Implementation of the ARBITRATION phase is a system option. Systems that do not implement this option can have only one initiator. The ARBITRATION phase is required for systems that use the RESELECTION phase.

The procedure the *ProDrive* uses to obtain control of the SCSI bus is as follows:

- 1) The *ProDrive* will first wait for the BUS FREE phase to occur. This phase is detected whenever both BSY and SEL are simultaneously and continuously false for a minimum of a *bus settle delay*.
- 2) It will then wait at least a *bus free delay* after detecting the BUS FREE phase (i.e., after BSY and SEL are both false for a *bus settle delay*) before driving any signal.

- 3) Following the *bus free delay* in Step 2, the *ProDrive* will arbitrate for the SCSI bus by asserting both **BSY** and its own **SCSI ID**; however, it will not start to 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.
- 4) After waiting at least an *arbitration delay* (measured from its assertion of **BSY**) the *ProDrive* will examine the DATA BUS. If a higher priority **SCSI ID** bit is true on the DATA BUS (DB(7) is the highest), the *ProDrive* has lost the arbitration and will release its signals and return to Step 1. If no higher priority **SCSI ID** bit is true on the DATA BUS, the *ProDrive* has won the arbitration and will assert **SEL**.
- 5) If the *ProDrive* wins arbitration, it will wait 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 will be released by the *ProDrive*. Parity is not valid during the ARBITRATION phase. During the ARBITRATION phase, DB(P) is undriven by the *ProDrive*.

5.2.3 SELECTION PHASE

The SELECTION phase allows an initiator to select a target (*ProDrive*) for the purpose of initiating a target function such as a READ or WRITE command.

NOTE: The I/O signal is undriven to distinguish this phase from the RESELECTION phase.

5.2.3.1 Non Arbitrating Systems

If the ARBITRATION phase is not implemented, the initiator must first detect the BUS FREE phase, then wait a minimum of a *bus clear delay*. Then, except in certain single initiator environments with initiators employing the single initiator option, the initiator must assert the desired target's **SCSI ID** and its own initiator **SCSI ID** (and the parity bit if parity checking is implemented) on the DATA BUS. After two *deskew delays*, the initiator must assert **SEL**. See Section 5.2.3.4 for a description of the single initiator option.

5.2.3.2 Arbitrating Systems

If the ARBITRATION phase is implemented, the 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. This device becomes an initiator by not asserting I/O. Except in certain single initiator environments with initiators employing the single initiator option, the initiator must assert the desired target's **SCSI ID** and its own initiator **SCSI ID** (and the parity bit if parity is implemented) on the DATA BUS. The initiator must then wait at least two *deskew delays* and release **BSY**, then wait at least a *bus settle delay* before looking for a response from the target.

5.2.3.3 All Systems

In all systems, the *ProDrive* will determine 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 *ProDrive* will examine the DATA BUS in order to determine the **SCSI ID** of the selecting initiator unless the initiator employed the single initiator option (5.2.3.4). The *ProDrive* will then assert **BSY** within a *selection abort time* of its most recent detection of being selected; this is required for correct operation of the timeout procedure. If parity is implemented, the *ProDrive* will not respond to a selection if bad parity is detected. Also, if more than two **SCSI ID** bits are on the DATA BUS, the *ProDrive* will not respond to selection.

At least two *deskew delays* after the initiator detects **BSY** is true, it must release **SEL** and may change the DATA BUS. The *ProDrive* will wait for the initiator to release **SEL** before setting an information phase.

5.2.3.4 Single Initiator Option

Initiators that do not implement the RESELECTION phase and do not operate in the multiple initiator environment may set only the target's SCSI ID bit and not their own SCSI ID bit during the SELECTION phase. This makes it impossible for the target to determine the initiator's SCSI ID.

5.2.3.5 Selection Timeout Procedure

Two selection timeout procedures are specified for clearing the SCSI bus if the initiator waits a minimum of a *selection timeout delay* and there has been no BSY response from the *ProDrive*:

- 1) Optionally, the initiator may assert the RST signal. (See Section 5.3.2.)
- 2) Optionally, the initiator may continue asserting SEL and release the DATA BUS. If the initiator has not detected BSY to be true after at least a *selection abort time* plus two *deskew delays*, the initiator shall release SEL, allowing the SCSI bus to go to the BUS FREE phase. The *ProDrive* will only respond to a selection if the selection was still valid within a *selection time* of its assertion of BSY. This ensures that an improper selection does not result (two targets connected to the same initiator, wrong target connected to an initiator, or a target connected to no initiator).

5.2.4 RESELECTION PHASE

The RESELECTION phase allows a target to reconnect to an initiator to continue some operation that was previously started by the initiator but was suspended by the target (i.e., the target disconnected by allowing a BUS FREE phase to occur before the operation was complete).

5.2.4.1 Reselection

RESELECTION can only be used in systems that implement the ARBITRATION phase.

Following 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 *ProDrive* becomes a target by asserting the I/O signal. It will also set the DATA BUS to a value that is the OR of its SCSI ID bit and the initiator's SCSI ID bit. The *ProDrive* will wait at least two *deskew delays* and release BSY, then will wait at least a *bus settle delay* before looking for a response from the initiator.

The initiator will determine 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. It must then assert BSY within a *selection abort time* of its most recent detection of being reselected; this is required for correct operation of the timeout procedure. If parity is implemented, the initiator must not respond to a RESELECTION if bad parity is detected. Also, it should not respond to a RESELECTION if more than two SCSI ID bits are on the DATA BUS. After the *ProDrive* detects BSY, it will also assert BSY and wait at least two *deskew delays*, then release SEL. It may then change the I/O signal and the DATA BUS. After the reselected initiator detects SEL false, it must release BSY. The *ProDrive* will continue asserting BSY until it is ready to relinquish the SCSI bus.

5.2.4.2 Reselection Timeout Procedure

A RESELECTION timeout procedure is specified for clearing the SCSI bus during a RESELECTION phase if the target waits for a minimum of a *selection timeout* period and there has been no BSY response from the initiator:

The *ProDrive* will continue asserting SEL and I/O and will release all DATA BUS signals. If it does not detect BSY to be true after at least a *selection abort time* plus two *deskew delays*, it will release SEL and I/O, allowing the SCSI bus to go to the BUS FREE phase. When responding to RESELECTION, the

ProDrive will ensure that the RESELECTION was still valid within a *selection abort time* of its assertion of **BSY**. Otherwise, an improper reselection could result (two initiators connected to the same target or the wrong initiator connected to a target).

5.2.5 INFORMATION TRANSFER PHASES

The COMMAND, DATA, STATUS, and MESSAGE phases are grouped together as the information transfer phases because they are all used to transfer data or control information via the DATA BUS.

The C/D, I/O, and MSG signals are used to distinguish between the different information transfer phases. (See Table 5-1.) 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 **ProDrive** can cause the BUS FREE phase by releasing MSG, C/D, I/O, and BSY.

TABLE 5-1 Information Transfer Phases

Signal			Phase Name	Direction of Transfer	Comment
MSG	C/D	I/O			
0	0	0	DATA OUT	Initiator to target	Data phase
0	0	1	DATA IN	Initiator from target	Data phase
0	1	0	COMMAND	Initiator to target	
0	1	1	STATUS	Initiator from target	
1	0	0	*		
1	0	1	*		
1	1	0	MESSAGE OUT	Initiator to target	Message phase
1	1	1	MESSAGE IN	Initiator from target	Message phase

Key: 0 = False, 1 = True, * = Reserved for future standardization

The information transfer phases use one or more REQ/ACK handshakes to control the information transfer. 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. Additionally, during the information transfer phases, the **ProDrive** will continuously envelope the REQ/ACK handshake(s) with C/D, I/O, and MSG in such a manner 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.

5.2.5.1 ASYNCHRONOUS TRANSFER

The **ProDrive** controls the direction of information transfer by means of the I/O signal. When I/O is true, information will be transferred from the **ProDrive** to the initiator. When I/O is false, information is transferred from the initiator to the **ProDrive**.

If I/O is true (transfer to the initiator), the **ProDrive** will drive DB(7-0,P) to their desired values, delay at least one *deskew delay* plus a *cable skew delay*, then assert REQ. DB(7-0,P) will remain valid until ACK is true at the drive. The initiator should read DB(7-0,P) after REQ is true, then signal its acceptance of the data by asserting ACK. When ACK becomes true at the **ProDrive**, the drive may change or release DB(7-0,P) and will release REQ. After REQ is false, the initiator should negate ACK. Once ACK is false, the **ProDrive** may continue the transfer by driving DB(7-0,P) and asserting REQ, as described above.

If I/O is false (transfer to the target) the **ProDrive** will request information by asserting REQ. The initiator should drive DB(7-0,P) to their desired values, delay at least one *deskew delay* plus a *cable skew delay*, then assert ACK. When ACK becomes true at the **ProDrive**, the drive will read DB(7-0,P), then release REQ. When REQ becomes false at the initiator, the initiator may change or release DB(7-0,P) and must negate ACK. The target may continue the transfer by asserting REQ, as described above.

5.2.5.2 SYNCHRONOUS TRANSFER

Synchronous data transfer may be used in the data phase only if it was previously agreed to by the initiator and target via the message system. The messages determine the use of synchronous mode by the two SCSI devices, establishing a REQ/ACK offset and transfer period. See the Synchronous Data Transfer Request message (Section 5.6.2).

The REQ/ACK offset specifies the maximum number of REQ pulses that can be sent by the target before corresponding ACK pulses are received from the initiator. This establishes a pacing mechanism. If the number of REQ pulses sent exceeds the number of ACK pulses received by the REQ/ACK offset, the *ProDrive* will not assert REQ again until it receives the next ACK pulse. The number of ACK and REQ pulses must be equal for the data phase to be successfully completed.

The *ProDrive* will assert REQ for at least an assertion period. Before asserting REQ, it will wait at least a transfer period from the last transition of REQ to true, and a minimum of a negation period from the last transition of REQ to false.

The initiator must send one pulse on the ACK signal for each REQ signal received. The ACK signal must be asserted for at least an assertion period. Before asserting the ACK signal, the initiator must wait at least a transfer period from the last transition of ACK to true and a negation period from the last transition of ACK to false.

If I/O is true, (transfer to the initiator), the *ProDrive* will first drive DB(7-0,P) to the appropriate values, wait at least one deskew delay plus a cable skew delay, then assert REQ. DB(7-0,P) will be held valid for at least one deskew delay plus one cable skew delay, plus one hold time after the assertion of REQ. The *ProDrive* will assert REQ for at least an assertion period. It may then release REQ and change or release DB(7-0,P). The initiator must read the value on DB(7-0,P) within one hold time of the transition of REQ to true. It must then respond with an ACK pulse.

If I/O is false, (transfer to the *ProDrive*), the initiator must transfer one byte for each REQ pulse received. After receiving a REQ pulse, the initiator must first drive DB(7-0,P) to the appropriate values, delay at least one deskew delay plus one cable skew delay, then assert ACK. DB(7-0,P) must be valid for at least one deskew delay plus one cable skew delay plus one hold time after the assertion of ACK. ACK must be asserted for a minimum of an assertion period. At that point, the initiator may negate ACK and may change or release DB(7-0,P). The *ProDrive* will read the value of DB(7-0,P) within one hold time of the transition of ACK to true.

5.2.6 **COMMAND PHASE**

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

5.2.7 **DATA PHASE**

The data phase encompasses both the DATA IN and the DATA OUT phases.

5.2.7.1 DATA IN PHASE

The DATA IN phase allows the target to request that data be sent to the initiator from the target. The *ProDrive* will assert the I/O signal and negate C/D and MSG during the REQ/ACK handshake(s) of this phase.

5.2.7.2 DATA OUT PHASE

The DATA OUT phase allows the target to request that data be sent from the initiator to the target. The *ProDrive* will negate the C/D, I/O, and MSG signals during the REQ/ACK handshake(s) of this phase.

5.2.8 STATUS PHASE

The STATUS phase allows the target to request that status information be sent from the target to the initiator. The *ProDrive* will assert C/D and I/O and negate the MSG signal during the REQ/ACK handshake of this phase.

5.2.9 MESSAGE PHASE

The message phase refers to both the MESSAGE IN and MESSAGE OUT phases. The first byte transferred in either of these phases must be a single-byte message or the first byte of a multiple-byte message. Multiple-byte messages must be wholly contained within a single message phase.

5.2.9.1 MESSAGE IN Phase

The MESSAGE IN phase allows the target to request that messages be sent to the initiator from the target. The *ProDrive* will assert C/D, I/O, and MSG during the REQ/ACK handshake(s) of this phase.

5.2.9.2 MESSAGE OUT Phase

The MESSAGE OUT phase allows the target to request that a message be sent from the initiator to the target. The *ProDrive* will invoke this phase at its convenience in response to the ATTENTION condition created by the initiator. (See Section 5.3.1 for a description of the ATTENTION condition.)

The *ProDrive* will assert C/D and MSG and negate I/O during the REQ/ACK handshake(s) of this phase. It will handshake byte(s) in this phase until ATN goes false.

If the *ProDrive* receives all the message byte(s) successfully (i.e., no parity errors), it will change to any information transfer phase other than the MESSAGE OUT phase and transfer at least one byte. The *ProDrive* may also indicate that it has successfully received the message byte(s) by changing to the BUS FREE phase (e.g., ABORT or BUS DEVICE RESET messages).

5.2.10 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 direction from out to in (target to initiator), the *ProDrive* will delay driving the DATA BUS by at least a *data release delay* plus a *bus settle delay* after asserting the I/O signal, and the initiator must release the DATA BUS 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 to out (initiator to target), the *ProDrive* will release the DATA BUS no later than a *deskew delay* after negating I/O.
- 3) The ATN and RST signals may change as defined under the descriptions for the ATTENTION condition (5.3.1) and RESET condition (5.3.2).

5.3 SCSI BUS CONDITIONS

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

5.3.1 ATTENTION CONDITION

The ATTENTION condition allows an initiator to inform a target that the initiator has a message ready. The target may get this message at its convenience 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 phases.
- The *ProDrive* may respond with the MESSAGE OUT phase.

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. Normally, the initiator negates ATN while REQ is true and ACK is false during the last REQ/ACK handshake of the MESSAGE OUT phase.

5.3.2 RESET CONDITION

The RESET condition is used to immediately clear all SCSI devices from the bus. This condition takes precedence over all other phases and conditions. SCSI devices create the RESET condition by asserting REQ for a minimum of a reset hold time. During the RESET condition, the state of all SCSI bus signals other than RST is not defined.

NOTE: The *ProDrive* will never assert RST, but it will respond to a RST asserted by another SCSI device.

When RST is asserted, the *ProDrive* will release all SCSI bus signals (except RST) within a bus clear delay of the transition of RST to true. The BUS FREE phase always follows the RESET condition.

5.4 SCSI BUS PHASE SEQUENCES

Phases are used on the SCSI bus in a prescribed sequence. In all systems, 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.

5.4.1 NON-ARBITRATING SYSTEMS

In systems which do not use the ARBITRATION phase, the BUS FREE phase is followed by the SELECTION phase, then one or more of the information transfer phases (COMMAND, DATA, STATUS, or MESSAGE). See Figure 5-1.

5.4.2 ARBITRATING SYSTEMS

In systems which use the ARBITRATION phase, the BUS FREE phase is followed by ARBITRATION, then SELECTION or RESELECTION, then one or more of the information transfer phases (COMMAND, DATA, STATUS, or MESSAGE). See Figure 5-2.

5.4.3 ALL SYSTEMS

There are no restrictions on the sequences of information transfer phases. A phase type may even be followed by the same phase type; for example, a data phase may be followed by another data phase.

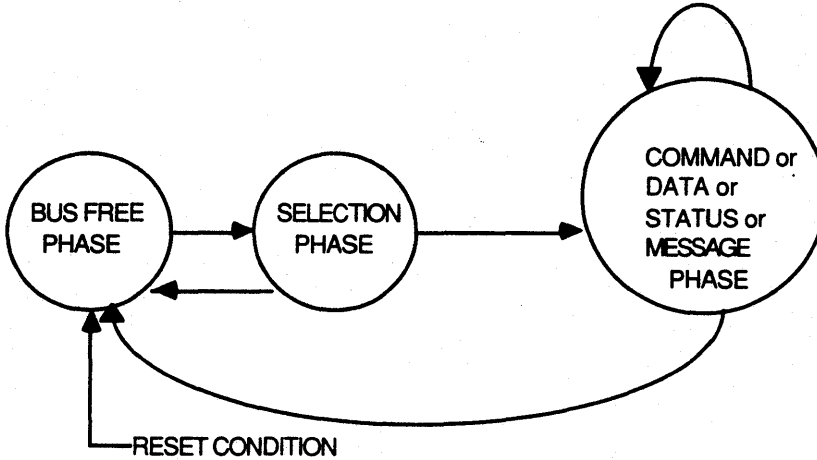


FIGURE 5-1 Phase Sequences without Arbitration

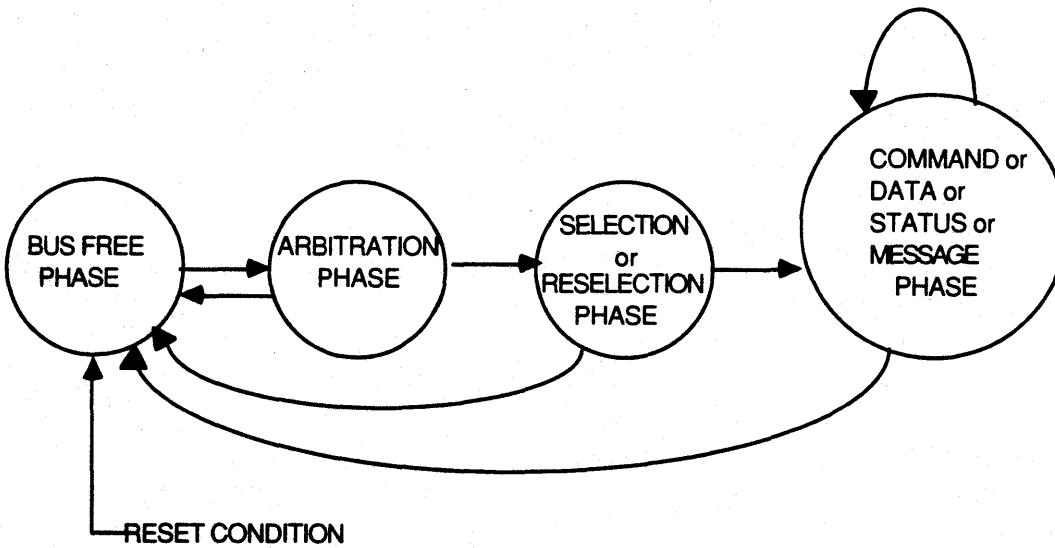


Figure 5-2 Phase Sequences With Arbitration

5.5 SCSI POINTERS

Consider the system shown in Figure 5-3 in which an initiator and target communicate on the SCSI bus to execute a command.

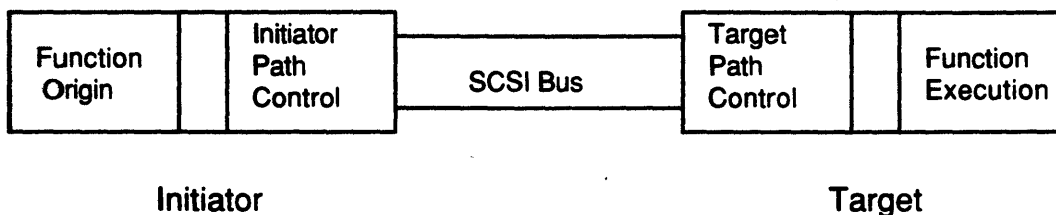


FIGURE 5-3 Simplified SCSI System

The SCSI architecture provides for two sets of three pointers within each initiator. The pointers reside in the initiator path control. The first set of pointers are the current (or active) pointers. These pointers are used to 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 current pointers in each initiator. The current pointers are used by the target currently connected to the initiator.

The second set of pointers are 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 for the current command. (See Section 5.7.1.) 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 (5.6.2) to the initiator. In response to this message, the initiator stores the value of the current data pointer into the saved data pointer. The target may restore the current pointers to their saved values by sending a RESTORE POINTERS message (5.6.2) to the initiator. The initiator moves the saved value of each pointer into the corresponding current pointer. Whenever a device disconnects from the SCSI bus, only the saved pointer values are retained. The current pointer values are restored from the saved values upon the next reconnection.

NOTE: On a READ, if the *ProDrive* disconnects before any data is transferred, the SAVE DATA POINTER message is not issued. Similarly, on a WRITE, if the drive disconnects after all data have been transferred, the SAVE DATA POINTER message is not issued.

5.6 MESSAGE SYSTEM SPECIFICATION

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

5.6.1 MESSAGE PROTOCOL

The *ProDrive* requires any SCSI device it communicates with to be able to receive and understand the COMMAND COMPLETE message. This is the only message an initiator communicating with the *ProDrive* is required to implement. To maximize flexibility, the *ProDrive* also supports all single byte (non-extended) messages defined in the ANSI SCSI Specification. The *ProDrive* will not send any message other than COMMAND COMPLETE until it is informed by the initiator that it can support other messages. The initiator does this in the SELECTION phase by asserting ATN prior to the SCSI bus condition of SEL true and BSY false. This informs the *ProDrive* that the initiator can at least generate a MESSAGE REJECT message if it does not understand a message from the *ProDrive*.

If the *ProDrive* detects the ATN signal asserted during SELECTION phase, it will enter MESSAGE OUT phase and take a message byte from the initiator. The *ProDrive* expects an IDENTIFY message at

this time. The NO OPERATION, BUS DEVICE RESET and ABORT messages will also function properly here. All other messages will be rejected with a MESSAGE REJECT message.

The IDENTIFY message the initiator sends to the *ProDrive* should specify LUN=0. If the initiator supports disconnect/reconnect, it should set bit 6 in the IDENTIFY message. (See Section 5.6.2.) Unless bit 6 is set, the *ProDrive* will not attempt to disconnect at any point during a command. Bit 6 should not be set unless the initiator can support receiving the SAVE DATA POINTER, and DISCONNECT messages. Upon receipt of a legitimate IDENTIFY message, the *ProDrive* will enter COMMAND phase and begin requesting command bytes from the initiator.

The *ProDrive* supports the messages shown in Table 5-2:

TABLE 5-2 Message Codes Supported By ProDrive

Code	Description	Direction	Supported
00 _H	COMMAND COMPLETE	In	
01 _H	EXTENDED MESSAGE - SYNCHRONOUS		
	DATA TRANSFER REQUEST	In	Out
02 _H	SAVE DATA POINTER	In	
03 _H	RESTORE POINTERS	In	
04 _H	DISCONNECT	In	
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
80 _H - FF _H	IDENTIFY	In	Out

KEY: In = *ProDrive* will originate message and send to Initiator.

Out = *ProDrive* will support receiving message from Initiator.

5.6.2 MESSAGES

The single byte messages supported by the *ProDrive* (Table 5-2) are listed below along with their code values and definitions.

COMMAND COMPLETE 00_H - This message is sent from the *ProDrive* to an initiator to indicate that the execution of a command (or series of linked commands) has terminated and that valid status has been sent to the initiator. After successfully sending this message, the *ProDrive* will go into the BUS FREE phase by releasing BSY. This message must be supported by any initiator selecting the *ProDrive*.

NOTE: The completion status of the command is indicated in the status byte.

EXTENDED MESSAGE 01_H - This message is sent to establish synchronous data transfer. The message and responses establish the transfer period and the REQ/ACK offset.

SYNCHRONOUS DATA TRANSFER REQUEST:

Byte	Value	Description
0	01h	Extended Message
1	03h	Extended Message Length
2	01h	SYNCHRONOUS DATA TRANSFER REQUEST code
3	m	Transfer Period (m times 4 nanoseconds)
4	x	REQ/ACK Offset

The transfer period is the clock rate for the transfer. The minimum transfer period for the *ProDrive* is 250 ns or 62 (3E_H). This value is equivalent to a maximum transfer rate of 4.0 MBytes/second. Table 5-3 shows the transfer rates supported and the transfer period values for the *ProDrive*.

The REQ/ACK offset is the maximum number of REQ pulses that may be sent before a corresponding ACK pulse is received at the *ProDrive*. A REQ/ACK offset value of zero indicates asynchronous mode. For the *ProDrive*, the maximum value of REQ/ACK offset is 8.

If the initiator recognizes that negotiation is required, it asserts ATN, 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 initiator's data handling requirements. The *ProDrive* responds in one of the following ways:

<i>ProDrive</i> Response	Implied Agreement
1) REQ/ACK offset less than or equal to the requested value; minimum transfer period equal to or greater than requested period.	REQ/ACK offset equal to <i>ProDrive</i> value; minimum transfer period equal to the <i>ProDrive</i> value.
2) REQ/ACK offset equal to zero.	Asynchronous transfer.
3) MESSAGE REJECT.	Asynchronous transfer.

TABLE 5-3 Transfer Rates Supported/Transfer Period Values

TRANSFER PERIOD VALUE		TRANSFER RATE IN MHZ
DEC	HEX	
0 - 62	00 - 3E _H	4.00
63 - 93	3F _H - 5D _H	2.67
94 - 125	5E _H - 7D _H	2.00
126 - 156	7E _H - 9C _H	1.60
157 - 187	9D _H - BB _H	1.33
188 - 218	BC _H - DA _H	1.14
219 - 250	DB _H - FA _H	1.00
251 - 255	FB _H - FF _H	0.89

If the *ProDrive* recognizes that negotiation is required, it sends a SYNCHRONOUS DATA TRANSFER REQUEST message to the initiator. The REQ/ACK offset is selected to prevent buffer and offset counter overflows, while the minimum transfer period is chosen to meet the *ProDrive's* data handling requirements.

The implied agreement will remain in effect until a BUS DEVICE RESET message is received, until a "hard" RESET condition occurs, or until one of the two devices elects to modify the agreement. Renegotiation at every selection is not recommended, since a significant performance impact is likely.

The default mode of data transfer is asynchronous. This mode is entered at power on, after a BUS DEVICE RESET message, or after a "hard" RESET condition. The SYNCHRONOUS DATA TRANSFER REQUEST message exchange can only take place following a SELECTION phase that includes the SCSI IDs for both the initiator and *ProDrive*. Violation of this rule may make data transfer impossible owing to disagreements among devices about the data transfer mode.

SAVE DATA POINTER 02_H - This message is sent from the *ProDrive* to direct the initiator to save a copy of the present active data pointer for the drive. (See Section 5.4 for a definition of pointers.) This message is usually sent just prior to the DISCONNECT message when disconnecting in the DATA phase.

DISCONNECT 04_H - This message is sent from the *ProDrive* to inform an initiator that the present physical data path is going to be broken (the *ProDrive* plans to disconnect by releasing BSY), but that a later reconnect will be required to complete the current operation. If the initiator detects the BUS FREE phase (other than as a result of an ABORT or BUS DEVICE RESET message or a RESET condition) without first receiving a DISCONNECT or COMMAND COMPLETE message, it should consider it a catastrophic error condition. The initiator should not save the data pointer as a result of this message.

INITIATOR DETECTED ERROR 05_H - This message is sent from an initiator to inform the *ProDrive* that an error (e.g., parity error on the SCSI bus) has occurred that does not preclude a retry of the operation. The *ProDrive* will terminate the command with a CHECK CONDITION status. The sense key will be set to ABORTED COMMAND with a sense code of Initiator Detected Error.

ABORT 06_H - This message is sent from the initiator to the *ProDrive* to clear the present operation. All pending data and status for the issuing initiator will be cleared, and the *ProDrive* will go to the BUS FREE phase. Pending data and status for other initiators will not be cleared. No status or ending message will be sent for the operation.

MESSAGE REJECT 07_H - This message will be sent by the *ProDrive* to an initiator if the last message received from that initiator was inappropriate or has not been implemented. This message will be interpreted in the same way if it is received from an initiator.

To indicate its intentions of sending this message, the initiator must assert the ATN signal prior to its release of ACK for the REQ/ACK handshake of the message that is to be rejected. When the *ProDrive* sends this message, it will change to MESSAGE IN phase and send the message prior to requesting additional message bytes from the initiator. This provides an interlock so that the initiator can determine which message is rejected. The initiator must support this message if it asserts ATN during the initial SELECTION phase of the command.

NO OPERATION 08_H - This message is sent from an initiator in response to the *ProDrive's* request for a message, when the initiator currently has no other valid message to send. No action will be taken by the *ProDrive* upon receipt of this message.

MESSAGE PARITY ERROR 09_H - This message is sent from the initiator to the *ProDrive* to indicate that one or more bytes in the last message it received had a parity error.

To indicate its intent to send this message, the initiator must assert ATN prior to releasing ACK for the REQ/ACK handshake of the message that has the parity error. This provides an interlock so the *ProDrive* can determine which message has the parity error.

LINKED COMMAND COMPLETE 0A_H - This message is sent from the *ProDrive* to an initiator to indicate that the execution of a linked command has been completed and status has been sent. The initiator must then set the pointers to the initial state for the next linked command. Refer also to Sections 5.7.1.8 and 5.7.1.9.

LINKED COMMAND COMPLETE (WITH FLAG) 0B_H - This version of the LINKED COMMAND COMPLETE message is used when the flag bit of the command is set to one. Refer also to Sections 5.7.1.8 and 5.7.1.9.

BUS DEVICE RESET 0C_H - This message is sent from an initiator to direct the *ProDrive* to clear all current commands. This message forces the drive to an initial state with no operations pending for any initiator. Upon recognizing this message, the *ProDrive* will go to the BUS FREE phase. This message does not affect MODE SELECT command parameters.

IDENTIFY 80_H - FF_H - These messages may be either sent from or received by the *ProDrive* to establish the physical path connection between an initiator and the drive.

Bit 7 - This bit is always set to one to distinguish an IDENTIFY message from the other messages.

Bit 6 - This bit is set to one only by the initiator. When set to one, it indicates that the initiator has the ability to accommodate disconnection and reconnection. It also indicates that the SAVE DATA POINTER, RESTORE POINTERS and DISCONNECT messages are supported by the initiator.

Bits 5-3 - Reserved; must be set to zero.

Bits 2-0 - These bits specify a logical unit number (LUN) in a target. For the *ProDrive*, the only valid LUN is zero.

When an IDENTIFY message is sent from the *ProDrive* to an initiator during reconnection, an implied RESTORE POINTERS message must be performed by the initiator prior to completion of this message.

5.6.3 MESSAGE ERROR RECOVERY STRATEGY

5.6.3.1 Parity Errors During Message Phase

Parity is an SCSI option. This section is relevant only if the parity option is enabled.

If the initiator detects a parity violation as the *ProDrive* transfers a message byte to it, it should ignore that message and immediately assert ATN (before releasing ACK on the offending byte). The initiator should continue receiving and ignoring bytes until the *ProDrive* requests a MESSAGE OUT byte. At that point, the initiator should send a MESSAGE PARITY ERROR message; the *ProDrive* will abort the command and release the bus. The sense key will be set to ABORTED COMMAND (0B_H) and the sense code set to Parity error on the SCSI bus (47_H).

If the *ProDrive* detects a parity error during a MESSAGE OUT phase, it will continue to request MESSAGE OUT bytes until the initiator deasserts ATN. This procedure should guarantee that the initiator transfers the entire message containing the parity error. The current command will be terminated,

the status set to CHECK CONDITION, the sense key set to ABORTED COMMAND (0B_H), and the sense code set to Parity error on the SCSI bus (47_H).

5.6.3.2 Rejected Messages

The *ProDrive* will send MESSAGE REJECT to the initiator any time it receives a message it does not support (e.g., extended messages) or a message that does not make sense at that time (e.g., the initiator sending COMMAND COMPLETE).

When the *ProDrive* receives MESSAGE REJECT from the initiator, it takes action based on which command was rejected.

COMMAND COMPLETE - The *ProDrive* goes to BUS FREE. This is not considered an error.

DISCONNECT - The *ProDrive* will stop trying to disconnect at this time. It may attempt to disconnect again at a later time.

IDENTIFY - The *ProDrive* only sends this when it is attempting to reconnect. If this message is rejected during reconnection, the present command will be terminated. The drive will post a CHECK CONDITION status, set the sense key to ABORTED COMMAND (0B_H), and set the sense code to Message reject error (43_H). The *ProDrive* will then go immediately to BUS FREE.

LINKED COMMAND COMPLETE - The *ProDrive* will go immediately to BUS FREE. The sense key will be set to ABORTED COMMAND (0B_H) and the sense code set to Message reject error (43_H).

LINKED COMMAND COMPLETE WITH FLAG - Same procedure as for LINKED COMMAND COMPLETE.

MESSAGE REJECT - The *ProDrive* will immediately terminate the current command with a CHECK CONDITION status. The sense key will be set to ABORTED COMMAND (0B_H) and the sense code set to Message reject error (43_H).

SAVE DATA POINTERS - Same procedure as for DISCONNECT message.

5.7 COMMAND IMPLEMENTATION

This section defines the SCSI commands supported by the *ProDrive* 40S/80S intelligent Disk Drives. Each command consists of a group of command bytes and an optional associated group of data bytes. After ARBITRATION, SELECTION, and any optional initial messages, the *ProDrive* will enter the COMMAND phase and request the command bytes. The opcode of the command determines how many bytes the *ProDrive* will request. After receipt of the command bytes, the *ProDrive* will enter DATA phase if a data structure is defined for the command. The data structure in a single command may transfer one or more logical blocks of data. The *ProDrive* may disconnect from the SCSI bus to allow activity by other SCSI devices while it is preparing to transfer data.

Upon completion of a command (successful or unsuccessful), the *ProDrive* will return a status byte to the initiator. Since most error and exception conditions cannot adequately be described with a single status byte, the CHECK CONDITION status code indicates that additional information is available. The initiator may issue a REQUEST SENSE command to retrieve this additional information.

The following subsections on each command describe the sequence of bytes an initiator must transfer to the *ProDrive* during the COMMAND phase to request a desired action from the drive. For those commands for which it is relevant, these sections also further describe the format of data bytes that may be transferred to or from the initiator following the COMMAND phase.

5.7.1 COMMAND DESCRIPTOR BLOCK (CDB)

A request is made to a device by transferring a Command Descriptor Block (CDB) to that device. The *ProDrive* supports two basic command formats: six-byte commands and ten-byte commands. The command format is recognizable from the opcode of the command. Six-byte commands have opcodes between 00_H and 1F_H; ten-byte commands have opcodes from 20_H to 3F_H or E0_H to FF_H. This section defines the CDB fields. The uses of the CDB fields in particular commands are fully described in Section 5.11.

5.7.1.1 Opcode

The opcodes (operation codes) for Groups 0 and 1 are listed in Table 5-4.

TABLE 5-4 Commands Supported By ProDrive

OPCODE	COMMAND	SECTION
00 _H	TEST UNIT READY	5.11.1
01 _H	REZERO UNIT	5.11.2
03 _H	REQUEST SENSE	5.11.3
04 _H	FORMAT UNIT	5.11.4
07 _H	REASSIGN BLOCKS	5.11.5
08 _H	READ	5.11.6
0A _H	WRITE	5.11.7
0B _H	SEEK	5.11.8
12 _H	INQUIRY	5.11.9
15 _H	MODE SELECT	5.11.10
16 _H	RESERVE	5.11.11
17 _H	RELEASE	5.11.12
1A _H	MODE SENSE	5.11.13
1B _H	START/STOP UNIT	5.11.14
1D _H	SEND DIAGNOSTIC	5.11.15
25 _H	READ CAPACITY	5.11.16
28 _H	READ EXTENDED	5.11.17
2A _H	WRITE EXTENDED	5.11.18
2B _H	SEEK EXTENDED	5.11.19
2E _H	WRITE AND VERIFY	5.11.20
2F _H	VERIFY	5.11.21
37 _H	READ DEFECT DATA	5.11.22
3B _H	WRITE BUFFER	5.11.23
3C _H	READ BUFFER	5.11.24
E8 _H	READ LONG	5.11.25
EA _H	WRITE LONG	5.11.26

5.7.1.2 Logical Unit Number (LUN)

The Logical Unit Number for the *ProDrive* is zero. The LUN is found in two places: bits 5-7 of byte 1 of the Command Descriptor Block and bits 0-2 of the IDENTIFY message field. (See Section 5.6.2.) The LUN field in both the CDB and IDENTIFY message field must be zero. If a LUN other than zero is specified in any command except INQUIRY and REQUEST SENSE, the command will be rejected with a CHECK CONDITION status and the sense key set to ILLEGAL REQUEST - Invalid LUN.

5.7.1.3 Logical Block Address (LBA)

The 21-bit (or 32-bit) Logical Block Address signifies the first or starting block of an operation. A Logical Block can be 512, 1024, or 2048 bytes in length. The MODE SELECT command is used to configure the Block Length. Each *ProDrive* is configured with a Logical Block Length of 512 bytes.

5.7.1.4 Transfer or Allocation Length

The transfer length in blocks, or the allocation length in bytes, is the number of blocks or bytes or data to be transferred for a single command.

- For six-byte commands, acceptable values are 00-FF_H. For block lengths, a value of 00_H transfers 256 blocks. See allocation byte lengths under specific commands.
- For 10-byte commands, acceptable values are 0000-FFFF_H. A value of 0000_H transfers no blocks.

5.7.1.5 Vendor Unique (VU)

Vendor unique bits allow for slight command modifications or special conditions to be selected. Vendor unique bits are to be filled with zeros.

5.7.1.6 Reserved (R)

These bits are reserved and must be set to zero by the initiator.

5.7.1.7 Flag (F)

If the link bit (5.7.1.8) is zero, the flag bit must be zero. Suppose the link bit is one. If the flag bit is zero, the target sends the LINKED COMMAND COMPLETE message when the command terminates; if the flag bit is one, it sends the LINKED COMMAND COMPLETE (WITH FLAG) message.

5.7.1.8 Link (L)

If the link bit is one, when the command terminates, the *ProDrive* sends one of the two messages defined by the flag bit (above). In addition, the *ProDrive* does not go to Bus Free, but immediately goes to the Command Out phase. If the link bit is zero, the *ProDrive* sends the normal COMMAND COMPLETE message.

5.7.1.9 Relative Address (RELADR)

This bit is found only in 10-byte commands (opcodes 20_H - 3F_H) and is not supported by the *ProDrive* 40S/80S.

NOTE: If the reserved bits of the IDENTIFY message or the vendor unique, reserved or relative address bits of the CDB are non-zero, a CHECK CONDITION status is returned with the sense key set to ILLEGAL REQUEST and sense code set to Illegal use of bit or byte in CDB or IDENTIFY message.

5.8 COMPLETION STATUS BYTE

A status byte will be sent from the *ProDrive* to the initiator during the STATUS phase at the termination of each command as specified in Tables 5-6 and 5-7, unless the command is cleared by an ABORT or BUS DEVICE RESET message, or by a "hard" RESET condition. Table 5-5 presents the status bytes; Table 5-7 defines the status codes as implemented on the *ProDrive*.

TABLE 5-5 Status Byte

Bit	7	6	5	4	3	2	1	0
Byte								
0	RESERVED	VENDOR UNIQUE	STATUS BYTE CODE				VENDOR UNIQUE	

TABLE 5-6 ProDrive Status Byte Code Bit Values

Bits of Status Byte								Status(es) Represented
7	6	5	4	3	2	1	0	
R	V	V	0	0	0	0	V	GOOD
R	V	V	0	0	0	1	V	CHECK CONDITION
R	V	V	0	1	0	0	V	BUSY
R	V	V	1	0	0	0	V	INTERMEDIATE/GOOD
R	V	V	1	1	0	0	V	RESERVATION CONFLICT

KEY: R = Reserved Bit (zero)
V = Vendor Unique Bit (zero)

TABLE 5-7 ProDrive Status Codes

STATUS BYTE CODE	MEANING
GOOD (00 _H)	COMMAND HAS COMPLETED WITH NO ERROR CONDITIONS.
INTERMEDIATE/ GOOD (10 _H)	LINKED COMMAND HAS COMPLETED WITH NO ERROR CONDITIONS. This code is issued for every command in a series of linked commands (except the last, for which the link bit is zero) unless CHECK CONDITION or RESERVATION CONFLICT is appropriate. If this code is not returned, the chain of linked commands is broken.
CHECK CONDITION (02 _H)	AN ABNORMAL CONDITION HAS OCCURRED. This code is issued whenever an error, exception or abnormal condition occurred during the execution of a command (the command may or may not have completed successfully). A REQUEST SENSE command should be issued following a CHECK CONDITION status to determine the nature of the condition.
BUSY (08 _H)	TARGET IS BUSY. This code is issued if the target is busy executing a previous command, after a disconnection has occurred, or if the target is otherwise unable to accept a command. The command that received the BUSY status is discarded and no action is taken; it may be reissued as if it were issued for the first time.
RESERVATION CONFLICT (18 _H)	ATTEMPTED ACCESS OF A RESERVED BLOCK, OR DEVICE. This code is issued when a device attempts to access a reserved area, in which case the command will be rejected. See RESERVE command.

5.9 READING AND WRITING

5.9.1 LOGICAL BLOCKS

The basic functions of a disk drive are to store and retrieve information. Information is stored on the *ProDrive* and retrieved as groups of 8-bit bytes. These groups of bytes have a standard size and are referred to as logical blocks. The size of a logical block (the number of bytes contained in each block) is set via the MODE SELECT command. The *ProDrive* will support three logical block sizes: 512, 1024, and 2048 bytes per block. The drive is initially configured as 512 bytes per logical block. A unique feature of the *ProDrive* is that when the default tracks/zone (6) is set, changing the block size will not destroy data on the drive; it simply changes the grouping of the information (e.g., 1024-byte blocks would be reconfigured as two 512-byte blocks). If a tracks/zone setting other than the default is used, changing block size could cause some data to become inaccessible.

To the user, the *ProDrive* appears as a series of logical blocks, each with its own unique address called the Logical Block Address (LBA). The first logical block on the drive is address 0. The address of the last logical block on the drive varies depending on the capacity of the drive and the size of the logical block.

5.9.2 LOGICAL BLOCK ADDRESS RANGES

	Block Size	Valid Logical Block Address Range Decimal	Hex
<i>ProDrive</i> 40S	512 or 200 _H	0 - 82,028	0 - 1406C _H
	1024 or 400 _H	0 - 41,013	0 - A035 _H
	2048 or 800 _H	0 - 20,505	0 - 5019 _H
<i>ProDrive</i> 80S	512 or 200 _H	0 - 164,057	0 - 280D9 _H
	1024 or 400 _H	0 - 82,028	0 - 1406C _H
	2048 or 800 _H	0 - 41,013	0 - A035 _H

NOTE: The number of available logical blocks may vary depending on the value set for tracks per zone (MODE SELECT command page 3) selected by the user.

If an initiator attempts to access a logical block at an address outside the valid address range, the command will not be executed. The drive will return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST - Invalid Logical Block Address was specified.

5.9.3 TRANSFERRING DATA

The actual storing away and retrieving of logical blocks is done with the WRITE and READ commands. WRITE will place data on the disk and READ will retrieve data from the disk. In both the READ and WRITE commands, the user (initiator) must specify the logical block address of the first logical block to be transferred and the total number of blocks to be transferred. The interpretation of a value of zero in the number of blocks to be transferred depends on which form of the READ or WRITE command is used.

- If the extended form of the commands is used (opcodes 28_H and 2A_H), a transfer length of zero implies transfer no data.
- The non-extended form of the command has only one byte to specify transfer length. If this shorter command format is used (opcodes 08_H and 0A_H), a transfer length of zero means transfer 256 blocks during the command.

The number of bytes transferred during the DATA phase following the command bytes is determined by the transfer length specified in the command and the logical block size:

- Number of Data Bytes = Logical BLock Size (in bytes) x Transfer Length (in blocks).

Note that in case of errors, a fewer number of bytes will sometimes be transferred.

The rate at which data is transferred to or from the disk depends solely on how densely the data is written on the disk and how fast the disk is rotating. Neither of these quantities can be easily modified, so the disk transfer rate should be regarded as a constant. The *ProDrive* has two data zones, an inner zone and an outer zone, with two different data rates:

- The transfer rate when the head is over data in the outer zone is 10 Mbit/sec (1.25 Mbyte/sec).
- When the head is over data in the inner zone, the transfer rate is 8 Mbit/sec (1 Mbyte/sec).

If the transfer rate across the SCSI bus is slower than this sustained disk transfer rate, the drive will run out of data if the transfer is a WRITE, or begin to have data collect in its buffer if the transfer is a READ. Other disk drive subsystems might require the user to interleave sectors on the disk to match the sustained disk transfer rate with the SCSI bus transfer rate. This is not necessary with the *ProDrive* since it includes a large on-board cache (64K bytes). All READ and WRITE transfers are channeled through this buffer, enabling the drive to maintain steady transfer when the transfer rate is less than 1.25 Mbyte/second.

This buffer also serves as an on-board cache (*DisCache*). The caching function can be enabled/disabled, and various cache parameters can be configured to best fit the application via the MODE SELECT command. Refer to the section on the MODE SELECT command (5.11.10) and Appendix A for a more detailed discussion of the *DisCache* feature.

5.10 CONFIGURING THE *PRODRIVE*

5.10.1 *PRODRIVE* OPERATING MODES

The manner in which the *ProDrive* operates can be changed to more precisely match its features with user requirements. This is referred to as changing the Operating Mode of the drive and is done through the use of the MODE SELECT and MODE SENSE commands. The MODE SELECT command is used to set the Operating Mode of the *ProDrive* to achieve the desired behavior. The MODE SENSE command may be used to determine the current Operating Mode of the drive, or to gather other information that would be useful in setting the Operating Mode.

An example of a common user-adjusted Operating Mode parameter is the number of retries the drive should attempt when it detects a read error. If an initiator wished to retry only once when the drive detected incorrect data, the initiator's software could first issue a MODE SENSE command to the *ProDrive* to determine its current configuration. The data returned to the initiator during the DATA phase of the MODE SENSE command would contain the current Mode Parameters, including how many retries the drive will attempt when it detects a read error. If the number of retries is not set to the desired number, the initiator could then send a MODE SELECT command with the data byte corresponding to the Retry Count Parameter set to one. From then on, the *ProDrive* would only retry once on READ commands.

5.10.2 OPERATING MODE TABLES

The *ProDrive* Operating Mode is determined by the contents of the Current Mode Table. Because of the need for frequent and fast access to its parameters, the Current Mode Table is stored in RAM. This table is referenced whenever there is more than one possible way for the drive to behave. In the previous example, the initiator will have set the Retry Count in the Current Mode Table to one. Each time a READ command is executed, the firmware checks the Current Mode Table and looks up the Retry Count Parameter. It then uses this number to determine how many times it should attempt to re-read a block if the data is detected to be incorrect.

Storing the Current Mode Table in RAM means that the drive's Operating Mode is lost when power is removed or the drive is reset. For this reason, a copy of the Current Mode Table can be saved on the disk itself. This saved copy is called the Saved Mode Table. The Saved Mode Table is stored on a hidden area of the disk that is not accessible by the user. This way, no user data storage area is sacrificed, nor can a user inadvertently erase the table. The Saved Mode Table is used to load the Current Mode Table at power-up or whenever the drive is reset. The contents of the Current Mode Table can be copied into the Saved Mode Table via the MODE SELECT command. If the Save Parameters bit is set to one in the MODE SELECT command (bit 0 of byte 1), the entire contents of the Current Mode Table will be transferred to the Saved Mode Table when the command is completed.

NOTE: If the MODE SELECT command makes changes to the Current Mode Table, these changes will be implemented first and then incorporated in the Saved Mode Table. In other words, if a MODE SELECT command contains new mode information and the Save Parameters bit is set, the new mode information will appear in the Saved Mode Table as well as in the Current Mode Table.

The Saved Mode Table is a very powerful tool for the user. Using the Save Parameters bit allows the drive to be permanently configured to the user's requirements with the execution of a single MODE SELECT command. This means that a once-in-a-lifetime configuration can be done (e.g., at the user's factory), eliminating the burden from the device driver of sending vendor specific MODE SELECT commands after every reset.

There are two other Mode Tables supported by the *ProDrive* that are of interest to the user. These are the Changeable Parameters Table and the Default Mode Table. Both of these tables are contained in the firmware ROM and are for reference only. They cannot be modified by the user. These two tables can be referenced only by the MODE SENSE command.

- The Changeable Parameters Table allows an initiator to determine which Operating Mode parameters the *ProDrive* will allow to be changed via a MODE SELECT command. If a parameter in the Current Mode Table is changeable, the corresponding entry will have all bits set to one. Before trying to change any Operating Mode parameter with a MODE SELECT command, the software driver should first check to make sure that the device will support changing that parameter.
- The Default Mode Table allows the user to restore the drive to a known or reference condition. If for any reason the Current and Saved mode tables are inaccessible, the *ProDrive* will use the default mode table.

5.11 COMMAND DESCRIPTIONS

Following are descriptions of the individual commands listed in Table 5-4. Refer to the REQUEST SENSE command (Section 5.11.3) for a description of error codes and sense keys. Refer to the Command Descriptor Block section (5.7.1) for definitions of the CDB fields.

5.11.1 TEST UNIT READY COMMAND: OPCODE = 00(hex)

The TEST UNIT READY command (Table 5-8) provides a means to check if the drive is up to speed and ready to accept commands requiring disk access.

TABLE 5-8 TEST UNIT READY Command

Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 00 _H								
1	LUN = 0				RESERVED = 0				
2-4	RESERVED = 0								
5	VU = 0			RESERVED = 0				F	L

When the *ProDrive* is ready, the completion status byte will indicate GOOD (00_H). If the drive is not ready, the completion status byte will indicate CHECK CONDITION (02_H), with the sense key set to NOT READY (02_H).

The commands which do not require disk access are:

REQUEST SENSE	INQUIRY *
RESERVE	SEND DIAGNOSTICS
RELEASE	START/STOP UNIT
READ BUFFER	WRITE BUFFER
MODE SELECT (if Save Parameters bit is not set)	
MODE SENSE (if Save Parameters are not requested)	

* If the *ProDrive* is not ready when the INQUIRY command is received, the disk is not accessed and the default inquiry data is returned (see 5.11.9).

The *ProDrive* will execute any of the above commands after a delay of one second, maximum, following application of power to the drive. They will not return CHECK CONDITION status with the NOT READY sense key even if the drive is not ready. All other commands could require disk access. (Refer to START/STOP UNIT command, Section 5.11.14 below.)

5.11.2 REZERO UNIT COMMAND: OPCODE = 01(hex)

The REZERO UNIT command (Table 5-9) requests that the drive actuator be repositioned to cylinder zero and head zero.

TABLE 5-9 REZERO UNIT Command

Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 01 _H								
1	LUN = 0				RESERVED = 0				
2-4	RESERVED = 0								
5	VU = 0			RESERVED = 0				F	L

5.11.3 REQUEST SENSE COMMAND: OPCODE = 03(hex)

5.11.3.1 Command Structure

The REQUEST SENSE command (Table 5-10) requests that the sense data be sent to the initiator.

The sense data applies to the previous command from the same initiator. Sense data is saved for an initiator until it is retrieved by that initiator or until another command is received from that initiator. Commands from any initiator will not alter the sense data saved for other initiators.

TABLE 5-10 REQUEST SENSE Command

Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 03 _H								
1	LUN = 0				RESERVED = 0				
2-3	RESERVED = 0								
4	ALLOCATION LENGTH (BYTES)								
5	VU = 0			RESERVED = 0				F	L

ALLOCATION LENGTH - specifies the maximum number of bytes allocated by the initiator for returned sense data. Acceptable values are 00-FF_H. (A value of 00 indicates that four bytes of data will be returned.) The *ProDrive* will terminate the DATA IN phase when the allocated number of bytes have been transferred or when all available sense data have been transferred to the initiator, whichever is less. For the *ProDrive*, an allocation length of 18 (12_H) is recommended.

If the allocation length prevents all available sense data from being sent to the initiator, the initiator may not use a subsequent REQUEST SENSE command to recover the remaining portion.

The *ProDrive* uses the extended format for sense data. (See Table 5-11.)

5.11.3.2 Extended Sense Format

TABLE 5-11 Extended Sense Format

Byte	Bit	7	6	5	4	3	2	1	0
0	VALID	ERROR CLASS AND CODE = 70 _H							
1	SEGMENT NUMBER = 0								
2	FM=0	EOM=1	ILI=0	R=0	SENSE KEY				
3 - 6	(MSB)	INFORMATION BYTE							(LSB)
7	ADDITIONAL SENSE LENGTH (BYTES) = 0A _H								
8-11	RESERVED = 0								
12	ADDITIONAL SENSE CODE								
13	RESERVED = 0								
14	FRU FAILED = 0								
15	FPV	C/D	VU	VU	BPV	BIT POINTER = 0			
16-17	(MSB)	FIELD POINTER							(LSB)

VALID - INFORMATION VALID (Byte 0, Bit 7) - Set to 1 if the information bytes contain valid data.

ERROR CLASS AND CODE (Byte 0, Bits 6-0) - Set to 70_H to indicate extended status.

SEGMENT NUMBER (Byte 1) - Set to zero for the *ProDrive*.

FM - FILE MARK (Bit 7, Byte 2) - Indicates that a filemark has been read; set to zero for the *ProDrive*.

EOM - END-OF-MEDIUM (Byte 2, Bit 6) - Indicates that an end-of-medium condition exists; set to zero for the *ProDrive*.

ILI - INCORRECT LENGTH INDICATOR (Byte 2, Bit 5) - Indicates that the requested logical block length does not match the block length on the medium. This bit is normally set to zero for the *ProDrive*; an exception is in response to the READ BUFFER command, when the requested transfer length is greater than the buffer size.

R - RESERVED (Byte 2, Bit 4) - Must be zero for the *ProDrive*.

SENSE KEY (Byte 2, Bits 3-0) - Values for sense key data are shown in Table 5-12.

INFORMATION BYTES (Bytes 3-6) - If the VALID bit is 1, the information bytes are valid and are defined as the logical block address associated with the sense key.

ADDITIONAL SENSE LENGTH (Byte 7) - The number of additional bytes to follow. This value will not be truncated if the allocation length in the command descriptor block is too small to transfer all of the additional sense bytes. The *ProDrive* uses a value of 0A H in byte 7.

ADDITIONAL SENSE CODE (Byte 12) - Refer to Table 5-12.

FRU - FIELD REPLACEABLE UNIT FAILED (Byte 14) - The format of this byte is vendor unique. A value of zero means that no FRU is to be reported.

FPV - FIELD POINTER VALID (Byte 15, Bit 7) - Set to zero indicates that the C/D bit and BPV bit, and bytes 16 and 17 are not valid. An FPV bit set to one indicates that the field pointer bytes 16 and 17, the C/D bit and BPV bit, are significant.

C/D - CONTROL/DATA BIT (Byte 15, Bit 6) - Set to one indicates that the value reported in the field pointer is the Command Descriptor Block (CDB) byte number for which an ILLEGAL REQUEST sense key was issued. A C/D bit of zero indicates that the value reported in the field pointer is the byte number of the DATA phase for which an ILLEGAL REQUEST sense key was issued.

VENDOR UNIQUE (Byte 15, Bits 5-4) - Bits 5 and 4 of byte 15 are vendor unique.

BPV - BIT POINTER VALID (Byte 15, Bit 3) - Set to zero indicates that the bit pointer field is not valid. A BPV bit set to one indicates that the bit pointer field (Bits 0 - 2) is valid.

BIT POINTER (Byte 15, Bits 2-0) - If BPV is set, this field points to the bit within the byte that is in error.

FIELD POINTER (Bytes 16-17) - These bytes represent an index into the Command Descriptor Block fields or the DATA phase fields for which an ILLEGAL REQUEST sense key was issued. In the case of multiple byte fields, the field pointer bytes index the most significant byte of the field for which an illegal request sense key was issued. These bytes are only valid if the Field Pointer Valid (FPV) bit is set to one.

TABLE 5-12 Sense Error Codes

Sense Key (hex)	Additional Sense Code (hex)	Description
0		NO SENSE. No specific sense key information to be reported. This would be the case for a successful command or a command that received a CHECK CONDITION status because one of the filemark, EOM, or ILI bits is set to one.
	00	No additional information
1		RECOVERED ERROR. The last command was completed successfully with some recovery action performed by the <i>ProDrive</i> . Details may be determined by examining the additional sense bytes and the information bytes.
	00	No additional information
	02	Recovered seek timeout
	10	Recovered ID CRC error
	11	Recovered data ECC on last retry

Table 5-12 Sense Error Codes (cont.)

Sense Key (hex)	Additional Sense Code (hex)	Description
	13	Recovered data sync timeout
	14	Recovered no record found
	15	Recovered seek error
	16	Recovered data marker not found
	17	Recovered data ECC with retries
	18	Recovered data ECC error
	86	Recovered unexpected sequencer error
	95	Recovered SOLO timeout
	96	Recovered bump
	97	Recovered underrun/overrun error
	98	Recovered timeout in settling
	A8	Spurious nmi interrupt
	AB	Requested format not available
2		NOT READY. Target cannot be accessed. Operator intervention may be required to correct this condition.
	00	No additional information
	B0	Drive recalibrating
	B1	Drive not up to speed
	B2	Drive waiting for command to start
3		MEDIUM ERROR. The command terminated with a non-recovered error condition that was probably caused by a flaw in the medium or an error in the recorded data.
	00	No additional information
	10	All IDs have CRC errors
	11	Uncorrectable data error
	13	Data sync timeout
	14	No record found
	16	Data marker not found
	19	Bad defect list
	1C	No primary defect list found
	31	Format failed or not formatted
	32	No more spares available
	80	Can't write system sector
	81	Can't read system sector
	95	SOLO timeout
	97	Underrun/overrun error
	A3	Reassign Blocks READ failure
	AA	Reallocated uncorrectable data read

Table 5-12 Sense Error Codes (cont.)

Sense Key (hex)	Additional Sense Code (hex)	Description
4		HARDWARE ERROR. The target detected a non-recoverable hardware failure while performing the command.
	00	No additional information
	01	No index signal
	02	Seek timeout
	03	Write fault
	06	Recalibrate failure
	09	Servoing error
	15	Seek error
	1B	Synchronous request error
	32	Defect list is full
	40	Buffer RAM failure
	41	ECC failure
	42	Power-on failure
	43	Message reject
	44	Firmware error
	45	Reselect timeout
	82	No digital P1 or P2 signal
	83	Analog P1 or P2 are bad
	84	Failure writing to format parameter RAM
	85	Rejected message was not sent
	86	Unexpected sequencer error
	87	A and B servos not equal
	88	Airlock stuck closed
	89	Bad head amplifier
	8A	Bad head select
	90	Synchronous acknowledge error
	91	FIFO unload error
	92	FIFO load error
	93	FIFO predicted full error
	94	Undocumented SPICY error
	96	Bump timeout
	98	Timeout in settling
	99	Bump retry counter expired
	9D	Motor never gets up to speed
	9E	Motor drops out of legal speed range
	9F	Internal ROM checksum error
	A0	External PROM checksum error
	A1	Sequencer rollover register failure
	A2	External RAM failure
	A4	Bad thermistor
	A6	A and B servos not detected

Table 5-12 Sense Error Codes (cont.)

Sense Key (hex)	Additional Sense Code (hex)	Description
	A7	Offtrack timeout
	A9	SOLO DMA pointer error
	AC	Airlock stuck open
	AD	No servo interrupt
5		ILLEGAL REQUEST. There was an illegal parameter in the command descriptor block or in the additional parameters supplied as data for a command. If the <i>ProDrive</i> detects an invalid parameter in the command descriptor block, it will terminate the command without altering the medium; if the invalid parameter is in the additional parameters supplied as data, it may have already altered the medium.
	00	No additional information
	19	Entered defect list in error
	1A	Parameter overrun
	20	Invalid command
	21	Invalid LBA
	22	Illegal function for device type
	24	Illegal field in CDB
	25	Invalid LUN
	26	Illegal field in parameter list
	8A	Invalid head
	8B	Invalid cylinder
	8C	Select from same initiator while active
	8D	Bad BPB/BPS
	8F	Invalid sector
	9B	Invalid period or offset in sync message
	9C	Active initiator attempted another select
	A5	Defect list out of order
	AE	Bad parameter(s) in mode page
6		UNIT ATTENTION. MODE SELECT parameters have been changed by another initiator, or the <i>ProDrive</i> has been reset by a bus device reset message, a "hard" reset condition (RST asserted) or a power-on reset. The UNIT ATTENTION condition will persist until receipt of a command other than INQUIRY or REQUEST SENSE. The command issued will not be performed; the CHECK CONDITION status will be reported, allowing the initiator to discover and clear the UNIT ATTENTION condition by issuing a REQUEST SENSE command. An INQUIRY command will be performed with no effect to the UNIT ATTENTION condition. If a REQUEST SENSE command is received before the <i>ProDrive</i> reports CHECK CONDITION for the UNIT ATTENTION condition, the condition will be reported and cleared.
	00	No additional information
	29	Drive reset
	2A	Mode select parameter changed
	8E	Unexpected SCSI interrupt occurred
	9A	Target attempted to reselect <i>ProDrive</i>

Table 5-12 Sense Error Codes (cont.)

Sense Key (hex)	Additional Sense Code (hex)	Description
B		ABORTED COMMAND. The <i>ProDrive</i> aborted the command. The initiator may be able to recover by trying the command again.
	00	No additional information
	40	Buffer RAM parity error
	47	Parity error on SCSI bus
	48	Initiator detected error
	49	Inappropriate/illegal message
E		MISCOMPARE. The source data did not match the data read from the medium.
	00	No additional information
	AF	Buffer corrupted

5.11.4 FORMAT UNIT COMMAND: OPCODE = 04(hex)

The FORMAT UNIT command (Table 5-13) assigns logical blocks to physical sectors for optimum sequential access (within the limitations of available spare blocks), skipping known defective areas. An option causes a repetitive (one byte) data pattern to be written in every block. The *ProDrive* is formatted when shipped from the factory, with data being undefined.

NOTE: Issuing this command typically causes loss of data, even when the repetitive data pattern option is not used. All data should be backed up prior to formatting.

5.11.4.1 Command Structure

TABLE 5-13 FORMAT UNIT Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 04 _H							
1		LUN = 0			FMTDAT	CMPPLST	DEFECT LIST FORMAT		
2		DATA PATTERN							
3-4		(MSB)	INTERLEAVE = XX						(LSB)
5		VU = 0			RESERVED = 0			F	L

FMTDAT - FORMAT DATA (Byte 1, Bit 4) - Set to one indicates that defective block data is supplied during the DATA OUT phase. The defect list included with this data specifies the defects that will be entered onto the defect map. The defect list refers to the current block length and current logical block addresses (not physical addresses). The format of the defect list is shown in Table 5-15. A FMTDAT bit of zero indicates that the DATA OUT phase will not occur, i.e., no defect list header and no defect data shall be supplied by the initiator. See Table 5-15.

CMPLST - COMPLETE LIST (Byte 1, Bit 3) - Set to one indicates the data supplied is the complete list of known initiator-specified or field replacement defects. Any previous initiator-specified defect map or defect data is erased. This purges any previous initiator-specified defect list and builds a new defect list, which includes the initiator-specified list and the factory defects. A CMPLST bit of zero indicates that the data supplied is in addition to existing defect data using the current format.

DEFECT LIST FORMAT (Byte 1, Bits 2-0) - Specifies additional information related to the defect list. See Table 5-14 for further information.

DATA PATTERN (Byte 2) - User data pattern to be written repetitively into each sector during FORMAT UNIT command (if this option is enabled by the Fill Data Pattern bit in Page 39_H of the MODE SELECT command).

INTERLEAVE FIELD (Bytes 3-4) - Specifies the interleave factor. Any value specified in this field by the initiator will be ignored by the *ProDrive*. The *ProDrive* uses a 1:1 interleave.

TABLE 5-14 FORMAT UNIT Command Variations

4 FMTDAT	Bit Reference (CDB byte 1)				Defect List Byte 1		Defect List Length	Option (See 5.11.4.2)
	3 CMPLST	2	1 DEFECT LIST FORMAT	0	7 FOV	6 DPRY		
1	1	0	X	X	1	1	0	1
1	1	0	X	X	0	0	0	2
1	0	0	X	X	1	1	0	3
0	X	X	X	X	NO DEFECT LIST*			4
1	1	0	X	X	1	1		5
1	1	0	X	X	0	0		6
1	0	0	X	X	1	1		7
1	0	0	X	X	0	0		8
COMMENTS								
1	X	1	0	X	Not Supported			
1	X	1	1	0	Vendor Unique (Not Used)			
1	X	1	1	1	Reserved			

Key: X = 1 or 0 (ignored by *ProDrive*)

*Since the DATA OUT phase does not occur, there is no defect list header.

The defect list shown in Table 5-15 contains a four-byte header which may be followed by defect descriptors. The defect list length is equal to four times the number of defect descriptors; it specifies the total length in bytes of the defect descriptors that follow. Each defect descriptor for the logical block format specifies a four-byte defect logical block address that contains the defect. The defect addresses must be in ascending order. The defect list length may be zero.

TABLE 5-15 Defect List - Logical Block Format

Byte	Bit	7	6	5	4	3	2	1	0
DEFECT LIST HEADER:									
0	RESERVED = 0								
1	FOV	DPRY	DCRT	STPF	RESERVED = 0				
2-3	(MSB)	DEFECT LIST LENGTH							(LSB)
Defect Descriptor(s):									
0-4	(MSB)	DEFECT LOGICAL BLOCK ADDRESS							(LSB)

FOV - FORMAT OPTIONS VALID (Byte 1, Bit 7) - Set to one authorizes the setting of bits 4 through 6 (STPF, DCRT, and DPRY). A FOV bit of zero indicates that the initiator requests the *ProDrive* default format scheme to be implemented for the functions defined by bits 4 through 6.

DPRY - DISABLE PRIMARY (Byte 2, Bit 6) - Set to one indicate that the *ProDrive* will exclude the factory defect map (primary list or P-list) from its list of flaws to manage while formatting. A DPRY bit set to zero indicates that the *ProDrive* will include the factory defect map in its list of flaws to manage while formatting. Note that the inclusion of the factory defect map is the default condition of the *ProDrive*.

DCRT - DISABLE CERTIFICATION (Byte 1, Bit 5) - Not supported by the *ProDrive*. Must be set to zero by the initiator.

STPF - STOP FORMAT (Byte 1, Bit 4) - Not supported by the *ProDrive*. Must be set to zero by the initiator.

5.11.4.2 Application of FORMAT UNIT Command

The *ProDrive* offers eight formatting options as follows:

- 1) Format with absolutely no defects
- 2) Format with original factory defects only
- 3) Format with grown defects only (discarding factory defects)
- 4) Format with existing defects (factory and grown defects)
- 5) Format with provided defects only (discarding factory and existing grown defects)
- 6) Format with provided defects in addition to factory defects (discarding existing grown defects)
- 7) Format with provided defects in addition to existing grown defects (discarding factory defects)
- 8) Format with provided defects in addition to existing defects

NOTE: With any of the above options, the list of grown defects is always updated to reflect the latest condition; meanwhile, the original factory defects are always preserved.

The following tables illustrate the setting of the FORMAT UNIT CDB and defect list header required to implement each of the listed options.

(1) Format with absolutely no defects.

FORMAT UNIT Command										
Byte	Bit	7	6	5	4	3	2	1	0	
0		OPCODE = 04 _H								
1		LUN = 0			1	1	0			
2		DATA PATTERN								
3-4		(MSB)	INTERLEAVE = XX						(LSB)	
5		VU = 0		RESERVED = 0			F	L		

Defect List Header										
Byte	Bit	7	6	5	4	3	2	1	0	
0		RESERVED = 0								
1		1	1	0	0	RESERVED = 0				
2-3		(MSB)	DEFECT LENGTH = 0						(LSB)	

NOTE: The list of grown defects will be erased.

(2) Format with original factory defects only.

FORMAT UNIT Command										
Byte	Bit	7	6	5	4	3	2	1	0	
0		OPCODE = 04 _H								
1		LUN = 0			1	1	0			
2		DATA PATTERN								
3-4		(MSB)	INTERLEAVE = XX						(LSB)	
5		VU = 0		RESERVED = 0			F	L		

Defect List Header										
Byte	Bit	7	6	5	4	3	2	1	0	
0		RESERVED = 0								
1		0	0	0	0	RESERVED = 0				
2-3		(MSB)	DEFECT LENGTH = 0						(LSB)	

NOTE: The list of grown defects will be erased.

(3) Format with grown defects only; discard factory defects.

FORMAT UNIT Command									
Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 04 _H								
1	LUN = 0			1	0	0			
2	DATA PATTERN								
3-4	(MSB)	INTERLEAVE = XX						(LSB)	
5	VU = 0		RESERVED = 0				F	L	

Defect List Header									
Byte	Bit	7	6	5	4	3	2	1	0
0	RESERVED = 0								
1	1	1	0	0	RESERVED = 0				
2-3	(MSB)	DEFECT LENGTH = 0						(LSB)	

NOTE: The list of grown defects will be erased.

(4) Format with existing defects (factory and grown defects). The data out phase is not used.

FORMAT UNIT Command									
Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 04 _H								
1	LUN = 0			0	0	0			
2	DATA PATTERN								
3-4	(MSB)	INTERLEAVE = XX						(LSB)	
5	VU = 0		RESERVED = 0				F	L	

NOTE: No defect list header or defect descriptor blocks follow the command.

(5) Format with provided defects only; discard factory and existing grown defects.

FORMAT UNIT Command										
Byte	Bit	7	6	5	4	3	2	1	0	
0		OPCODE = 04 _H								
1		LUN = 0			1	1	0			
2		DATA PATTERN								
3-4		(MSB)	INTERLEAVE = XX						(LSB)	
5		VU = 0		RESERVED = 0			F	L		

Defect List Header										
Byte	Bit	7	6	5	4	3	2	1	0	
0		RESERVED = 0								
1		1	1	0	0	RESERVED = 0				
2-3		(MSB)	DEFECT LENGTH						(LSB)	

NOTE: The defect descriptor blocks follow the defect list header.

(6) Format with provided defects in addition to factory defects; discard existing grown defects)

FORMAT UNIT Command										
Byte	Bit	7	6	5	4	3	2	1	0	
0		OPCODE = 04 _H								
1		LUN = 0			1	1	0			
2		DATA PATTERN								
3-4		(MSB)	INTERLEAVE = XX						(LSB)	
5		VU = 0		RESERVED = 0			F	L		

Defect List Header										
Byte	Bit	7	6	5	4	3	2	1	0	
0		RESERVED = 0								
1		0	0	0	0	RESERVED = 0				
2-3		(MSB)	DEFECT LENGTH						(LSB)	

NOTE: The defect descriptor blocks follow the defect list header. The provided defects will replace the existing grown defects.

(7) Format with provided defects in addition to existing grown defects; discard factory defects)

FORMAT UNIT Command									
Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 04 _H								
1	LUN = 0			1	0	0			
2	DATA PATTERN								
3-4	(MSB)	INTERLEAVE = XX						(LSB)	
5	VU = 0		RESERVED = 0				F	L	

Defect List Header									
Byte	Bit	7	6	5	4	3	2	1	0
0	RESERVED = 0								
1	1	1	0	0	RESERVED = 0				
2-3	(MSB)	DEFECT LENGTH = 0						(LSB)	

NOTE: The defect descriptor blocks follow the defect list header. The existing list of grown defects will be added with the provided defects, becoming the updated grown defects.

(8) Format with provided defects in addition to existing defects

FORMAT UNIT Command									
Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 04 _H								
1	LUN = 0			1	0	0			
2	DATA PATTERN								
3-4	(MSB)	INTERLEAVE = XX						(LSB)	
5	VU = 0		RESERVED = 0				F	L	

Defect List Header									
Byte	Bit	7	6	5	4	3	2	1	0
0	RESERVED = 0								
1	0	0	0	0	RESERVED = 0				
2-3	(MSB)	DEFECT LENGTH = 0						(LSB)	

NOTE: The defect descriptor blocks follow the defect list header. The existing list of grown defects will be added with the provided defects, becoming the updated grown defects.

5.11.5 REASSIGN BLOCKS COMMAND: OPCODE = 07(hex)

The REASSIGN BLOCKS command (Table 5-16) requests the *ProDrive* to reassign the defective logical blocks to areas on the drive reserved for this purpose.

The initiator transfers a defect list during the DATA OUT phase following the command bytes; the defect list contains the logical block addresses to be reassigned by the *ProDrive*. The drive will reassign the physical medium used for each logical block address in the list. The data contained in the logical blocks specified in the defect list will be preserved if recoverable within the limits prescribed by MODE SELECT error recovery parameters; the data in all other logical blocks on the medium will be preserved. If a logical block that has previously been reassigned is specified to be reassigned, the block will be reassigned again. The defective block address will be added to the drive's field replacement defect map.

NOTES: The REASSIGN BLOCKS command should not be used to redundantly reassign defective logical blocks which have already been so reassigned with the automatic reallocation feature of MODE SELECT.

Block reassignment can degrade performance by requiring spare locations to be accessed. This can be remedied by moving a file to a more appropriate area (as determined using the READ CAPACITY command) or possibly by reassigning all logical block addresses with the FORMAT UNIT command.

TABLE 5-16 REASSIGN BLOCKS Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 07H							
1		LUN = 0				RESERVED = 0			
2-4		RESERVED = 0							
5		VU = 0		RESERVED = 0				F	L

The REASSIGN BLOCKS defect list (Table 5-17) contains a four-byte header followed by one or more defect descriptors. The length of each defect descriptor is four bytes. The defect list length field specifies the total length in bytes of the defect descriptors that follow. The defect list length is, therefore, equal to four times the number of defect descriptors.

TABLE 5-17 REASSIGN BLOCKS Defect List

Byte	Bit	7	6	5	4	3	2	1	0	
Defect List Header:										
0-1	RESERVED = 0									
2-3	(MSB)	DEFECT LIST LENGTH						(LSB)		
Defect Descriptor(s):										
0-4	(MSB)	DEFECT LOGICAL BLOCK ADDRESS						(LSB)		

The defect descriptor specifies a four-byte defect logical block address that contains the defect. The defect addresses must be in ascending order. All of the 512-byte sectors associated with a logical block (1, 2, or 4 sectors) will be reassigned.

If the drive has insufficient capacity to reassign all of the defective logical blocks, the command will terminate with a CHECK CONDITION status and the sense key will be set to MEDIUM ERROR. The logical block address of the first logical block not reassigned will be returned in the information bytes of the sense data.

5.11.6 READ COMMAND: OPCODE = 08(hex)

The READ command (Table 5-18) requests that the target transfer data to the initiator.

5.11.6.1 Command Structure

TABLE 5-18 READ Command

Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 08 _H								
1	LUN = 0			(MSB)	LOGICAL BLOCK ADDRESS				
2-3	LOGICAL BLOCK ADDRESS								(LSB)
4	TRANSFER LENGTH								
5	VU = 0		RESERVED = 0				F	L	

LOGICAL BLOCK ADDRESS (Byte 1, Bits 4-0; Bytes 2-3) - Specifies the logical block at which the READ operation will begin.

TRANSFER LENGTH (Byte 4) - Specifies the number of contiguous logical blocks of data to be transferred. A transfer length of zero indicates that 256 blocks shall be transferred. Acceptable values are 00-FF_H.

5.11.6.2 READ Command Operation

Read operations on the *ProDrive* are buffered using a 64K-byte buffer. When data is read from the drive, it is first stored in the buffer. After a logical block has been read successfully into the buffer, those data bytes are transferred from the buffer to the SCSI bus.

The two operations involved in reading, transferring data from the disk to the buffer and transferring data from the buffer to the SCSI bus, are essentially independent processes. The first operation, transferring data from the disk to the buffer, will continue as long as the transfer length indicates that there is more data to be read from the disk and there is room in the buffer. The second operation, transferring data from the buffer to the SCSI bus, will start whenever the buffer contains at least one logical block. If the buffer fills completely because the second operation (buffer to SCSI bus) is slower than the first (disk to buffer), transfer to the buffer will be temporarily halted to allow the transfer from the buffer to the SCSI bus to free-up room in the buffer. Transfer from disk to buffer continues until the transfer length is exhausted. Transfer from the buffer to the SCSI bus continues until the first operation is completed and the buffer is totally emptied.

The disconnect/reconnect strategy is tied to the dual processes of filling and emptying the buffer. The *ProDrive* will not disconnect unless the initiator sends an IDENTIFY message with the "I Support Disconnect" bit (bit 6) set. If disconnect is supported by the initiator, the drive will disconnect whenever the buffer is empty and the transfer count is not exhausted. The point at which reconnect occurs is controlled by the Buffer Full Ratio (MODE SELECT Page 2 byte 2). When the buffer fills to the level specified by the Buffer Full Ratio, the *ProDrive* will initiate a reconnection. When reconnection to the bus is established, the buffer to SCSI bus transfer operation will resume. If there is a delay in establishing the reconnection (e.g., the bus is busy), the disk to buffer operation will continue until the buffer is full, or the number of blocks requested has been reached.

5.11.7 **WRITE COMMAND: OPCODE = 0A(hex)**

The WRITE command (Table 5-19) requests that the data transferred to the target be written in the area specified by the logical block address.

5.11.7.1 Command Structure

TABLE 5-19 WRITE Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 0A _H							
1		LUN = 0			(MSB) LOGICAL BLOCK ADDRESS				
2-3		LOGICAL BLOCK ADDRESS							(LSB)
4		TRANSFER LENGTH							
5		VU = 0		RESERVED = 0				F	L

LOGICAL BLOCK ADDRESS (Byte 1, Bits 4-0; Bytes 2-3) - Specifies the logical block at which the WRITE operation will begin.

TRANSFER LENGTH (Byte 4) - Specifies the number of contiguous logical blocks to be transferred. A transfer length of zero indicates that 256 blocks will be transferred. Acceptable values are 00-FF_H.

5.11.7.2 WRITE Command Operation

WRITE commands on the *ProDrive* are buffered using a 64K-byte buffer. Data to be stored on the disk, is first stored in the buffer. When the head is correctly positioned on the track over the appropriate data area, data will be written from the buffer to the disk.

The two operations involved in writing, transferring data from the SCSI bus to the buffer and transferring data from the buffer onto the disk, are essentially independent processes. The first operation, transferring data from the SCSI bus into the buffer, will continue as long as the transfer length indicates that there is more data to be transferred across the SCSI bus from the initiator and there is room in the buffer. If the buffer fills completely, the transfer of data across the SCSI bus will temporarily halt. The second operation, transferring data from the buffer onto the disk, will occur as long as the buffer is not empty and the head is correctly positioned over the appropriate data area. The only interaction between these two operations involves the buffer level. The buffer-to-disk operation will stop if the SCSI bus-to-buffer transfer process cannot keep up and the buffer empties. In turn, the SCSI-to-buffer transfer will temporarily halt if the buffer-to-disk transfer process falls behind and the buffer fills completely.

The disconnect/reconnect strategy is tied to the dual processes of filling and emptying the buffer. The *ProDrive* will not disconnect unless the initiator sends an IDENTIFY message with the "I Support Disconnect" bit (bit 6) set. If disconnect is supported by the initiator, the drive will disconnect whenever it can no longer transfer data from the SCSI bus to the buffer because the buffer is full (or the transfer count is exhausted). The point at which reconnection occurs is controlled by the Buffer Empty Ratio (MODE SELECT Page 2 byte 3). This ratio determines how low the buffer level must get via data transfer to disk before reconnection is attempted. After a successful reconnection, the SCSI bus-to-buffer transfer operation will resume.

5.11.8 **SEEK COMMAND: OPCODE = 0B(hex)**

The SEEK command (Table 5-20) requests that the drive seek to the specified logical block address.

TABLE 5-20 SEEK Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 0BH							
1		LUN = 0		(MSB)	LOGICAL BLOCK ADDRESS				
2-3		LOGICAL BLOCK ADDRESS							(LSB)
4		RESERVED = 0							
5		VU = 0	RESERVED = 0				F	L	

LOGICAL BLOCK ADDRESS (Byte 1, Bits 5-0; Bits 2-3) - Specifies the logical block to which the actuator will be repositioned after the SEEK operation is complete.

5.11.9 INQUIRY COMMAND: OPCODE = 12(hex)

The INQUIRY command (Table 5-21) requests that information regarding identification of the target be sent to the initiator.

5.11.9.1 Command Structure

TABLE 5-21 INQUIRY Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 12 _H							
1		LUN = 0			RESERVED = 0				
2-3		RESERVED = 0							
4		ALLOCATION LENGTH (BYTES)							
5		VU = 0		RESERVED = 0				F	L

ALLOCATION LENGTH - Specifies the maximum number of bytes that the initiator has allocated for returned INQUIRY data. A value of 00 indicates that no data will be returned. Acceptable values are 00-FF_H. The *ProDrive* will terminate the DATA IN phase when the allocation length bytes have been transferred or when all available INQUIRY data have been transferred to the initiator, whichever is less. (For the *ProDrive*, an allocation length of 130 (82_H) is recommended.)

5.11.9.2 INQUIRY DATA Format

TABLE 5-22 INQUIRY DATA Format

Byte	Bit	7	6	5	4	3	2	1	0
0		PERIPHERAL DEVICE TYPE = 0							
1		RMB = 0	DEVICE TYPE QUALIFIER = 0						
2		RESERVED = 0		ECMA VERSION = 0			ANSI VERSION = 1		
3		RESERVED = 0				RESPONSE DATA FORMAT = 1			
4		ADDITIONAL LIST LENGTH							

PERIPHERAL DEVICE TYPE (Byte 0) - Set to a value of zero for the *ProDrive* (Direct Access Device), unless the LUN specified in the Command Descriptor Block is invalid. If the LUN is invalid, the peripheral device type is set to 7F_H. The reset of the data bytes is not affected and are returned as if the LUN was set to a value of zero.

RMB - REMOVABLE MEDIUM BIT (Byte 1, Bit 7) - Always set to zero for the *ProDrive* to indicate non-removable media.

DEVICE TYPE QUALIFIER (Byte 1, Bits 6-0) - Not supported by *ProDrive*; it is set to a value of zero.

ECMA VERSION (Byte 2, Bits 5-3) - Set to zero to indicate that the *ProDrive* does not claim compliance to the European Computer Manufacturers Association version of SCSI.

ANSI VERSION (Byte 2, Bits 2-0) - Set to one to indicate compliance with the ANSI specification for SCSI.

RESPONSE DATA FORMAT (Byte 3, Bits 3-0) - Set to one to indicate compliance with the Common Command Set proposed by an ANSC X3T9.2 working group.

ADDITIONAL LIST LENGTH (Byte 4) - Specifies the length in bytes of the list of drive identification information. The *ProDrive* identification information is shown on the following chart. If the allocation length of the command descriptor block is too small to transfer all of the vendor unique parameters, the additional length value will not be adjusted to reflect the truncation.

ProDrive DRIVE IDENTIFICATION INFORMATION

BYTE	Information
5	Vendor Unique = 0
6 - 7	Reserved = 0
8 - 15	Vendor Identification = 'QUANTUM'
16 - 20	Product Identification (Model) = P40S (P80S)
21 - 31	Product Identification (Part Number) = 940-40-94XX (980-80-94XX) XX is replaced by the appropriate digits
32 - 35	Microcode Revision Level (Variation Code) = 'VV' VV is replaced by the appropriate variation code
36 - 43	Microcode Date = 'MM/DD/YY' MM = month DD = day YY = year
44 - 55	Drive Serial Number = 'ccymmdd-ssss' cc = capacity (40 or 80) y = last digit of year drive built mm = month dd = day ssss = drive sequence number
56 - 97	Reserved = 0
98 - 119	Vendor Unique

NOTE: Bytes 8 through 55 are ASCII values. If the drive is not ready when the INQUIRY command is received, it will be unable to return the correct data for bytes 16-31 and 44-55. In this case, the data returned will be the default data as shown in the following table.

BYTES	DATA
16 - 31	"P40S 940-40-94XX "
44 - 55	"DRV SER NUM "

5.11.10 MODE SELECT COMMAND: OPCODE = 15(hex)

The MODE SELECT command (Table 5-23) provides a means for the initiator to specify device parameters to the drive. A MODE SELECT command will override any previous selection of device parameters, even from another initiator. Execution of the command will create a UNIT ATTENTION condition for other initiators, provided that at least one parameter is changed.

5.11.10.1 Command Structure

TABLE 5-23 MODE SELECT Command

Bit	7	6	5	4	3	2	1	0
Byte								
0	OPCODE = 15 _H							
1	LUN = 0			RESERVED = 0				SP
2	RESERVED = 0							
3	RESERVED = 0							
4	PARAMETER LIST LENGTH (BYTES)							
5	VU = 0		RESERVED = 0				F	L

When the *ProDrive* is powered on and the motor spins up, the most recent set of device parameters is read from an unaddressable area on the drive, and a UNIT ATTENTION condition is set for all initiators. (See the Saved Mode Table, Section 5.10.)

- If the parameter values cannot be successfully read from the Saved Mode Table, they will revert to their default values as shipped from the factory and the additional sense code will be set to 2A_H as if another initiator altered the parameters.
- If the parameter values are read successfully, the additional sense code will be set to 29_H to indicate a reset.

NOTE: If bit 1, Byte 2 of MODE SELECT, Page 39_H is set to a value of one, the UNIT ATTENTION condition will not occur; see Section 5.11.10.5.

SP - SAVE PARAMETERS (Byte 1, Bit 0) - If set to one, only the saveable pages of the Current Mode Table will be copied to the Saved Mode Table. See Section 5.10 for a description of the Saved Mode Table.

PARAMETER LIST LENGTH (Byte 4) - Specifies the length in bytes of the MODE SELECT parameter list that will be transferred during the DATA OUT phase. A parameter list length of zero indicates that no data will be transferred. This condition should not be considered an error.

5.11.10.2 MODE SELECT Parameter List

The MODE SELECT parameter list (Table 5-24) contains a four-byte header, followed by zero or one block descriptor, then zero or more "pages".

TABLE 5-24 MODE SELECT Parameter List

Byte	Bit	7	6	5	4	3	2	1	0	
Mode Select Header:										
0		RESERVED = 0								
1		MEDIUM TYPE = 0								
2		RESERVED = 0								
3		BLOCK DESCRIPTOR LENGTH (BYTES)								
Block Descriptors										
0		DENSITY CODE = 0								
1-3	(MSB)	NUMBER OF BLOCKS = 0						(LSB)		
4		RESERVED = 0								
5-7	(MSB)	BLOCK LENGTH						(LSB)		
Page Descriptor(s):										
0		RESERVED = 0	PAGE CODE							
1		PAGE LENGTH								
2 to n		REFER TO PAGE DESCRIPTION								

MEDIUM TYPE (Byte 1) - Set to zero for default (currently mounted medium type) since the *ProDrive* has non-removable media.

BLOCK DESCRIPTOR LENGTH (Byte 3) - Specifies the length in bytes of all the block descriptors. It is equal to the number of block descriptors times eight; it does not include the pages, if any. A block descriptor length of zero indicates that no block descriptors will be included in the parameter list. A single block descriptor is used for the *ProDrive*.

BLOCK DESCRIPTORS: The block descriptors specify the logical block length for the drive including a density code, number of blocks, and block length.

DENSITY CODE (Byte 0) - Set to zero, indicating the default density of the medium, since the *ProDrive* uses only one density.

NUMBER OF BLOCKS (Bytes 1-3) - Specifies the number of logical blocks on the medium that meet the density code and block length in the block descriptor. A value of zero indicates that all remaining logical blocks of the drive have the medium characteristics specified by the block descriptor. Any non-zero value within the capacity of the *ProDrive* can be used to limit access of the drive to a certain number of blocks.

BLOCK LENGTH (Bytes 5-7) - The block length specifies the length in bytes of each logical block described by the block descriptor. For the *ProDrive*, allowable values are 512 (200_H), 1024 (400_H), or 2048 (800_H). The default block length is 512 (200_H).

NOTE: The block length may be altered without reformatting the drive or affecting stored data.

PAGE DESCRIPTOR(S):

PAGE CODE (Byte 0, Bits 5-0) - Pages are optional; they may be included in any order, immediately following the block descriptor. The mode parameters are divided into pages to avoid having to specify all Mode Parameters each time a MODE SELECT command is issued. A page is the minimum unit that can be specified in a MODE SELECT or MODE SENSE command. Each time a page is referenced, all parameters on that page must be specified. Changeable parameters may be set to any acceptable values; non-changeable parameters must be set to zero.

The pages are numbered for reference. Each page contains parameters grouped by functionality. For example, Page 1 contains the Read/Write Error Recovery Parameters. These are the parameters which determine drive behavior during a data handling error. The Retry Count Parameter is located on this page, as are the bits which turn on/off error detection, and determine if soft errors are reported.

The *ProDrive* supports the following pages:

<u>Page</u>	<u>Description</u>
01 _H	Read/Write Error Recovery Parameters
02 _H	Disconnect/Reconnect Control Parameters
03 _H	Direct Access Device Format Parameters
04 _H	Rigid Disk Drive Geometry Parameters*
37 _H	Quantum Unique Control Parameters
39 _H	Quantum Unique Drive Control Parameters

* Read-only. Can only be referenced via the MODE SENSE command.

PAGE LENGTH (Byte 1) - Indicates the number of bytes of the page that will follow, beginning with the first byte of flags or values and continuing consecutively. The page length must be set to the value returned by the *ProDrive* in the MODE SENSE Page Length byte. Otherwise, a CHECK CONDITION status with a sense key of ILLEGAL REQUEST will result.

5.11.10.3 Error Recovery Parameters, Page Code 1H

Bit	7	6	5	4	3	2	1	0
0	RESERVED = 0		PAGE CODE = 1H					
1	PAGE LENGTH = 6H							
2	AWRE	ARRE	TB	RC	EEC	PER	DTE	DCR
3	RETRY COUNT							
4	CORRECTION SPAN							
5	HEAD OFFSET COUNT = 0							
6	DATA STROBE OFFSET COUNT = 0							
7	RECOVERY TIME LIMIT = 0							

DCR - DISABLE CORRECTION (Byte 2, Bit 0) - Set to one indicates that the data will be transferred without correction, whether or not it is possible to correct it. A DCR bit of zero indicates that the data will be corrected if possible; uncorrectable data will be transferred with no attempt at correction, although retries will still be attempted. If RC (bit 4 of byte 2) is set to one, this bit is ignored. The default is zero.

DTE - DISABLE TRANSFER ON ERROR (Byte 2, Bit 1) - Set to one indicates that the *ProDrive* will create the CHECK CONDITION status immediately upon detection of an error, if PER (bit 2 of byte 2) is also set to one. Data transfer to the initiator will be terminated; the block in error may or may not be transferred to the initiator depending on the setting of the TB bit. A DTE bit set to zero enables data transfer for any data which can be recovered within the limits of the Error Recovery Flags. Any errors that would be posted are not posted until the transfer length is exhausted. If PER is zero, or RC is one, this bit is ignored. The default is zero.

PER - POST ERROR (Byte 2, Bit 2) - Set to zero indicates that the *ProDrive* will not create the CHECK CONDITION status for errors recovered within the limits established by the other Error Recovery Flags. Recovery procedures exceeding the limits established by the other Error Recovery Flags will be posted. The transfer may terminate prior to exhausting the transfer length depending on the error and state of the other Error Recovery Flags. A PER bit (bit 2 of byte 2) set to one will enable reporting of the CHECK CONDITION status for detected errors, with the appropriate sense key. If multiple errors occur, the sense data will report the block address of the unrecoverable error; if no unrecoverable error occurred, it will report the last block with recovered error. The default is zero.

EEC - ENABLE EARLY CORRECTION (Byte 2, Bit 3) - Set to one indicates that the *ProDrive* will use its ECC algorithm if two consecutive equal error syndromes (non-zero syndromes) are detected. It will not perform read retries before applying correction unless it determines the error to be uncorrectable. Seek or positioning retries and the recovery procedure retries of the message system are not affected by the value of this bit. An EEC bit set to zero indicates that the *ProDrive* will use its normal recovery procedures when an error occurs. (See Appendix A for information on ECC.) If the RC bit is one, this bit is ignored. The default is zero.

RC - READ CONTINUOUS (Byte 2, Bit 4) - Set to one instructs the *ProDrive* to transfer the requested length without adding delays which would increase data integrity, i.e., delays caused by the *ProDrive's* error recovery schemes. Thus, to maintain a continuous flow of data and avoid delays, the *ProDrive* will send data which may be erroneous; ignored errors will not create the CHECK CONDITION status. An RC bit set to zero indicates that time-consuming operations for error recovery are acceptable during data transfer. The default is zero.

TB - TRANSFER BLOCK (Byte 2, Bit 5) - Set to one, if DTE bit (bit 1 of byte 2) is also set to one, indicates that the failing block data (recovered or unrecoverable) will be transferred to the initiator. A TB bit of zero, when DTE bit is set to one, indicates that the failing block will not be transferred to the initiator. If DTE is zero, or RC is one, this bit is ignored. On unrecoverable errors, TB is checked regardless of the state of DTE. The default is zero.

ARRE - AUTOMATIC READ REALLOCATION ENABLED (Byte 2, Bit 6) - Set to one indicates that the *ProDrive* will enable automatic reallocation of bad blocks. The execution of the automatic reallocation is similar to the function of the REASSIGN BLOCKS command, but is initiated by the *ProDrive* when a hard error is encountered, i.e., same non-zero ECC syndrome on two consecutive retries. (See Appendix A.) An ARRE bit set to zero indicates that the *ProDrive* will not perform automatic reallocation of bad blocks. If RC is one, this bit is ignored. The default is zero.

AWRE - AUTOMATIC WRITE REALLOCATION ENABLED (Byte 2, Bit 7) - Not supported by *ProDrive*. Must be set to zero by the initiator.

RETRY COUNT (Byte 2) - The number of times the *ProDrive* will attempt to recover from data errors by rereading before applying correction. The default is 8.

CORRECTION SPAN (Byte 4) - Specifies the size in bits of the largest read data error on which correction may be attempted. It can be set to values from 0-11; the default is 11.

NOTE: The Head Offset Count, Data Strobe Offset, and Recovery Time Limit (Bytes 5 - 7) are not supported by *ProDrive*.

The following table summarizes the valid modes of operation on the *ProDrive*.

EEC	PER	DTE	DCR	Description
0	0	0	0	Normal error recovery procedure. Read retries are attempted until good data is read, a stable syndrome is obtained, or the retry count is exhausted. ECC is invoked if needed when correction is possible. Complete data transfer occurs unless an uncorrectable error is encountered. Only uncorrectable errors are reported.
0	0	0	1	Same as (0,0,0,0) except no ECC correction is attempted. If read retries are not successful, data transfer is stopped and an unrecoverable error is reported.
0	0	1	0	Invalid Request
0	0	1	1	Invalid Request
0	1	0	0	Same as (0,0,0,0) except all data errors (recoverable and unrecoverable) are reported. A recoverable error is reported after the data transfer is completed.
0	1	0	1	Same as (0,0,0,0) except all data errors are reported. A data error recovered via read retries is reported after the data transfer is completed.
0	1	1	0	Read retries are attempted until good data is read, stable syndrome is obtained, or the retry count is exhausted. If needed, ECC is invoked if correction is possible. Data transfer is stopped upon error detection and all data errors are reported.
0	1	1	1	Same as (0,1,1,0) except no ECC correction is attempted. If read retries are not successful, the error is reported as unrecoverable.
1	0	0	0	ECC is invoked immediately if correction is possible. If error is uncorrectable, read retries are attempted until good data is read, a stable syndrome is obtained, or the retry count is exhausted. Complete data transfer occurs unless an unrecoverable error is encountered. Only unrecoverable errors are reported.
1	0	0	1	Invalid Request
1	0	1	0	Invalid Request
1	0	1	1	Invalid Request
1	1	0	0	Same as (1,0,0,0) except all data errors are reported. A recoverable error is reported after the data transfer is completed.
1	1	0	1	Invalid Request
1	1	1	0	Same as (1,0,0,0) except data transfer is stopped upon error detection (recoverable and unrecoverable) and all data errors are reported.
1	1	1	1	Invalid Request

5.11.10.4 Disconnect/Reconnect Control Parameters, Page Code 2_H

Byte	Bit	7	6	5	4	3	2	1	0
0		RESERVED = 0			PAGE CODE = 2 _H				
1		PAGE LENGTH = A _H							
2		BUFER FULL RATIO							
3		BUFER EMPTY RATIO							
4-5	(MSB)	BUS INACTIVITY LIMIT = 0						(LSB)	
6-7	(MSB)	DISCONNECT TIME LIMIT = 0						(LSB)	
8-9	(MSB)	CONNECT TIME LIMIT = 0						(LSB)	
10-11		RESERVED							

Buffer Full Ratio (Byte 2) - Indicates to the *ProDrive* how full the buffer must be prior to reconnecting, for commands requiring data transfer to the initiator (unless the buffer contains all the required data). The *ProDrive* disconnects on a read when there is no data in the buffer (buffer is empty). The buffer full ratio value represents the percentage of the buffer that will fill prior to reconnection, i.e., 255 (FF_H) represents 100% full, 128 (80_H) represents 50% full, and so on. Each bit is equal to 1/256th of the maximum buffer size. The default value is 0 (00_H): at least 512 bytes must be transferred to the buffer before reconnection.

Buffer Empty Ratio (Byte 3) - Indicates to the *ProDrive* how empty the buffer must be prior to reconnecting to fetch more data, for commands requiring data transfer from the initiator (unless the buffer can hold all the required data). This value represents the percentage of the buffer that will empty, i.e., 255 (FF_H) represents 100% empty, 128 (80_H) represents 50% empty, and so on. Each bit represents 1/256th of the maximum buffer size. The default value is 255 (FF_H): the buffer must be completely empty before reconnection.

NOTES: Both the Buffer Full Ratio and the Buffer Empty Ratio are rounded (down or up, respectively) by the *ProDrive* to the nearest multiple of 512 bytes for commands requiring logical block transfer.

None of the remaining bytes (4 through 11) is implemented on the *ProDrive*.

5.11.10.5 Direct-Access Device Format Parameters. Page Code 3H

Byte	Bit	7	6	5	4	3	2	1	0
0		RESERVED = 0			PAGE CODE = 3H				
1		PAGE LENGTH = 16H							

Handling of Defects Fields

2-3	(MSB)	TRACKS PER ZONE							(LSB)
4	(MSB)	ALTERNATE SECTORS PER ZONE = 0							
5		ALTERNATE SECTORS PER ZONE = 1H							(LSB)
6	(MSB)	ALTERNATE TRACKS PER ZONE = 0							
7		ALTERNATE TRACKS PER ZONE = 0							(LSB)
8	(MSB)	ALTERNATE TRACKS PER VOLUME = 0							
9		ALTERNATE TRACKS PER VOLUME = 0							(LSB)

Track Format Field

10	(MSB)	SECTORS PER TRACK = 0							
11		SECTORS PER TRACK = 0							(LSB)

Sector Format Fields

12	(MSB)	DATA BYTES PER PHYSICAL SECTOR = 02H							
13		DATA BYTES PER PHYSICAL SECTOR = 0							(LSB)
14	(MSB)	INTERLEAVE = 0							
15		INTERLEAVE = 1H							(LSB)
16	(MSB)	TRACK SKEW FACTOR = 0							
17		TRACK SKEW FACTOR = 07H							(LSB)
18	(MSB)	CYLINDER SKEW FACTOR = 0							
19		CYLINDER SKEW FACTOR = 0FH							(LSB)

Drive Type Field

20	SSEC=1	HSEC=0	RMB=0	SURF=0	INS=0	RESERVED=0			
21-23	RESERVED = 0								

HANDLING OF DEFECTS FIELDS:

TRACKS PER ZONE (Byte 2-3) - Indicates the number of tracks per defect zone on the *ProDrive*. The default value is six. This value is the only changeable field in page 3H. A change in zone size will be effective after the FORMAT UNIT command is executed.

ALTERNATE SECTORS PER ZONE (Bytes 4-5) - Indicates that the *ProDrive* will deallocate one sector per zone from the initiator addressable blocks during the FORMAT UNIT command. These sectors will be available as replaceable sectors for defective sectors.

ALTERNATE TRACKS PER ZONE (Bytes 6-7) - Set to zero; the *ProDrive* does not allocate alternate tracks.

ALTERNATE TRACKS PER VOLUME (Bytes 8-9) - Set to zero; the *ProDrive* does not allocate alternate tracks.

TRACK FORMAT FIELD:

SECTORS PER TRACK (Bytes 10-11) - Indicates the number of physical sectors the *ProDrive* allocates per disk track. The value of zero indicates that the *ProDrive* has a variable number of sectors per track (28 or 35).

SECTOR FORMAT FIELDS:

DATA BYTES PER PHYSICAL SECTOR (Bytes 12-13) - Indicates the number of data bytes the *ProDrive* will allocate per physical sector. This value may be different than the logical block size in the block descriptor section of the MODE SELECT data. This implies that the *ProDrive* set an equal number of sectors per track accordingly. The *ProDrive* has 512 data bytes per physical sector.

INTERLEAVE (Bytes 14-15) - The *ProDrive* has an interleave factor of one.

TRACK SKEW FACTOR (Bytes 16-17) - Indicates the number of physical sectors between the last logical block of one track and the first logical block on the next sequential track of the same cylinder. This field is set to 7 for the *ProDrive*.

CYLINDER SKEW FACTOR (Bytes 18-19) - Indicates the number of physical sectors between the last logical block of one cylinder and the first logical block on the next sequential cylinder. This field is set to 15 for the *ProDrive*.

SSEC - SOFT SECTOR (Byte 20, Bit 7) - Always set to one for the *ProDrive*, indicating that it uses soft-sector formatting.

HSEC - HARD SECTOR (Byte 20, Bit 6) - Always set to zero, indicating that the *ProDrive* does not use hard sector formatting. The HSEC and SSEC bits are mutually exclusive.

RMB - REMOVABLE (Byte 20, Bit 5) - Set to zero for the *ProDrive*, indicating that the logical unit is not removable.

SURF - SURFACE (Byte 20, Bit 4) - Set to zero to indicate that the *ProDrive* will allocate progressive addresses to all sectors within a cylinder prior to allocating sector addresses to the next cylinder.

INHIBIT SAVE (INS) (Byte 20, Bit 3) - Set to zero to indicate that the *ProDrive* will save the parameters of the page defined by Page Code 4H as a read only page.

5.11.10.6 Quantum Unique Control Parameters. Page Code 37_H

Byte	Bit	7	6	5	4	3	2	1	0
0		RESERVED = 0		PAGE CODE = 37 _H					
1		PAGE LENGTH = 0E _H							
2		RESERVED = 0	PSM	SSM	WIE	PO	PE	CE	
3		NUMBER OF CACHE SEGMENTS							
4		MINIMUM PREFETCH							
5		MAXIMUM PREFETCH							
6-15		RESERVED = 0							

PSM - PRESERVE SYNCHRONOUS MODE (Byte 2, Bit 5) - Set to one indicates the *ProDrive* will not clear the table of synchronous mode parameters for all initiators when the drive is reset. A PSM bit set to zero will cause all these parameters to be cleared when the drive is reset. The default is zero.

SSM - SEND SYNCHRONOUS MESSAGE (Byte 2, Bit 4) - Set to one indicates that the *ProDrive* will initiate sending the Extended Message (01) Synchronous Data Transfer Request to the initiator. A SSM bit set to zero indicates that the initiator must initiate sending the Synchronous Data Transfer Request message. The default is zero.

NOTE: The following parameters control the operation of Quantum's unique *DisCache* feature. See Appendix A for a description of *DisCache*, and more information on these options.

WIE - WRITE INDEX ENABLE (Byte 2, Bit 3) - All data from WRITES create a cache segment stored in the cache and indexed by the cache table. A WIE bit set to zero indicates that the *ProDrive* will overwrite this segment in the cache on the next READ or WRITE. A WIE bit set to one indicates that the *ProDrive* will treat this segment as if it had been generated by a READ. Setting WIE to zero preserves more data in the cache from READs, increasing the likelihood that the data for subsequent READ requests will be in the cache; the magnitude of this increase depends on the size and frequency of WRITE requests. The default is zero.

PO - PREFETCH ONLY (Byte 2, Bit 2) - Set to one indicates that the *ProDrive* will only retain prefetch data in the cache; the originally requested read data will be overwritten with prefetch data. A PO bit set to zero indicates that both original read data and prefetched data will be retained in the segment. The default is zero.

PE - PREFETCH ENABLE (Byte 2, Bit 1) - Set to one indicates that the *ProDrive* will perform prefetching. A PE bit set to a value of zero indicates that no prefetching will occur. The CE bit must be set to one to enable use of the PE bit. The default is one.

CE - CACHE ENABLE (Byte 2 Bit 0) - Set to one indicates that the *ProDrive* will activate caching on all READS. A CE bit set to zero indicates that the *ProDrive* will disable caching and use the 64K RAM as a transfer buffer only. The default is one.

NUMBER OF CACHE SEGMENTS (Byte 3) - Indicates to the *ProDrive* the number of segments to index in the cache, i.e., the number of entries in the cache table. Valid entries are 1, 2, 4, 8, 16. Any other entry will result in a CHECK CONDITION status with a sense key of ILLEGAL REQUEST. The default is four.

MINIMUM PREFETCH (Byte 4) - Indicates to the *ProDrive* the minimum number of logical blocks to prefetch on a cache miss for a READ command. The valid range is 0 to 128; any value outside this range will result in a CHECK CONDITION status with a sense key of ILLEGAL REQUEST. The default value is one.

MAXIMUM PREFETCH (Byte 5) - Indicates to the *ProDrive* the maximum number of logical blocks to prefetch on a cache miss for a READ command. The valid range is 0 to 128; any value outside this range will result in a CHECK CONDITION status with a sense key of ILLEGAL REQUEST. The default is 16.

5.11.10.7 Quantum Unique Drive Control Parameters. Page Code 39_H

Byte	Bit	7	6	5	4	3	2	1	0
0		RESERVED = 0			PAGE CODE = 39 _H				
1		PAGE LENGTH = 6 _H							
2		DIO	DII	FDB	RUEE	FDPE	R=0	DUA	DRT
3		DDIS	DELDIS	RESERVED = 0		SSID	SCSIADR		
4-7		RESERVED = 0							

DIO - DISABLE IDENTIFY OUT (Byte 2, Bit 7) - Set to one indicates that the *ProDrive* will not require an IDENTIFY message from the initiator to be able to disconnect and reconnect. A DIO bit set to zero indicates that the *ProDrive* will require the initiator to send the IDENTIFY message to be able to disconnect. The default is zero.

DII - DISABLE IDENTIFY IN (Byte 2, Bit 6) - Set to one indicates that the *ProDrive* will not send an IDENTIFY message after reconnecting to an initiator. A DII bit set to zero indicates that the *ProDrive* will send the IDENTIFY message after reconnecting. The default is zero.

FDB - FAST DEASSERTION OF BUSY (Byte 2, Bit 5) - Not used nor required by applications using the *ProDrive*. It is included to maintain software compatibility with Quantum's Q200 Series™ disk drives.

RUEE - REALLOCATE UNCORRECTABLE ERROR ENABLED (Byte 2, Bit 4) - Set to one indicates that the *ProDrive* will automatically reallocate uncorrectable hard errors if the ARRE bit in Page 1 of the Error Recovery Parameters is set. The uncorrectable (bad) data is written to a new block and a new ECC (one that is correct for this data) is appended. Reading the new block will result in a MEDIUM (re-allocated uncorrectable data read) error with Sense key set to 3, and sense code set to AA_H. Any write to the new block will clear this condition. A RUEE bit set to zero indicates that the *ProDrive* will not attempt automatic reallocation if the hard error encountered is determined to be uncorrectable. In this case, a CHECK CONDITION with a sense key of MEDIUM ERROR - Uncorrectable Data Error will result. The default is zero.

FDPE - FILL DATA PATTERN ENABLED (Byte 2, Bit 3) - Set to one indicates that the *ProDrive* will write the data pattern specified in Byte 2 of the FORMAT UNIT command into every user-accessible sector of the drive when a FORMAT UNIT command is executed. A FDPE bit set to zero indicates that the *ProDrive* will ignore the information in Byte 2 of the FORMAT UNIT command. Issuing a FORMAT UNIT command will typically cause loss of data, even if FDPE is set to zero; users should back up data prior to formatting. The default is zero.

NOTE: Bit 3 of byte 2 is reserved; it must be set to zero.

DUA - DISABLE UNIT ATTENTION (Byte 2, Bit 1) - Set to one indicates that the *ProDrive* will not issue a CHECK CONDITION status with the UNIT ATTENTION sense key on the first command after a reset. The first command issued after the reset condition will be executed as usual. A DUA bit set to zero indicates that the unit attention condition will exist after the *ProDrive* has been powered-on or reset (by a BUS DEVICE RESET message or a "hard" RESET condition). The default is zero.

DRT - DISABLE RESELECTION TIMEOUT (Byte 2, Bit 0) - Set to one indicates that the *ProDrive* will not timeout during a reselection request. A DRT bit set to zero indicates that the *ProDrive* will clear the bus if there is no BSY response from the initiator after a selection time out period (250 msec). The default is zero.

DDIS - DISABLE DISCONNECTION (Byte 3, Bit 7) - Set to one prevents disconnection and reconnection during a data transfer (READ and WRITE). The initial disconnection due to the implied seek of a READ command is *not* prevented, but no other disconnects will occur. For a WRITE command, the *ProDrive* will disconnect after all data has been transferred into the buffer. A DDIS bit set to zero indicates no suppression of disconnection. The default value is zero.

DELDIS - DELAY OF DISCONNECTION (Byte 3, Bit 6) - Not used nor required by applications using the *ProDrive*. It is included to maintain software compatibility with Quantum's Q200 Series disk drives.

SSID - SOFTWARE SELECTABLE ID (Byte 3, Bit 3) - Set to zero indicates that the drive SCSI ID will be determined by the value set by the jumpers on the drive PCB at all times. An SSID bit set to one indicates that the drive SCSI ID will be determined by the value of the SCSIADR bits (bits 0-2 of byte 3); the value set by the jumpers will be ignored. When the SSID bit is set to one, the SCSI ID will not be altered until the next RESET or power up of the drive. If upon initial power-up, the SSID bit is set to one (i.e., it was previously set and saved to the disk), the SCSIADR bits will determine the SCSI ID; otherwise, the SCSI ID will be determined by the jumpers on the PCB. The default value of SSID is zero.

SCSIADR - SCSI Address (Byte 3, Bits 2-0) - Determines the SCSI ID, if SSID (bit 3 of byte 3) is set to one. If SSID is set to zero, the SCSI ID is determined by jumpers on the PCB. See the description of SSID, above. The default is zero.

5.11.11 RESERVE COMMAND: OPCODE = 16(hex)

The RESERVE command (Table 5-25) is used to reserve a logical unit for the use of the initiator or another specified (third party) SCSI device. This command requests that the drive be reserved for the exclusive use of the initiator (or third party) until the reservation is superseded by another valid RESERVE command from the same initiator or is released by a RELEASE command from the same initiator, a BUS DEVICE RESET message from any initiator, or a "hard" RESET condition. A logical unit reservation will not be granted if the drive is reserved by another initiator. It is permissible for an initiator to reserve the drive when it is currently reserved for that initiator; in that case, the reservation identification and the extent list length will be ignored.

If the drive is reserved for another initiator, it will respond by either returning a RESERVATION CONFLICT status or, if disconnection is allowed, by queuing the reserve request and disconnecting.

If, after honoring the reservation, any other initiator then subsequently attempts to perform any command on the reserved drive (other than a RELEASE command which will be ignored, or a reserve command which may be queued), the command will be rejected with RESERVATION CONFLICT status.

TABLE 5-25 RESERVE Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 16H							
1		LUN = 0			3RDPTY	3RD PARTY DEVICE ID		EXTENT	
2		RESERVATION IDENTIFICATION = XX							
3-4		(MSB)	EXTENT LIST LENGTH = XX						(LSB)
5		VU=0			RESERVED = 0			F	L

EXTENT - EXTENT RESERVATION (Byte 1, Bit 0) - Must be set to zero. If this bit is set to one, the *ProDrive* will reject the RESERVE command with CHECK CONDITION status with the ILLEGAL REQUEST sense key.

3RDPTY - THIRD-PARTY RESERVATION (Byte 1, Bit 4) - This is an option for the RESERVE command that allows an initiator to reserve a logical unit for another SCSI device. It is intended for use in multiple-initiator systems that use the COPY command.

5.11.12 RELEASE COMMAND: OPCODE = 17(hex)

The RELEASE command (Table 5-26) is used to release a previously reserved logical unit. It is not an error for an initiator to attempt to release a reservation that is not currently active.

TABLE 5-26 RELEASE Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 17H							
1		LUN = 0			3RDPTY	3RD PARTY DEVICE ID		EXTENT	
2		RESERVATION IDENTIFICATION							
3-4		RESERVED = 0							
5		VU=0			RESERVED = 0			F	L

EXTENT - EXTENT RESERVATION (Byte 1, Bit 0) - Must be set to zero. If this bit is set to one, the *ProDrive* will reject the RELEASE command with CHECK CONDITION status with the ILLEGAL REQUEST sense key.

3RDPTY - THIRD-PARTY RESERVATION (Byte 1, Bit 4) - An option for the RESERVE command that allows an initiator to release a logical unit that was previously reserved via the third-party reservation option. It is intended for use in multiple-initiator systems that use the COPY command. If the third-party bit is zero, the third-party release option is not requested. If it is set to one, the *ProDrive* will release the specified logical unit, but only if the reservation was made using the third-party reservation option by the same initiator for the same SCSI device specified in the third-party device ID field.

5.11.13 MODE SENSE COMMAND: OPCODE = 1A(hex)

The MODE SENSE command (Table 5-27) provides a means for the target to report its peripheral device parameters to the initiator. This command complements the MODE SELECT command.

5.11.13.1 MODE SENSE Command Structure

TABLE 5-27 MODE SENSE Command

Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = 1AH								
1	LUN = 0			RESERVED = 0					
2	PCF		PAGE CODE						
3	RESERVED = 0								
4	ALLOCATION LENGTH								
5	VU=0		RESERVED = 0				F	L	

PCF - PAGE CONTROL FIELD (Byte 2, Bits 7,6) - Defines the type of page parameter values to be returned. There are four options:

Report Current Values (PCF = 00)

The page defined by the page code is returned to the initiator with fields and bits set to current values. The current values are either:

- as set in the last successfully completed MODE SELECT command
- identical to the saved values if no MODE SELECT commands were issued since the last power-up or reset.

Fields and bits not supported by the *ProDrive* are set to zero.

Report Changeable Values (PCF = 01)

The page defined by the page code is returned to the initiator with all fields and bits changeable by the initiator set to ones. Fields and bits not allowed to be changed by the initiator are set to zero.

Report Default Values (PCF = 10)

The page defined by the page code is returned to the initiator with fields and bits set to the *ProDrive's* default values (i.e. as shipped from the factory). Fields and bits not supported by the *ProDrive* are set to zero. If there is confusion over whether a returned value of zero indicates a default parameter or a nonsupported parameter, the initiator can examine the changeable values.

Report Saved Values (PCF = 11)

The page defined by the page code is returned to the initiator with fields and bits set to saved values. The saved values are either:

- as set in the last successfully completed MODE SELECT command with the SP (Save Parameters) bit 0, byte 1 of the CDB set to one.
- identical to the Default values if no MODE SELECT commands with the SP bit set were ever issued (and completed successfully).

Fields and bits not supported by the *ProDrive* are set to zero.

PAGE CODE (Byte 2, Bits 5-0) - For all the above options, the Page Length byte value returned indicates the number of bytes the *ProDrive* supports within each page. This value must be specified in the Page Length field (Byte 1 of each Page Descriptor) when issuing the MODE SELECT command. The page code specifies the particular page information to be returned to the initiator in the MODE SENSE data. The *ProDrive* supports the following pages:

Page	Description
01H	Read/Write Error Recovery Parameters
02H	Disconnect/Reconnect Control Parameters
03H	Direct-Access Device Format Parameters
04H	Rigid Disk Drive Geometry Parameters (valid for MODE SENSE command only)
37H	Quantum Unique Control Parameters
38H	Read-only; included for compatibility with Q200 Series drives
39H	Quantum Unique Drive Control Parameters
3FH	Return all pages to the initiator (valid for MODE SENSE command only)

The MODE SENSE data provides information to the initiator on the configuration of the *ProDrive's* Format Parameters and Drive Geometry Parameters, if Pages 03H and 04H, respectively, are specified. If Page 3FH is specified, information from all pages implemented by the *ProDrive* will be returned to the initiator in the MODE SENSE data. This page code is only valid in the MODE SENSE command. Specifying page code 04H in a MODE SELECT command will result in a CHECK CONDITION status with Illegal Request sense key.

NOTE: If the allocation length is set to 12 bytes or less, the page code field is ignored and illegal page numbers are accepted. If the allocation length is greater than 12 bytes, an illegal page code will be rejected. This allows the initiator to receive the 4-byte header and 8-byte block descriptor without receiving specific page information.

ALLOCATION LENGTH (Byte 4) - Specifies the number of bytes the initiator has allocated for returned MODE SENSE data. An allocation length of zero indicates that no MODE SENSE data will be transferred. Any other value indicates the maximum number of bytes that should be transferred. The *ProDrive* will terminate the DATA IN phase when allocation length bytes have been transferred or when all available MODE SENSE data have been transferred to the initiator, whichever is less.

MODE SENSE DATA - The MODE SENSE data (Table 5-28) contain a four-byte header, followed by an eight-byte block descriptor, then zero or more "pages". The meanings and organization of these data are the same as for the corresponding MODE SELECT data (Section 5.11.10.2), as modified by the option specified in the page control field of CDB byte 2.

5.11.13.2 MODE SENSE DataTable 5-28 *MODE SENSE Data*

Byte	Bit	7	6	5	4	3	2	1	0
0	SENSE DATA LENGTH								
1	MEDIUM TYPE = 0								
2	WP=0	RESERVED = 0							
3	BLOCK DESCRIPTOR LENGTH = 8								

Block Descriptor

0	DENSITY CODE = 00								
1-3	(MSB)	NUMBER OF BLOCKS = 0						(LSB)	
4	RESERVED = 0								
5-7	(MSB)	BLOCK LENGTH						(LSB)	

Page Descriptors

0	PS	R=0	PAGE CODE						
1	PAGE LENGTH								
2 to n	REFER TO PAGE DEFINITION AND SECTION 5.11.10								

SENSE DATA LENGTH (Byte 0) - 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.

WP - WRITE PROTECTED (Byte 2, Bit 7) - Always set to zero for the *ProDrive*, indicating that the drive is write enabled.

BLOCK DESCRIPTOR LENGTH (Byte 3) - Specifies the length in bytes of all the block descriptors. It is set to eight for the *ProDrive*.

BLOCK DESCRIPTORS: The block descriptor specifies the medium characteristics for the drive with a density code, number of blocks, and block length. These characteristics have the same meanings as the corresponding fields in the MODE SELECT parameter list (Section 5.11.10.2).

PAGE DESCRIPTORS:

PS - PARAMETERS SAVEABLE (Byte 0, Bit 7) - Set to zero in each page header indicates that the supported parameters of that page cannot be saved by the *ProDrive*. A PS bit set to one indicates that the supported parameters of the page can be saved by the *ProDrive*. All pages with parameters that can be changed by the user can be saved on the *ProDrive*.

5.11.13.4 Rigid Disk Drive Geometry Parameters. Page Code 4H

Byte	Bit	7	6	5	4	3	2	1	0
0		RESERVED = 0			PAGE CODE = 4H				
1		PAGE LENGTH = 12H							
2	(MSB)	NUMBER OF CYLINDERS = 0							
3		NUMBER OF CYLINDERS = 3H							
4		NUMBER OF CYLINDERS = 42H (LSB)							
5		NUMBER OF HEADS (3H or 6 H)							
6-8	(MSB)	STARTING CYLINDER - WRITE PRECOMPENSATION = 0							(LSB)
9	(MSB)	STARTING CYLINDER - REDUCED WRITE CURRENT = 0							
10		STARTING CYLINDER - REDUCED WRITE CURRENT = 02H							
11		STARTING CYLINDER - REDUCED WRITE CURRENT = 4EH (LSB)							
12-13	(MSB)	DRIVE STEP RATE							(LSB)
14-16	(MSB)	LANDING ZONE CYLINDER = 0							(LSB)
17-19		RESERVED = 0							

NOTE: The *ProDrive* 40S/80S disk drives have 834 cylinders.
The *ProDrive* 40S has three heads; the *ProDrive* 80S has six heads.

The write precompensation starting cylinders, reduced write current starting cylinders, and drive step rate fields are handled by the embedded SCSI controller on the *ProDrive*.

LANDING ZONE CYLINDER (Bytes 14-16) - Specifies two's complement location where the target will position the disk heads prior to stopping the spindle with the START/STOP UNIT command. This field is only meaningful with drives which do not automatically seek to the Landing Zone before stopping the spindle. The *ProDrive* automatically parks the heads in the Landing Zone, using AIRLOCK, upon disconnection of power.

5.11.14 START/STOP UNIT COMMAND: OPCODE = 1B(hex)

The START/STOP UNIT command (Table 5-29) requests that the logical unit be enabled or disabled for further operations.

TABLE 5-29 START/STOP UNIT Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 1BH							
1		LUN= 0			RESERVED = 0				IMMED
2-3		RESERVED = 0							
4		RESERVED = 0							START
5		VU=0		RESERVED = 0				F	L

IMMED - IMMEDIATE (Byte 1, Bit 0) - Set to one indicates that status will be returned as soon as the operation is initiated. An **IMMED** bit set to zero indicates that status will be returned after the operation is completed.

START (Byte 4, Bit 0) - Set to one requests that the drive be started. A **START** bit set to zero requests that the drive be stopped. A request to start or stop the *ProDrive* may be repeated without error; there will be no effect on the drive if the requested condition is the same as its current condition.

NOTES: A shorting plug (labeled WS) on the *ProDrive* PCB disables/enables the auto-start option. If the shorting plug is not installed, no command is required to start the drive. If the shorting plug is installed, a START/STOP UNIT command is required to enable the drive for operation; this configuration is recommended only for systems requiring power sequencing of devices (usually to limit power supply surge currents).

When the *ProDrive* is stopped, due to a START/STOP UNIT command, both the spindle motor and actuator are disabled and do not draw appreciable currents. Starting the drive requires up to 30 seconds before commands requiring disk access can be executed. See TEST UNIT READY, Section 5.11.1, above.

5.11.15 SEND DIAGNOSTIC COMMAND: OPCODE = 1D(hex)

The SEND DIAGNOSTIC command (Table 5-30) requests the drive to perform diagnostic tests on itself. This command is usually followed by a RECEIVE DIAGNOSTIC RESULTS command, except when the SELF TEST (bit 2 of byte 1) is set to one.

5.11.15.1 Command Structure

TABLE 5-30 SEND DIAGNOSTIC Command

Bit	7	6	5	4	3	2	1	0
Byte								
0	OPCODE = 1DH							
1	LUN= 0			RESERVED = 0		SELF TEST	DEVOFL	UNITOFL
2	RESERVED = 0							
3-4	(MSB) PARAMETER LIST LENGTH							(LSB)
5	VU=0		RESERVED = 0			F	L	

SELF TEST (Byte 1, Bit 2) - Set to one directs the *ProDrive* 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 is successful, the command will be terminated with a GOOD status; otherwise, the command will be terminated with a CHECK CONDITION status with the sense key set to HARDWARE ERROR.

DEVOFL - SCSI DEVICE OFF-LINE (Byte 1, Bit 1) - Not supported. If this bit is set to one on the *ProDrive*, the command will be terminated with a CHECK CONDITION status; the sense key set will be set to ILLEGAL REQUEST with sense code invalid field.

UNITOFL - LOGICAL UNIT OFF-LINE (Byte 1, Bit 0) - Not supported. If this bit is set to one on the *ProDrive*, the command will be terminated with a CHECK CONDITION status; the sense key will be set to ILLEGAL REQUEST with sense code invalid field.

PARAMETER LIST LENGTH (Bytes 3-4) - 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 will be transferred. This condition will not be considered an error.

5.11.15.2 Diagnostic Parameter List

VENDOR UNIQUE (VU) - Vendor Unique, format to be defined.

5.11.16 READ CAPACITY COMMAND: OPCODE = 25(hex)

The READ CAPACITY command (Table 5-31) provides a means for the initiator to request information regarding the capacity of the disk drive.

TABLE 5-31 READ CAPACITY Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 25H							
1		LUN=0			RESERVED = 0				RELADR=0
2-5		(MSB) LOGICAL BLOCK ADDRESS (LSB)							
6-7		RESERVED = 0							
8		VU=0	RESERVED = 0						PMI
9		VU=0	RESERVED = 0				F		L

PMI - PARTIAL MEDIUM INDICATOR (Byte 9, Bit 0) - Set to zero indicates that 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 set to one indicates that 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 in data transfer will be encountered. This logical block address will be greater than or equal to the logical block address specified in the command descriptor block.

The eight bytes of READ CAPACITY data shown in Table 5-32 will be sent during the DATA IN phase of the command.

TABLE 5-32 READ CAPACITY Data

Byte	DESCRIPTION
0-3	(MSB) LOGICAL BLOCK ADDRESS (LSB)
4-7	(MSB) BLOCK LENGTH (LSB)

NOTE: Due to the physical organization of sectors and logical block assignments on the *ProDrive*, the system designer can predict the initial LBA for all cylinders with a high level of confidence. Formatting assigns consecutive logical block addresses to sectors on a cylinder, with only rare exceptions. The designer can be relatively certain that records stored beginning at a cylinder boundary will occupy contiguous physical sectors (skipping occasional defective sectors according to the defect map) and thus will be optimally accessible. However, exceptions do occur due to grown defects and sector ID errors. Therefore it is recommended that the designer rely on the READ CAPACITY command to check for optimal file assignment.

5.11.17 READ EXTENDED COMMAND: OPCODE = 28(hex)

The READ EXTENDED command (Table 5-33) requests that the target transfer data to the initiator.

TABLE 5-33 READ EXTENDED Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 28 _H							
1		LUN = 0			RESERVED = 0				RELADR=0
2-5	(MSB)	LOGICAL BLOCK ADDRESS						(LSB)	
6		RESERVED = 0							
7-8	(MSB)	TRANSFER LENGTH						(LSB)	
9		VU=0		RESERVED = 0				F	L

LOGICAL BLOCK ADDRESS (Bytes 2-5)- Specifies the logical block at which the read operation is to begin.

TRANSFER LENGTH (Bytes 7-8) - Specifies the number of contiguous logical blocks of data that are to be transferred. A transfer length of zero indicates that no logical blocks are to be transferred. This condition will not be considered an error. Any other value indicates the number of logical blocks that are to be transferred.

5.11.18 WRITE EXTENDED COMMAND: OPCODE = 2A(hex)

The WRITE EXTENDED command (Table 5-34) requests that the target write the data transferred by the initiator to the medium.

TABLE 5-34 WRITE EXTENDED Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 2A _H							
1		LUN = 0			RESERVED = 0				RELADR=0
2-5	(MSB)	LOGICAL BLOCK ADDRESS						(LSB)	
6		RESERVED = 0							
7-8	(MSB)	TRANSFER LENGTH						(LSB)	
9		VU=0		RESERVED = 0				F	L

LOGICAL BLOCK ADDRESS (Bytes 2-5) - Specifies the logical block at which the write operation is to begin.

TRANSFER LENGTH (Bytes 7-8) - 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 will not be considered an error and no data will be written. Any other value indicates the number of logical blocks that will be transferred.

5.11.19 SEEK EXTENDED COMMAND: OPCODE = 2B(hex)

The SEEK EXTENDED command (Table 5-35) requests that the logical unit seek to the specified logical block address.

TABLE 5-35 SEEK EXTENDED Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 2BH							
1		LUN = 0			RESERVED = 0				RELADR=0
2-5		(MSB) LOGICAL BLOCK ADDRESS (LSB)							
6-8		RESERVED = 0							
9		VU=0		RESERVED = 0				F	L

5.11.20 WRITE AND VERIFY COMMAND: OPCODE = 2E(hex)

The WRITE AND VERIFY command (Table 5-36) instructs the *ProDrive* to write the data transferred from the initiator to the medium and verify that the data is written correctly.

TABLE 5-36 WRITE AND VERIFY Command

Byte	Bit	7	6	5	4	3	2	1	0	
0		OPCODE = 2EH								
1		LUN = 0			RESERVED = 0				BYTCHK	RELADR=0
2-5		(MSB) LOGICAL BLOCK ADDRESS (LSB)								
6		RESERVED = 0								
7-8		(MSB) TRANSFER LENGTH (LSB)								
9		VU=0		RESERVED = 0				F	L	

BYTCHK - BYTE CHECK (Byte 1, Bit 1) - Must be set to zero. The *ProDrive* only supports medium verification (ECC) (BYTCHK set to zero); it does not support a byte-to-byte comparison of the data on the medium and the data sent from the initiator (BYTCHK set to one). If this bit is set to one, the command will be terminated with a CHECK CONDITION status with ILLEGAL REQUEST sense key.

LOGICAL BLOCK ADDRESS (Bytes 2-5) - Specifies the logical block at which the write operation is to begin.

TRANSFER LENGTH (Bytes 7-8) - 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 will not be considered an error and no data will be written.

5.11.21 VERIFY COMMAND: OPCODE = 2F(hex)

The VERIFY command (Table 5-37) requests that the target verify the data written on the medium.

TABLE 5-37 VERIFY Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 2FH							
1		LUN = 0			RESERVED = 0			BYTCHK	RELADR=0
2-5		(MSB)	LOGICAL BLOCK ADDRESS						(LSB)
6		RESERVED = 0							
7-8		(MSB)	VERIFICATION LENGTH						(LSB)
9		VU=0		RESERVED = 0				F	L

BYTCHK - BYTE CHECK (Byte 1, Bit 1) - Must be set to zero. See the explanation of BYTCHK in the WRITE AND VERIFY command (Section 5.11.20). If this bit is set to one, the command will be terminated with a CHECK CONDITION status with the ILLEGAL REQUEST sense key.

LOGICAL BLOCK ADDRESS (Bytes 2-5) - Specifies the logical block at which the verify operation is to begin.

VERIFICATION LENGTH (Bytes 7-8) - Specifies the number of continuous logical blocks of data that are to be verified. A transfer length of zero indicates that no logical blocks are to be verified. This condition will not be considered an error. Any other value indicates the number of logical blocks to be verified.

5.11.22 READ DEFECT DATA COMMAND: OPCODE = 37(hex)

The READ DEFECT DATA command (Table 5-38) requests that the target transfer the medium defect data to the initiator.

TABLE 5-38 READ DEFECT DATA Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 37H							
1		LUN = 0			RESERVED = 0				
2		RESERVED = 0			P	G	DEFECT LIST FORMAT		
3-6		RESERVED = 0							
7-8		(MSB)	ALLOCATION LENGTH					(LSB)	
9		VU=0		RESERVED = 0			F	L	

P - PRIMARY (BYTE 2, BIT 4) - Set to one indicates that the initiator requests the primary (factory) list of defects be returned.

G- GROWN (BYTE 2, BIT 3) - Set to one indicates that the initiator requests the grown list of defects be returned.

NOTE: With bits P and G both set to a value of one, the *ProDrive* is requested to return the primary and the grown list of defects. Only the Defect List Header bytes will be returned if both the P and G bits are set to a value of zero.

DEFECT LIST FORMAT (Byte 2, Bits 2-1) - Specifies the preferred format for the defect list to be returned by the *ProDrive*. If a format not supported by the *ProDrive* is requested, the drive will return the defect data in Physical Sector Format. In this case, the *ProDrive* will create the CHECK CONDITION status with RECOVERED ERROR sense key after the defect list data list has been transferred. Two defect data formats are supported by the *ProDrive*:

PHYSICAL SECTOR FROM INDEX FORMAT (101_B) - This format will return the physical cylinder, head and sector location from index of the medium defects.

BYTES OFFSET FROM INDEX (100_B) - This format will return the physical cylinder, head and the bytes offset from index of the defect location. The offset number reported represents the first byte of the defective sector.

ALLOCATION LENGTH (Bytes 7-8)- Specifies the number of bytes the initiator has allocated for returned defect data. An allocation length of zero indicates that no defect data are to be transferred. Any other value indicates the maximum number of bytes to be transferred. The *ProDrive* will terminate the DATA IN phase when allocation length bytes have been transferred or when all available defect data have been transferred to the initiator, whichever is less.

The defect data list contains a four byte header (Table 5-39) followed by zero or more defect descriptors.

TABLE 5-39 Defect List Header

Bit	7	6	5	4	3	2	1	0
0	RESERVED = 0							
1	RESERVED = 0			P	G	DEFECT LIST FORMAT		
2-3	(MSB)	DEFECT LIST LENGTH						(LSB)

P AND G (Byte 1, Bits 4 & 3) - Indicate which defect list is actually returned by the *ProDrive*. The defect list format specifies the actual format of the defect list returned by the *ProDrive*. The formats of the defect descriptors are shown in Tables 5-40 and 5-41. The defect list length specifies the total length in bytes of the defect descriptors that follow. The defect list length is equal to eight times the number of defect descriptors. If the allocation length of the CDB is too small to transfer all of the defect descriptors, the defect list length will not be adjusted to reflect the truncation.

TABLE 5-40 Physical Sector Format

Byte	Defect Descriptor(s):							
0-2	(MSB)	CYLINDER NUMBER						(LSB)
3	HEAD NUMBER							
4-7	(MSB)	SECTOR NUMBER						(LSB)

TABLE 5-41 Bytes Offset From Index Format

Byte	Defect Descriptor(s):							
0-2	(MSB)	CYLINDER NUMBER						(LSB)
3	HEAD NUMBER							
4-7	(MSB)	BYTES OFFSET						(LSB)

5.11.23 WRITE BUFFER COMMAND: OPCODE = 3B(hex)

The WRITE BUFFER command (Table 5-42) is used in conjunction with the READ BUFFER command as a diagnostic function for testing the target memory and the SCSI bus integrity. This command will not alter the medium.

TABLE 5-42 WRITE BUFFER Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 3BH							
1		LOGICAL UNIT NUMBER			RESERVED = 0			MODE	
2		BUFFER ID = 0							
3-5		RESERVED = 0							
6-8		(MSB)	TRANSFER LENGTH					(LSB)	
9		CONTROL BYTE							

BUFFER ID (Byte 2) - Must be set to zero. Any other Buffer ID code will result in a CHECK CONDITION status with a sense key of ILLEGAL REQUEST (05H).

TRANSFER LENGTH (Bytes 6-8) - Specifies the maximum number of bytes that are to be transferred during the DATA OUT phase.

The function of this command and the meaning of the transfer length field depend on the contents of the mode field. The mode field is defined as follows:

Bit2	Bit1	Bit0	MODE
0	0	0	Write combined header and data
0	0	1	Vendor unique
0	1	0	Write data
0	1	1	Reserved
1	0	0	Not supported
1	0	1	Not supported
1	1	0	Reserved
1	1	1	Reserved

5.11.23.1 COMBINED HEADER AND DATA Mode (000B)

In this mode, data to be transferred is preceded by a four-byte header which contains all reserved bytes. These four bytes of header must be accounted for in the specified transfer length (bytes 6-8); the amount of data to be stored in the *ProDrive* buffer is the transfer length minus four. The initiator should attempt to ensure that the transfer length is not greater than four plus the available length returned in the header of the READ BUFFER command (mode 000B). If the transfer length exceeds this amount, the *ProDrive* will return CHECK CONDITION status with the sense key of ILLEGAL REQUEST (05H).

5.11.23.2 VENDOR UNIQUE Mode (001B)

Not used by *ProDrive*.

5.11.23.3 DATA Mode (010B)

In this mode, the DATA OUT phase contains buffer data. The transfer length (bytes 6-8) specifies the maximum number of bytes that will be transferred during the DATA OUT phase and stored in the buffer. The initiator should attempt to ensure that the transfer length does not exceed the capacity of the buffer. (The buffer capacity can be determined by the available length field in the READ BUFFER header.) If the transfer length field specifies a transfer that would exceed the buffer capacity, the *ProDrive* will return CHECK CONDITION status with a sense key of ILLEGAL REQUEST (05H).

5.11.24 READ BUFFER COMMAND: OPCODE = 3C(hex)

The READ BUFFER command (Table 5-43) is used in conjunction with the WRITE BUFFER command as a diagnostic function for testing *ProDrive* memory and the SCSI bus integrity. This command does not alter the medium.

TABLE 5-43 READ BUFFER Command

Byte	Bit	7	6	5	4	3	2	1	0
0		OPCODE = 3CH							
1		LOGICAL UNIT NUMBER			RESERVED			MODE	
2		BUFFER ID = 0							
3-5		RESERVED = 0							
6-8		(MSB)	ALLOCATION LENGTH						(LSB)
9		CONTROL BYTE							

BUFFER ID (Byte 2) - Must be set to zero. Any other Buffer ID code will result in a CHECK CONDITION status with a sense key of ILLEGAL REQUEST (05H).

ALLOCATION LENGTH (Bytes 6-8) - Specifies the maximum number of bytes the initiator has allocated for returned information. An allocation length of zero indicates that no header or data bytes are to be transferred; any other value indicates the maximum number of bytes to be transferred.

The function of this command and the meaning of the allocation length field depend on the contents of the mode field. The mode field is defined as follows:

Bit2	Bit1	Bit0	MODE
0	0	0	Read combined header and data
0	0	1	Vendor unique
0	1	0	Read data
0	1	1	Not supported
1	0	0	Reserved
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

5.11.24.1 COMBINED HEADER AND DATA Mode (000B)

In this mode, header and data bytes are returned to the initiator during the DATA IN phase. A four-byte READ BUFFER header (Table 5-44) is followed by data bytes from the *ProDrive* data buffer. The specified allocation length (bytes 6-8) must account for both header and data bytes. The *ProDrive* terminates the DATA IN phase when the allocated number of bytes of header plus data have been transferred or when all available header and data have been transferred to the initiator, whichever occurs first.

TABLE 5-44 READ BUFFER Header

Byte	Bit	7	6	5	4	3	2	1	0
0		RESERVED							
1-3		(MSB)	AVAILABLE LENGTH						(LSB)

AVAILABLE LENGTH (Bytes 1-3) - Specifies the total number of data bytes available in the drive's data buffer. This number is not reduced to reflect the allocation length nor is it reduced to reflect the actual number of bytes written using the WRITE BUFFER command. Following the READ BUFFER header, the *ProDrive* will transfer data from its data buffer. The number of data bytes transferred following the READ BUFFER header will be the allocation length minus four or 64K bytes, whichever is less.

5.11.24.2 VENDOR UNIQUE Mode (001B)

Not used by *ProDrive*.

5.11.24.3 DATA Mode (010B)

In this mode, the DATA IN phase contains buffer data only. The *ProDrive* terminates the DATA IN phase when the allocated number of bytes of data have been transferred or when all data have been transferred to the initiator, whichever occurs first.

5.11.25 READ LONG COMMAND: OPCODE = E8(hex)

The READ LONG command (Table 5-45) requests that the *ProDrive* transfer data to the initiator. For each sector read, the *ProDrive* will transfer 512 data bytes followed by 6 ECC bytes.

TABLE 5-45 READ LONG Command

Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = E8 _H								
1	LUN = 0			(MSB) LOGICAL BLOCK ADDRESS					
2-3	LOGICAL BLOCK ADDRESS								(LSB)
4	TRANSFER LENGTH								
5	VU = 0		RESERVED = 0				F		L

LOGICAL BLOCK ADDRESS - Specifies the logical block at which the READ LONG operation will begin.

TRANSFER LENGTH - Specifies the number of logical blocks to be transferred. A transfer length of zero indicates that no logical blocks are to be transferred. Acceptable values are 00-FF_H.

5.11.26 WRITE LONG COMMAND: OPCODE = EA(hex)

The WRITE command (Table 5-19) requests that the data transferred to the *ProDrive* be written in the area specified by the logical block address. The data passed during the WRITE LONG operation includes 512 data bytes followed by 6 ECC bytes for each sector. The WRITE LONG command is usually preceded by a READ LONG command. The number and order of the bytes in the WRITE LONG command should be the same as in the READ LONG command.

TABLE 5-46 WRITE LONG Command

Byte	Bit	7	6	5	4	3	2	1	0
0	OPCODE = EA _H								
1	LUN = 0			(MSB) LOGICAL BLOCK ADDRESS					
2-3	LOGICAL BLOCK ADDRESS								(LSB)
4	TRANSFER LENGTH								
5	VU = 0		RESERVED = 0				F		L

LOGICAL BLOCK ADDRESS - Specifies the logical block at which the WRITE LONG operation will begin.

TRANSFER LENGTH - Specifies the number of contiguous logical blocks of data to be transferred. A transfer length of zero indicates that logical blocks will be transferred. Acceptable values are 00-FF_H.

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6.1 GENERAL INFORMATION

The ProDrive features extremely high reliability. This is achieved through the simplicity of the mechanical design and the extensive use of microelectronics. These drives are designed for fast, easy subassembly replacement with no adjustments, greatly reducing the amount of downtime for unscheduled repairs.

6.2 MAINTENANCE PRECAUTIONS

Observing the following precautions during service activity will help avoid damage to the drive and personal injury to the service technician.

- a) Do NOT open or remove the metal bubble or its seals.
- b) Do not lift the drive by the faceplate or the PCB.
- c) Avoid harsh shocks to the drive at any time.
- d) Do not move the drive for 20 seconds after DC power is removed; this ensures that the actuator is completely locked.

6.3 PREVENTATIVE MAINTENANCE

No preventative maintenance is required for the *ProDrive*.

6.4 MAINTENANCE LEVELS, EQUIPMENT AND SPARES

6.4.1 LEVELS OF MAINTENANCE

Corrective maintenance on the drive requires certain minimum levels of technical expertise and facilities. Capabilities in this area will vary greatly from user to user. Maintenance procedures for the *ProDrive* are categorized in two levels. The first level involves on-site exchange of subassemblies or the drive itself. The second level involves service center and/or factory repair or refurbishment of assemblies and the printed circuit board.

6.4.1.1 Level 1

Unit replacement, circuit board exchange, external shock mount subassembly replacement.

6.4.1.2 Level 2

Level 1 plus major disassembly and refurbishment of the drive and repair of circuit boards.

NOTE: A user's service activity should be limited to Level 1 procedures during the warranty period. The Quantum warranty is null and void if any Level 2 procedure has been attempted. In addition, no repairs are authorized within the HDA. All time and material required to restore the drive to working order will be billed at prevailing rates.

6.4.2 TOOLS, EQUIPMENT AND SPARES

6.4.2.1 Level 1

The following listed items should be available to personnel providing Level 1 maintenance on the *ProDrive*:

- One drive control PCBA. Quantum part number 800-00-9304
- One shock mount bracket assembly, Quantum part number 480-00-0054
- A #2 Phillips tip

6.4.2.2 Level 2

If the ability to do Level 2 repairs is required, please contact Quantum for information.

Quantum's *ProDrive Series* Intelligent Disk Drives incorporate *DisCache*, a 64K-byte look-ahead disk cache, to enhance drive performance. This integrated feature is user-programmable, using the MODE SELECT command, and can significantly improve system throughput. The cache parameters are programmable, so the cache can be configured in real time to best meet overall system requirements.

DISCACHE DESCRIPTION

DisCache anticipates host-system requests for data and stores that data for faster access. When the host requests a particular segment of data, the caching feature uses a prefetch strategy to "look-ahead" and automatically store the subsequent data from the disk into high-speed RAM (Random Access Memory). If the host requests this subsequent data, the RAM is accessed rather than the disk.

Since typically 50 percent or more of all disk requests are sequential, there is a high probability that subsequent data requested will be in the cache. This cached data can be retrieved in microseconds rather than milliseconds. As a result, *DisCache* can provide substantial time savings during half or more of all disk requests. In these instances, *DisCache* may save most of the disk transaction time by eliminating the seek and rotational latency delays that dominate the typical disk transaction. For example, in a 1K-byte data transfer, these delays comprise 80 percent of the elapsed time.

DisCache works by continuing to fill its cache memory with adjacent data after transferring data requested by the host. Unlike a non-caching controller, Quantum's disk controller continues a read operation after the requested data has been transferred to the host system. This read operation terminates after a programmed amount of subsequent data has been read into the cache segment. During write operations, *DisCache* employs a write-through design, in which data written to the drive is written immediately to the disk. This design ensures data integrity in case of a power loss.

The cache memory is 64K bytes of a DRAM buffer allocated to hold the data which can be directly accessed by the host via the READ and WRITE commands. The memory functions as a group of segments (ring buffers) with rollover points at the end of each segment (buffer). The unit of data stored is the logical block (i.e., a multiple of the 512 byte sector). Therefore, all accesses to the cache memory must be in multiples of the sector size. In those cases where the cache memory must be used for scratch memory, as in the case of a FORMAT UNIT command, or where the size of the logical block may change, as in the MODE SELECT command, the cache will be emptied. The commands that will force emptying of the cache are:

FORMAT UNIT	READ DEFECT DATA
INQUIRY	READ LONG
MODE SELECT	REASSIGN BLOCKS
MODE SENSE	VERIFY
READ CAPACITY	WRITE LONG

PERFORMANCE BENEFITS

In a drive without *DisCache*, during sequential reads, there would be a delay due to rotational latency even if the disk actuator were already positioned at the desired cylinder. *DisCache* eliminates this rotational latency time -- 8 milliseconds on average -- when requested data resides in the cache.

Moreover, the disk often must service requests from multiple processes in a multitasking or multiuser environment. In these instances, while each process may request data sequentially, the disk drive must share time among all these processes. In most disk drives, the heads must move from one location to another. With *DisCache*, even if another process interrupts, the Quantum drive continues to access the data sequentially from its high-speed memory. In handling multiple processes, *DisCache* achieves it most

impressive performance gains, saving both seek and latency time -- 27 milliseconds on average -- when desired data resides in the cache.

MAXIMUM FLEXIBILITY, EASY TO USE

Quantum designed *DisCache* to be extremely flexible because cache performance is highly application-dependent. Programmable options enable users to adjust caching parameters to optimize performance. These options can be specified and subsequently modified using the SCSI MODE SELECT command. Table A-1 outlines the programmable parameters; the discussion following the table explains the parameters and how they can be used.

TABLE A-1 *DisCache* Programmable Parameters

Programmable Parameters	DisCache Function	Input Range	Default Value
Cache enable/disable	Activates cache when set (bit=1)	0,1	1
Number of Cache Segments	Sets number of cache segments to be maintained	1,2,4,8,16	4
Write Indexing Enable/Disable	Allows data from write operation to be overwritten in the cache memory to increase cache utilization when this bit is disabled (=0).	0,1	0
Prefetch Only	Allows only prefetch data to be kept in the cache; data from current read is not saved.	0,1	0
Maximum Prefetch	Sets maximum amount of data to be prefetched	0-128 logical blocks	16
Minimum Prefetch	Sets minimum amount of data to be prefetched	0-128 logical blocks	1
Prefetch Enable	Enables/disables prefetch operation	0,1	1

Through the use of these programmable parameters, the caching feature can be tailored to optimize individual system performance. The programmable parameters shown in Table A-1 can be found on MODE SELECT Page 37H. When the Cache Enable/Disable bit (Byte 2, bit 0), is set to zero, caching is disabled. Disabling the cache allows the entire 64 KB of RAM to be used as a transfer buffer. Applications requiring sustained data transfers may benefit from disabling the cache. When disabling the cache, you essentially disable the prefetching and segment divisions. The default value of this bit is one (Cache enabled).

The cache is divided into equal sized segments. Each segment contains one cache entry. A cache entry consists of the data just written to the disk or the requested READ data plus its corresponding prefetch data.

The number of cache segments (Byte 3) indicates how the cache will be divided and the number of entries in the cache table. Setting the number of cache segments to one creates one large 64 KB segment. This may be advantageous for those systems which transfer large blocks of data; however, since this one segment can only hold one cache entry, the data involved with the next access to the disk will overwrite all that is currently in the cache. Setting the number of cache segments to sixteen creates sixteen segments of 4 KB

each. With this configuration you have many different cache entries; however, your transfer buffer is limited to the cache segment size, which happens to be 4 KB in this case. Also, with a small transfer buffer, you may not be able to store the entire block transferred or, there may not be enough room for the desired amount of prefetch data. The default value is four cache segments of 16 KB each. This value was chosen as a compromise between having a large number of cache entries and having a large transfer buffer.

The *ProDrive Series* disk drives use a Least Recently Used segment replacement strategy. Each time there is a cache hit on a segment or when data on a segment is replaced, this segment gets time stamped as the most recently used. On a data transfer operation involving reading from or writing to the disk, this data replaces the data in the least recently used cache segment. With Write Indexing disabled (Byte 2, bit 3 set to zero), the *ProDrive* automatically marks the segment storing data from a WRITE as the least recently used. This strategy preserves more data in the cache from READs, increasing the likelihood that requested data lies in the cache. The default setting is zero (Write Indexing disabled).

The Prefetch Only bit determines whether the *ProDrive* will retain both prefetch and READ data in the cache or will retain only prefetch data. When this bit (Byte 2, bit 2) is set to one, the *ProDrive* will only keep prefetch data within a cache segment; the originally requested READ data will be overwritten with prefetch data. If the system anticipates that the requested READ data will not be re-read in the near future (within a certain number of other requests), there is no need to use cache space to store this READ data. Chances for a cache hit on the next READ request will be better if additional prefetch data were stored in place of the READ data in this situation. The default setting is zero (Prefetch Only off).

The size of the cache segments may affect how much data is prefetched. The requested READ data takes up a certain amount of space in the cache segment so the corresponding prefetch data could essentially occupy the rest of the space within the segment. The other factors determining prefetch size are the maximum and minimum prefetch. Values for the prefetch range from 0 to 128 (512-byte) logical blocks. The minimum prefetch indicates the minimum number of logical blocks that must be prefetched before the next drive command can be executed. The maximum prefetch indicates the maximum number of logical blocks that can be prefetched. If another command is issued to the *ProDrive* drive while it is prefetching, *ProDrive* will abort the prefetch only after it has prefetched the minimum number of logical blocks. The minimum prefetch default value is set to one logical block and the maximum prefetch default value is set to sixteen logical blocks.

The Prefetch Enable/Disable option (Byte 2, bit 1) was used by Quantum engineers when developing *ProDrive's DisCache*. If you feel your system's performance would be better with the prefetching feature disabled, or you see no need for using look-ahead prefetching in your application, disabling the entire cache may be more beneficial than simply disabling the prefetch. The default setting is one (Prefetch enabled).

DESIGNED FOR HIGH PERFORMANCE

DisCache was designed with high performance in mind by incorporating both programmable options and low overhead. *DisCache* is configured by Quantum to guarantee that system disk requests are handled as a first priority and look-ahead caching occurs only during the drive's idle time. Efficient cache management ensures minimum command processing time (a few hundred microseconds) associated with this feature.

Finally, the disk drive is the ideal location for this type of look-ahead cache because here the least amount of system overhead is involved. System-level caches incur the same amount of overhead in reading requested data as in anticipating requests. In either case, the system must access the disk and delay other disk accesses as well as other operations. With *DisCache*, anticipating requested data occurs during otherwise idle time and does not delay other disk accesses. From the system perspective, the overhead cost is minimal while the benefit may be quite significant.

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INTRODUCTION

The *ProDrive* disk drives are shipped from the factory as "hard sectored" drives. That is, all physical sector addresses are written on the disks before the drives are shipped. Sector size and number of sectors per track are, therefore, not user selectable. The SCSI peripheral bus uses "logical blocks" as the means of transferring data to and from the disk drives. This appendix describes the physical format of the *ProDrive* as it is defined at the factory prior to shipment.

TRACK FORMAT

The *ProDrive Series* drives use information on the disks to define the physical sectors. Each sector is capable of holding 512 bytes of data (plus 6 bytes for ECC). Tracks 0 to 589 contain 35 sectors; tracks 590 to 833 contain 28 sectors. One sector is used as a spare for every 6 tracks for defect management. (See Appendix C.) For the *ProDrive 40S* (2 disks, 3 heads), the first 590 cylinders have 105 physical sectors available and the last 243 cylinders have 84 sectors. The *ProDrive 80S* (3 disks, 6 heads) has 210 and 168 sectors available. These sectors are sequentially numbered beginning with cylinder 0, head 0 through cylinder 833, head 5 in the case of the *ProDrive 80S*; or cylinder 833, head 2 in the case of the *ProDrive 40S*. Therefore, the *ProDrive 40S* contains 82,029 sequentially-numbered sectors, and the *ProDrive 80S* contains 164,058 sequentially-numbered sectors, each capable of storing 512 bytes of data.

TRACK AND CYLINDER SKEWING

Since the *ProDrive 40S/80S* drives are storage subsystems with integrated SCSI controllers, the function and design of the controller can be optimized specifically for the drive. One method of optimization employed by Quantum to improve data throughput is skewing sector addresses. The purpose of track and cylinder skewing is to minimize latency time and thus increase data throughput when data is sequentially accessed to or from the disk. The two types of skewing employed, track and cylinder skewing, are described below.

TRACK SKEWING

Track skewing reduces latency time which results when the drive must switch read/write heads to access sequential data. Figure B-1 provides an example of track skewing. A track skew is employed such that the next logical sector of data to be accessed will be under the read/write head once the head switch is made and data is ready to be accessed. Since head switch times are defined on *ProDrive*, the sector addresses can be optimally positioned across track boundaries to minimize the latency time which results when a head switch has to be performed.

Head 0	0	1	2	3	4	5	6	7	8	9	10	11	12	...	30	31	32	33	34
Head 1	63	64	65	66	67	68	69	70	71	35	36	37	38	...	58	59	60	61	62
Head 2	91	92	93	94	95	96	...	103	104	105	70	71	72	73	74	...	89	90	

FIGURE B-1 Example Of A 7-Sector Track Skew
(Shown On An Outer 35-Sector Track)

CYLINDER SKEWING

Cylinder skewing is also used on *ProDrive* to minimize latency time during sequential accessing of data. However, instead of minimizing latency time due to head switching, as with track skewing, cylinder skewing is used to minimize latency time due to a single-cylinder seek. The next logical sector of data which crosses a cylinder boundary is positioned on the drive such that after a single-cylinder seek is performed, and the drive is ready to continue accessing data, the sector to be accessed is positioned directly under the read/write head. Therefore, the cylinder skew takes place between the last sector of data on the last head at a cylinder and the first sector of data on the first head at the next cylinder. Figure B-2 provides an example of cylinder skewing. Since single-cylinder seek times are defined on the drive, the sector addresses can be optimally positioned across cylinder boundaries to minimize the latency time which results when a seek has to be performed.

Cyl 0																					
Head 2	0	1	2	3	4	5	6	7	8	9	10	11	12	13	...	30	31	32	33	34	35
Cyl 1																					
Head 0	54	55	56	57	58	59	...	67	68	35	36	38	39	...	49	50	51	52	53		

FIGURE B-2 Example Of A 15-Sector Cylinder Skew

INTRODUCTION

To ensure long-term data integrity, Quantum's *ProDrive Series* intelligent disk drives incorporate media defect handling and error correcting code capabilities. These integrated features eliminate the need for user defect maps, for writing dedicated utility software for defect mapping, and for testing time required during system integration at an OEM site. During system integration and regular use, the drive can continue to scan and compensate for any new defective sectors which may show up later on the disks.

DEFECT DETECTION

Any discrepancy between recorded data and recovered data at the sector level is defined as a data error. In high density digital recording systems, it is necessary to provide an error detection and correction scheme to enhance the operational performance and increase the reliability of the system.

Data errors can be either "soft" (those that are not readily repeatable) or "hard" (those that are repeatable with high probability). Soft errors are generally related to the signal-to-noise ratio of the system. They represent marginal conditions of the media, heads, read/write circuitry, and the controller data synchronizer circuits. Hard errors are most often due to defects, pits, scratches, or thin spots in the media. These defective media areas can be detected and skipped (not used for storage).

DEFECT MANAGEMENT

FACTORY FOUND DEFECTS

ProDrive disk drives are scanned in the factory for defective sectors on the disks. Those defective sectors are deallocated prior to shipment. A factory Defect Map, duplicated on tracks on the drive allocated for this purpose, will contain the locations of all defective sectors found in the drive.

One sector is allocated per defect zone as a replacement sector. Defects found at the factory are skipped using an "In-Line" sparing method, which replaces each sector with the next sector on the track (see Figure C1). In the rare instance where more than one defect is found within the same zone, the additional defects will be mapped into the nearest adjacent zone with a spare sector available. The defect zone size (number of tracks/zone) is a changeable parameter in operating mode page 3 via the MODE SELECT command. The default defect zone size is six tracks per zone in both the *ProDrive* 40S and 80S. Changing the zone size will not affect drive operation until after the execution of a FORMAT command.

This approach minimizes media used for replacement and reduces access time to the replacement sector. In addition, cylinder boundaries are well defined, with a simple relationship between each initial sector's physical and logical block addresses, thus providing the host a method to ensure that file records can be stored within cylinder boundaries for optimal accessibility.

ProDrive								Sectors/ track	
40S Head	80S Head								
CYL 0	CYL 0	x+0	x+1	x+2		25 x+	26 x+	27 x+	28
						32	33	34	35
1	1	28 x+	xxxx	29 x+		52 x+	53 x+	54 x+	
		35		36		66	67	68	
2	2								
CYL+1 0	3								
1	4								
2	5	139 x+	140 x+	141 x+		164 x+	165 x+	166 x+	
		174	175	176		206	207	208	

NOTES: x = logical block address
 xxxx = deallocated sector
 Zone size is six tracks/zone (default)

FIGURE C-1 Factory Found Defects

FIELD FOUND DEFECTS

ProDrive Series disk drives also contain a Replacement Sector Map in the event additional defects are found during drive usage. Field found, or "grown" defects are also mapped into the one replacement sector located at the end of each zone. However, data from field-found defective sectors are mapped directly into the spare sector location (without shifting subsequent logical blocks, as in the case of the In-Line sparing method); see Figure C2. Similar to the factory sparing method, in the rare instance where there are more than one defect per zone, the additional defects will be mapped into the nearest adjacent zone with a spare sector available. This approach ensures that in most cases a long seek to an alternate cylinder will not be necessary in order to manage additional defects found during drive usage.

ProDrive									Sectors/ track
40S Head	80S Head								
CYL 0	CYL 0	x+0	x+1	x+2		25 x+	26 x+	27 x+	28
						32	33	34	35
1	1	28 x+	xxxx	30 x+		53 x+	54 x+	55 x+	
		35		37		67	68	69	
2	2								
CYL+1 0	3								
1	4								
2	5	140 x+	141 x+	142 x+		165 x+	166 x+	29 x+	
		175	176	177		207	208	36	

NOTES: x = logical block address
 xxxx = deallocated sector
 Zone size is six tracks/zone (default)

FIGURE C-2 Field Found Defects

Two software configuration "switches" (Post Error and Automatic Reallocation) are available for host control of the field replacement operation. Post Error determines whether or not the *ProDrive* will notify the host every time corrected data is passed from the drive. Automatic Reallocation determines whether or not, when corrected data is passed to the host, the drive will automatically add the physical location of that sector onto the Replacement Sector Map, move that sector of data into a replacement sector, then check that the sector was properly duplicated. These two software switches allow the selection of four possible options by the host. The option desired by the host will be specified via the SCSI Mode Select command. (See Section 5.11.10.)

Option 1 (Post Error off, Automatic Reallocation off): This is a "no action" option. That is, the host will not be informed that corrected data is being passed, nor will the *ProDrive* take any action to map out the suspect sector.

Option 2 (Post Error off, Automatic Reallocation on): This is a transparent replacement option. When corrected data is passed from the drive, it will not notify the host of the action. However, the drive will automatically add the physical location of the sector containing the corrected data onto the Replacement Sector Map, move that sector of data into a replacement sector, then verify that the move was completed correctly.

Option 3 (Post Error on, Automatic Reallocation off): Every time corrected data is passed to the host, the *ProDrive* will notify the host of the recovered error. The drive will not take action to map out the suspect sector.

By logging suspect block addresses passed from the drive, the host can use the SCSI REASSIGN BLOCKS command or the FORMAT UNIT command to manage new defects. The REASSIGN BLOCKS command

can be used to add new defective block locations to the Replacement Sector Map and move the data from those sectors into replacement sectors. Alternately, the drive can be reformatted using the logged suspect block addresses with the FORMAT UNIT command. (See Reformatting.)

Option 4 (Post Error on, Automatic Reallocation on): Every time corrected data is passed to the host, the *ProDrive* will notify the host of the recovered error. Also, the drive will automatically add the physical location of that sector onto the Replacement Sector Map, move that sector of data into a replacement sector, and verify that the move was completed correctly.

Reformatting: The SCSI FORMAT UNIT command issued from the host will cause the drive to reorganize data on the disk in a manner identical to the way it was formatted in the factory (i.e., using an In-Line sparing method). In addition to using the original factory In-Line Defect Map and the field Replacement Sector Map, the reformatting operation can also be performed using a host-supplied list of defective logical blocks. If the number of tracks per zone has been altered since the last FORMAT UNIT command, the new zone size will be used in reorganizing the spare sectors.

ERROR CORRECTING CODE

The Quantum *ProDrive Series* implementation of error correcting code is a 48-bit computer generated cyclic code, allowing correction of an 11 bit single burst error. In addition, a retry/correction strategy is used to avoid using ECC on soft errors.

OPERATION OF ECC:

If the syndrome is 0 (no errors), data is passed to the SCSI bus.

If the syndrome is not 0 (an error has occurred) and the DISABLE CORRECTION (DCR) bit is set, the *ProDrive* performs a retry. If the retry count reaches the limit, the *ProDrive* will attempt to use ECC to correct the data. The data will be transferred regardless of whether it is actually possible to correct the data.

If the syndrome is not 0 (an error has occurred), and

- the error is correctable and the ENABLE EARLY CORRECTION (EEC) bit is set, the *ProDrive* retries the read and compares the latest syndrome with the previous syndrome and if:

Latest syndrome = 0 The latest data is passed onto the SCSI bus.
(Latest try had no errors)

Syndromes are equal The *ProDrive* corrects the data and passes this corrected data onto the SCSI bus. (Defect error)

Syndromes are unequal The *ProDrive* performs a retry. (Soft error) If the retry count has reached the limit, the *ProDrive* corrects the data and passes this corrected data to the SCSI bus.

- the error is correctable, and the EEC bit is zero, the *ProDrive* performs a retry and rereads the sector. When the EEC bit is set to zero, the *ProDrive* will exhaust the retry count before attempting to correct the data.
- the error is not correctable, the *ProDrive* performs a retry and rereads the sector. If the retry count reaches the limit, the *ProDrive* reports an uncorrectable data error and no data is passed.

Actuator	An actuator positions the read/write heads at the desired cylinder. The Quantum actuator consists of a rotary voice coil and the head mounting arms. One end of the head mounting arms attach to the rotor with the read/write heads attached at the opposite end. As current is applied to the rotor, it rotates, positioning the heads over any cylinder on the surface.
Block	The SCSI interface uses logical blocks when transferring data across the bus. A block of data can be set equal to 512, 1024 or 2048 bytes.
Byte	This term indicates an 8-bit unit of information.
Command Descriptor Block (CDB)	The structure used to communicate requests from an initiator to a target.
Connect	The function that occurs when an initiator selects a target to start an operation.
Cylinder	A set of tracks on multiple recording surfaces at any one actuator position or location. The <i>ProDrive</i> 40S and 80S have 834 data cylinders.
Data Error	Any discrepancy between recorded and recovered data at the sector level. See Appendix C.
Disconnect	The function that occurs when a target releases control of the SCSI bus, allowing it to go to the BUS FREE phase.
Disk/Platter	A very flat circular substrate upon which a magnetic thin film is deposited or coated. Each disk has two surfaces for recording information.
Initiator	An SCSI device (usually a host system) that requests an operation to be performed by another SCSI device.
Latency Time	The period of time in which the read/write heads are waiting for the data to rotate into position such that they can be accessed. Based on the disk rotating speed of 3662 RPM, the maximum latency time is 16.4 milliseconds, and the average latency time is 8.2 milliseconds.
Logical unit	A physical or virtual device addressable through a target.
Logical unit number	An encoded three-bit identifier for the logical unit
LSB	Least Significant Bit
LUN	Logical Unit Number
ms	Millisecond (10^{-3} seconds)
MSB	Most Significant Bit
Media	The magnetic film that is deposited or coated on an aluminum substrate which is very flat and in the shape of a disk. The media is overcoated to prevent damage to the heads or media during head take off and landing.
μ s	Microsecond (10^{-6} seconds)

ns	Nanosecond (10^{-9} seconds)
One	A true signal value.
Reconnect	The function that occurs when a target selects an initiator to continue an operation after a disconnect.
Reserved	The term used for bits, bytes, fields, and code values that are set aside for future standardization.
SCSI address	The octal representation of the unique address (0-7) assigned to an SCSI device. This address would normally be assigned and set in the SCSI device during system installation.
SCSI ID	The bit-significant representation of the SCSI address referring to one of the signal lines DB(7-0).
SCSI device	A host computer adapter or a peripheral controller or an intelligent peripheral that can be attached to the SCSI bus.
Sector	A physical portion of a track on the disk which is used to store data. The physical sector size is set at 512 bytes on the <i>ProDrive</i> , plus 6 bytes for ECC. Each sector is preceded by ID data, which cannot be overwritten.
Shipping/ Landing Zone	A circular area inside of track 833. The heads are pulled over this area whenever DC power is removed or the disks slow below 3423 RPM for more than 2 sec. This area is used to prevent the heads from touching the surface in data areas, adding to the data integrity and reliability of Quantum drives.
Signal assertion	The act of driving a signal to the true state.
Signal negation	The act of driving a signal to the false state or allowing the cable terminators to bias the signal to the false state (by placing the driver in the high impedance condition).
Signal release	The act of allowing the cable terminators to bias the signal to the false state (by placing the driver in the high impedance condition).
Status	One byte of information sent from a target to an initiator upon completion of each command.
Surface	One side of a disk in the drive. Surface 0 is the area of the bottom disk where read/write head 0 writes and reads data.
Target	An SCSI device that performs an operation requested by an initiator.
Track	A ring of constant radius on the surface of a disk where data are recorded.
Vendor unique	Indicates bits, fields, or code values that are vendor specific.
Winchester Technology	When used in reference to a disk drive, means that the drive uses continuously loaded, low mass, high compliance head assemblies. Both the head assemblies and the disks operate in a sealed, contamination free environment to allow flying heights of 11 microinches or less. As the heads are continuously loaded, they will contact the media surface when the disk is not spinning. To prevent damaging the media or heads, overcoated media is used.

- xxH** Numbers followed by a capital H subscript or denoted (hex) are hexadecimal values. All other numbers are decimal values.
- Zero** A false signal value.

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APPENDIX E QUANTUM REPAIR PROCEDURE

Quantum has two service centers as shown on page iv of this manual. *ProDrive* disk drives may be sent to either of these service centers for repair. The following paragraphs describe the procedure for returning drives to one of Quantum's service centers.

RETURN MATERIAL AUTHORIZATION (RMA OR RA)

- A) Quantum requires the following from the customer:
- 1) Model number.
 - 2) Quantum's serial number.
 - 3) Reason for return.
 - 4) Customer's purchase order number.
- B) In return, the customer will receive the following information from the Quantum Service Representative:
- 1) A Return Material Authorization Number (RMA or RA Number).
 - 2) Information regarding applicable charges.
 - 3) The address to return the drive.

REPAIR CHARGES

Flat rate charges apply for all out-of-warranty products returned to Quantum for repair. There is one flat rate charge for all repairs requiring work outside the cover, and a different flat rate for repairs requiring work inside the cover.

Repair of units shipped directly to a Quantum Repair Facility in the United States from International locations will be subject to a surcharge of seventy dollars (\$70. U.S.) per shipment to cover the cost of freight forwarding and special handling.

For repair and surcharges in Europe, contact the appropriate repair facility.

PRODRIVE SERIES DRIVE REVISION IDENTIFICATION

Quantum uses a series code identification to indicate revision level of the *ProDrive Series* drives as they are manufactured. A series code label is attached to the drive base casting. Whenever a significant change is made to the drive, a new series code will be used to distinguish the drives with the latest change from drives which were manufactured prior to the change.

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